MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 427 JUNE, 1945

Carnation Wilt Diseases and Their Control

By E. F. Guba

Wilt diseases cause serious losses in greenhouse carnation culture in Massachusetts. This bulletin is intended to help the carnation grower understand these diseases and to acquaint him with proven control measures.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

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CARNATION WILT DISEASES AND THEIR CONTROL

By E. F. Guba, Research Professor of Botany[1]

INTRODUCTION

The culture of carnations in greenhouses represents a large industry in Massachusetts and nearby adjoining areas. This industry is concentrated within a radius of 40 miles of Boston. Each year approximately 26,000,000 or more carnation cut flowers are produced in this area. The flowers are shipped to markets throughout the eastern half of the United States, as far south as Miami, Florida, and as far west as Chicago and St. Louis, and to nearby wholesale markets. In addition a large number of flowers is retailed on the growers' premises, for which no accurate production figures are available. The average gross return to the grower over several years prior to the war period has been about 3¼ cents per flower. The climate and soil in New England seem especially well adapted to carnation culture and to the production of flowers with desirable keeping and shipping qualities.

The industry has experienced large losses from carnation diseases, notably from blight caused by the fungus *Alternaria dianthi* and branch rot caused by *Fusarium dianthi*, and other diseases collectively manifesting the common symptom of wilt. The occurrence of the blight disease in epidemic proportions annually over several years, and the importance of the carnation cut flower industry in Massachusetts, have offered adequate justification for this study and for a broad treatment of the general subject of carnation diseases.

The subject matter of this paper has been arranged essentially into sections conforming to the various stages or practices in carnation culture. Information is presented regarding desirable treatments and cultural methods in relation to the control of carnation wilt diseases. The contributions of earlier investigators are freely offered. This procedure has seemed desirable in view of an extensive literature, especially from the United States and England, with which our growers are not familiar.

CLASSIFICATION OF CARNATION WILT DISEASES IN MASSACHUSETTS

The fungous diseases of greatest consequence encountered in the culture of carnations in Massachusetts are spot, blight, and canker caused by *Alternaria dianthi* Stev. & Hall.; root and crown rot caused by *Fusarium avenaceum* (Fr.) Sacc., *Fusarium culmorum* (W. G. Smith) Sacc., and other Fusarium species; branch rot or Fusarium wilt caused by *Fusarium dianthi* Prill. & Delacr.; and stem rot caused by *Rhizoctonia solani* Kühn. Symptoms of diseased carnation plants associated with these pathogenic organisms are wilting, yellowing, browning, and death of the branches or the entire plant. Distinctive and characteristic manifestations of disease are peculiar to each causal organism. The principal and most distinctive symptoms are expressed by various appropriate common names. Some common names have been employed rather loosely or without the scientific Latin counterpart, and this has led to some confusion in the literature.

[1]The author appreciates gratefully the generous cooperation and goodwill of the carnation growers of Massachusetts and the New England Carnation Growers' Association in his service to their industry.

Spot, Blight, and Canker

This disease, caused by the fungus *Alternaria dianthi* Stev. & Hall (Fig. 1, 2), is manifested by spotting of the foliage, flowers, and stems; blighting of the foliage; and cankering and rotting of the branches, followed by wilting, browning, and death of the branches. The discolored diseased areas become covered with a black layer of spores especially under moist atmospheric conditions. The spots at first have a slightly purplish color and are surrounded by a halo; later they become brown and shriveled, and as they coalesce the disease assumes the character of blight. The calyx and corolla lobes are also infected, especially in the field. The branches are infected most frequently at the nodes just above the stem, and this is the most common form of infection among the benched plants in the greenhouse. The brown discolored areas at the nodes partially or completely girdle the branch. At first the fungus is restricted to the bark or outside of the cambium. Ultimately, the canker progresses deeper into the branch. The leaves become dull green and marked with whitish or pale streaks, and then wilt. The infected portion of the branch below acquires a brown or blackish color, and the dark-colored rot extends to the pith. Black crusts of spores form over the region of the branch where the rot is localized, and some of the black deposit remains long after the branch has died. The branches become completely desiccated and assume the color of straw.

The fungus is associated with a brownish or blackish basal and axillary decay of cuttings in the sand bench (Fig. 3).

History

The Alternaria blight of the carnation was recognized as one of the important plant diseases in the United States in 1905 and considerable damage was reported among varieties of the Mrs. Thomas Lawson type (Orton 48, Woods 81). In October 1902 Irving Gingrich of South Bend, Indiana, submitted blighted carnation plants to Professor B. O. Longyear, Michigan State College, with information that the disease was especially severe on the variety "White Cloud." The fungus was identified as *Macrosporium nobile* Vize. The writer learned of the specimen deposited in the Herbarium of the Department of Botany, Michigan State College, from a published record by Coons (20). Study of this material showed that the organism is *Alternaria dianthi* which was described seven years later (62) on the basis of material found in Raleigh, North Carolina. In the meantime, Clinton (14) reported a serious occurrence of the Alternaria disease on carnations in a greenhouse at Greenfield Hill, Connecticut; and Woods (82) reported that the disease was especially destructive to the varieties Enchantress and Lawson, designated the "softer types." The plants acquired the disease during their growing period in the field and were damaged seriously after benching.

More recently, the disease has been epidemic in the Northeastern States, notably New York, New Jersey, Pennsylvania (49), Virginia, Connecticut, Massachusetts, New Hampshire, and Maine. In this general area frequent serious instances of the disease and plant failures have occurred. Less frequent occurrences of the disease are recorded from Colorado, Indiana, Michigan, Missouri, Texas, and Wisconsin, and it was reported in 1932 to be a limiting factor in the production of light-colored varieties grown under lath near Los Angeles, California. The disease has been serious on carnations in certain portions of Canada, notably in St. Anne, Quebec; Lincoln, Middlesex, and Cobourg counties of Ontario; and also in garden patches of Dianthus throughout the province of New Brunswick, especially in the vicinity of Fredericton (16, 45). It has been reported on *Dianthus* sp. from Puerto Rico (54).

An Alternaria disease of carnations has been prevalent at San Remo and Porto Maurizio, Italy, and in Sicily (3, 13, 50, 66). The pathogenicity of the fungus was established. It was designated *Alternaria dianthi* with, however, no satisfactory degree of confirmation.

Sorauer (57) reported a spotting and blighting of carnations in Germany associated with attacks of an Alternaria fungus. Death of carnation flower buds in Czechoslovakia is reported to be due to *Alternaria brassicae* Sacc. var. *dianthi* Zimm. (84). Moesz (47) reported a disease of carnation in Hungary analogous to carnation blight and associated with a fungus regarded as *Alternaria dianthi* Stev. & Hall. McAlpine (43) described the fungus *Alternaria longispora* on withered portions of carnation leaves at Sydney, Australia.

In 1927, Corbett (21) in England reported a wilt disease, associated with a brownish basal stem decay, among carnation plants four months from the rooting stage. Inoculation of plants with a spore suspension of the Alternaria fungus produced all of the symptoms characteristic of the disease caused by the fungus *Alternaria dianthi*. Its introduction into England was unquestionably associated with the importation of infected cuttings from the United States at a time when the disease was prevalent and destructive here. Since the disease has not been reported further, it has apparently not become established (74).

TABLE I. SPORE DIMENSIONS OF SPECIES OF ALTERNARIA AND MACROSPORIUM REPORTED ON MEMBERS OF THE CARYOPHYLLACEAE.

Host and Fungus	Spore Size (Microns)	Authority
Dianthus Caryophyllus		
Alternaria dianthi	26-123 × 10-20	Stevens & Hall, No. Carolina (62)
" "	31-70 × 10-15	Gingrich*, Indiana
" "	45-117 × 14-26	Guba, Massachusetts
" "	26-103 × 13-38	Corbett, England (21)
" "	45-72 × 12-19	Overholts, Pennsylvania (49)
" "	20-54 × 5-17	Natural host } Elliot (26)
" "	10-54 × 5-25	Synthetic Agar } Elliot (26)
" "	35-90 × 13-40	Bean Agar } Elliot (26)
" "	30-110 × 10-30	Passalacqua, Italy (50)
" "	30-90 × 10-20	" " "
" "	33-100 × 20-27	Moesz, Hungary (47)
A. brassicae var. *dianthi*	60-100 × 12-15	Zimmerman, Czechoslovakia (84)
" " " "	23-45 × 14-17	" "
A. longispora	100-160 × 16-25	McAlpine, Australia (43)
Macrosporium congestum	31-75 × 18-36	Bresadola, Italy (8)
M. dianthi	42-53 × 15-20	D'Almeida and da Camara, Portugal (2)
Dianthus plumarius		
M. dianthemphus	35-50 × 10-17	Hume, Florida (35)
Dianthus seguieri		
M. seguierii	30-70 × 10-16	Allescher, Germany (1)
Dianthus sp.		
M. nobile	60-80 × 40	Vize, England (17, 18)
Saponaria		
M. saponariae	50-80	Peck, New York (51)
" "	22-80 × 7-14	Young (83)
Silene		
M. truncatum	50 × 23	Fautrey and Lambotte, France (27)
M. verruculosum	45-95 × 22-38	Bubak, Switzerland (11)

*Original specimen of *Alternaria dianthi* from Terre Haute, Indiana, deposited in Herbarium, Dept. of Botany, Michigan State College, East Lansing, Michigan.

Species of Alternaria and Macrosporium on the Caryophyllaceae

Several species of Alternaria and Macrosporium have been described on members of the Caryophyllaceae, and they all appear to be distinct from *Alternaria dianthi* (Table 1). *Macrosporium nobile* Vize was found in dead stems and leaves of Dianthus at Forden, England, by Rev. J. E. Vize and originally reported by M. C. Cooke (17, 18). Later British accounts of *Macrosporium nobile* (19, 41, 42) described the fungus as being definitely parasitic to carnations in England. The type specimen, Vize, Micro Fungi Brit. No. 63, however, bears only the fungus *Heterosporium echinulatum* (Berk.) Cke., a prevalent fungus on Dianthus associated with small gray leaf spots. The Macrosporium described by Vize may be regarded as secondary and saprophytic. The name appeared once in the American literature (20).

Cash (12) reported *Alternaria dianthi* on blighted foliage of *Lychnis chalcedonica* L. collected at Sitka, Alaska. The writer's examination of this material revealed an abundance of Cladosporium, apparently parasitic, also some Heterosporium, and a trace of Alternaria which was inadequate for identification and might more properly have been ignored in the naming of the specimen. Seymour (55) listed *Cladosporium herbarum* (P). ex Lk. on many species of Dianthus and Lychnis, and apparently the same fungus is involved in the specimen in question. Bisby and others (7) reported *Alternaria dianthi* on *Dianthus barbatus* Linn. The specimen also bears the fungus *Heterosporium echinulatum* (Berk.) Cke. in much greater abundance. The fascicles of conidiophores arising from the stomata and dotting the blighted foliage belong to Heterosporium.

Inoculations of *Dianthus caryophyllus* and cabbage with conidia of *Alternaria dianthi* were readily successful on Dianthus and unsuccessful on cabbage (26). So far as is known, the fungus is restricted to the genus Dianthus. It has been reported on *D. tristus* Vel., *D. barbatus* Linn., *D. plumarius* Linn., *D. chinensis* var. *heddewigii* (Linn.) Regel, and *D. Allwoodii* Hort. (6).

Root and Crown Rot

This disease, caused by the fungi *Fusarium avenaceum* (Fr.) Sacc., *F. culmorum* (W. G. Smith) Sacc., *F. poae* (Pk.) Wr., etc., is featured by a progressive wilting, collapse, and browning of the entire plant. The roots gradually rot away to the root head. The base of the stem is invaded and rotted. Reddish areas appear among the brown decayed stem and roots. The generalized rotting of roots and crown which characterize this disease is caused by many species of Fusarium, of which the three mentioned are most commonly responsible. These organisms also cause a serious rotting of the snags and nodes in the branches, and wilting of the parts above the infection centers. The disease can be bad in two- and three-year-old flowering stock. These organisms also cause a common soft basal rot of cuttings during the rooting period in the sand bench and after transplanting. Frequently complete failures result among rooted stock.

Destructive occurrences of the disease are frequent in July and August among newly benched plants, especially in wet, poorly drained soil. The disease has been the subject of extensive studies by Dowson (24), White (71-75), and Wickens (77, 78).

Branch Rot or Fusarium Wilt

This disease, caused by the fungus *Fusarium dianthi* Prill. & Delacr., is characterized by browning of the conductive tissue, wilting, yellowing, and gradual rotting of the stem and branches, and straw-colored dead remains (Fig. 6).

The disease can be recognized by the slow wilting and withering of the individual branches accompanied by changes in color from normal to dull green, then to yellow or straw. There is a progressive discoloration of the vascular or conductive tissue from the normal pale green to a yellowish, reddish, and brownish color. Infection is established in the roots, in the stem, or in the branches. Wilting does not appear until the disease has advanced considerably around the periphery of the branch or stem above and below the point of infection. The branches are progressively invaded by the fungus through the conducting tissue from the stem, and the brown color and dry rot spread radially and vertically. Frequently only the branches on the rotted side of the stem wilt and change color. Ultimately, the entire plant succumbs. Plants may live harboring infection for a long time without showing symptoms of disease. Pinkish spore masses of the fungus are usually evident on the surface of the stem and in the base of the branches at the level of the soil. The fungus is essentially a vascular parasite causing a typical wilting of the branches and subsequently a dry rot of the stem and branches. The disease may appear at any stage in the culture of carnations, but the losses are most significant in the summer and fall months. In 1914 Peltier (53) proposed the name "branch rot" for this Fusarium wilt disease, and this name is generally used by the growers. It is also called Fusarium wilt (5, 78), which appears to be a more appropriate name. The causal fungus has more recently been designated *Fusarium oxysporum* Schl. f. *dianthi* (Prill. & Delacr.) Snyder and Hansen (56).

Stem Rot

This disease, caused by the fungus *Rhizoctonia solani* Kühn, is characterized by a progressive wilting, collapse, and browning of the entire plant, associated with a soft decay of the stem at the soil line. The foliage acquires a pale or dull greenish color. The leaves wilt slightly at first, then more generally, and finally the entire plant collapses. The stem at the soil level is soft and moist and the bark is easily rubbed off with the fingers. The wood beneath the decayed bark at first remains firm. The roots remain intact and attached to the stem. The stem of the dead plant becomes fibrous as disintegration continues. Compact brownish clumps or sclerotia of the fungus are present on the decayed bark, and the mycelium of the fungus is present about the stem and adjacent soil.

This fungus is an omnipresent inhabitant of soil. It attacks cuttings in the sand bench and propagating house; rooted plants in the flats (Fig. 7), where it causes a troublesome basal rot; and all subsequent stages of the plant in the field and in the greenhouse. The association of the Rhizoctonia fungus with the stem rot disease of carnations was established in 1899 (25), but even before that time the disease was widely distributed on carnations throughout the United States. Its occurrence in Massachusetts was reported in 1902 (64). The fungus attacks all kinds of plants and it has been the subject of extensive research (52, 53).

TEMPERATURE RELATIONS OF THE PATHOGENES CAUSING WILT

The optimum temperature for growth and for spore germination of the pathogenic organisms considered in this paper lies in a range of 75° to 88° F. The optimum and highest temperatures of the year prevail in the greenhouse in July and August, and after the benches are newly planted.

The optimum temperature for spore germination and growth of *Alternaria dianthi* is about 75° F., and at 40° and 90° growth is almost completely inhibited.

Fusarium avenaceum and *F. culmorum*, the root-rotting organisms, grow best at temperatures around 80° F. Dowson (24) reported that the optimum growth temperature for these organisms was 79° and the maximum about 100°. White (71) stated that the optimum temperature for growth was generally above 77°, and Starkey (61) found that 80° was most favorable for infection. In Colorado (60, 61) the greatest losses from root rot occur in October at minimum temperatures somewhat above 50°. With temperatures maintained somewhat below 50° up to mid-December, the losses are reduced by more than one-half.

The optimum temperature for the growth of *Fusarium dianthi*, the branch rot organism, is about 80° F., the maximum about 95°. Van der Bijl (67) found that the optimum temperature was in a range of 77° – 86° and that no growth occurred at 32° and 104°. Wickens (78) found that 84.2° was the optimum temperature for growth in culture, strong growth occurred at 95°, and none at 50°. Bickerton (5) reported that the optimum, minimum, and maximum temperatures are approximately 80°, 43°, and 97° respectively.

The optimum temperature for growth of *Rhizoctonia solani*, the stem rot organism, is 86°–88° F. (53). High soil temperature and excessive soil moisture are both extremely favorable. When both these conditions are present, infection and the progress of the disease are greater than in the presence of either alone. The losses from stem rot are high in the months of July, August, and September but relatively insignificant during the colder months and in the warmer months of the spring season. With the advanced age and growth of the plants the stem rot disease is almost totally absent.

INFECTION

The subject of infection of carnations by the various important wilt producing pathogenes has been widely investigated and the important contributions on the subject are reviewed here.

Alternaria Spot, Blight, and Canker

Severe infection not predisposed by injuries can occur at the leaf axils where the fungus is favored by the retention of moisture (62). Corbett (21) observed circular discolored areas with black centers on leaves and stems following inoculation of carnation plants with a water suspension of spores of Alternaria, and the inoculation of a freshly cut stem caused a dying back to the node and the wilting of the adjacent branches.

Injured plants are readily infected (62). Foliage injuries from drought, chemicals applied to control pests, and infestations of red spider mite can contribute to serious incidences of Alternaria blight in the field. The pointed tips of the leaves sometimes die from drought conditions and then are invaded by the fungus which subsequently progresses farther into the leaf blade. The leaves of two potted carnation plants were injured by pricking them with a needle; two other plants were not so injured. The plants were sprayed with spores in water and incubated in a damp atmosphere. The needle-pricked plants showed 117 distinct infections in contrast to 63 on the uninjured plants.

The Alternaria blight disease can be readily produced artificially by spraying carnation plants with a water suspension of spores of the fungus and incubating the plants in a humid atmosphere. These single spore infections appear as numerous small purple spots each surrounded by a halo (Fig. 4). Subsequently areas in the leaves and flowers wither and turn brown and become covered with a black mass of spores. Infection is readily obtained in this way on varieties which show resistance under natural conditions in the field. Infection is also readily obtained by inserting a piece of the fungus from culture in the axils of the flowering branches and maintaining a moist swab of cotton about the point of inoculation.

Fusarium Root and Crown Rot

The generalized rotting of carnation roots, stems, and branches due to several distinct species of Fusarium is well known. Starkey (58, 59, 60, 61) traced the development of the disease from the fine roots in the remote parts of the root system to the crown and into the stem. The roots decay and slough off and infection spreads from root to root in the soil. Plants with sound roots were not infected in soil inoculated with spores of *F. culmorum* or in contaminated soil under conditions favorable for good root action (71, 72, 74, 76, 78), but cuttings planted in contaminated sand readily succumbed. Spores or pieces of culture of *F. culmorum* applied to stabs in the stems and to wounds at the nodes or to the cut ends of stems caused rotting at the point of inoculation and dying-back of the branches. Dowson (24) reported that infection occurs only through wounds in the presence of high temperature and high soil and atmospheric moisture.

Both *Fusarium culmorum* and *F. avenaceum* are associated with a devastating basal rot of cuttings in sand and of the roots of plants in subsequent stages of growth. These organisms are active pathogenes, but well-established uninjured plants growing under favorable cultural conditions are never affected. In a few instances devastating cases of root rot have been noted in association with both a heavy soil infestation of garden symphylids and poor growing conditions—essentially wet soil and the absence of good drainage—and the latter factor appeared more significant than the small amount of root injury caused by the symphylids. Nevertheless, these creatures are general feeders and destroy the fine roots, and consequently can be regarded as a contributing factor. White (74, 76) stated that injuries to the roots by wireworms and wood lice contributed to root rot infection after planting. Severe damage from *F. culmorum* has been noted after the flowering stock had been mulched with manure; in other instances following applications of concentrated chemical fertilizers, and also following the use of cuttings from stock plants showing a prevalent rotting about the nodes and snags in the branches.

The importance of injuries in relation to infection was confirmed by a series of demonstrations. Bits of inoculum from authentic cultures of *F. avenaceum* and *F. culmorum* were transferred to axils of flowering shoots of Nina Brener carnations in June, twelve months after benching. The points of inoculation were wrapped in moist cotton. Rotting followed only where the cutting in the axil had been removed. Transfers of similar inoculum into incisions in the stem were successful; without incisions infection failed. With an authentic culture of *F. culmorum* from England, eleven inoculations through injuries in the stems of young potted plants yielded positive infections; without injuries five stem inoculations were negative and three were positive. With an authentic culture of *F. poae* from Germany, eight of the nine inoculations at injuries in the stems developed active cankers and nine inoculations made without injuries failed to cause infection. With a culture from England designated *F. herbarum* (Corda) Fr. = *F. avenaceum* (Fr.) Sacc., nine inoculations yielded six positive infections when the inoculum was applied to injuries and only negative results when the inoculum was applied to the stem without injuries. With an authentic culture of *F. avenaceum* from Germany, decay and dying back of the branches followed nine inoculations at injuries; inoculum applied to stems not injured at the point of inoculation also yielded positive infections. With *F. sporotrichioides* Sherb. from Germany, six inoculations at injuries were positive and three were negative; without injury all were negative. In these tests infection following inoculations with *F. poae*, *F. avenaceum*, and *F. culmorum* were particularly devastating. When the inoculum from pure cultures of these organisms was buried in the soil about injured roots and the plants cared for in the ordinary way, no disease symptoms developed.

Fusarium Branch Rot

Peltier (53) reported that the branch rot fungus infects carnation plants through wounds. Wickens (78) showed that cuttings planted in contaminated sand or inoculated at wounds were a total loss. Infection was established at the cut surface at the base of the cutting. Inoculations were usually successful through wounds but never through unwounded tissue. Wight (79) reported that soil contamination with the fungus was not likely to cause disease in sound plants. Van der Bijl (67) obtained successful infections by inserting pieces of cultures of the fungus into needle pricks in the stems below the natural soil level. Bickerton (5) reported successful infections of young rooted plants by inserting inoculum of the pathogen into wounds at the base of the stem and by dipping the roots into a water suspension of spores. It appeared to him that the large majority of infections are initiated in the roots. Similar evidence was secured by the writer.

Pure culture material of *Fusarium dianthi* containing an abundance of spores was macerated and added to sterile water. Forty rooted cuttings of each of eighteen varieties were washed free of sand and then immersed in the water suspension of spores and planted in steam-sterilized soil in flats. Within a month most of the plants of some varieties were totally destroyed; others showed symptoms of infection. The fungus was easily isolated from both the roots and stems, and the path of the fungus high up in the shoots was recognized by the discoloration of the water-conducting tissue. Obviously the roots were injured in lifting the plants from the sand, thus assisting the fungus in its infection process.

In the general area of New England the branch rot disease appears throughout the year among established plants and is usually most prominent after the benching season, 5 to 8 months from propagation. At this time the temperatures are excessive, frequent watering is required, and the plants have experienced considerable injury from handling and transplanting. As the plants resume growth and the weather becomes colder, the disease progresses more slowly and is masked by the fresh green growth, but it becomes important again in the warm months after winter. The disease is especially troublesome in certain varieties and among some classes of stock, indicating that the continuity of the disease is closely bound up with cuttings from contaminated stock plants.

In the writer's experiments, 12 transfers from a culture of the fungus into incisions in the stems and branches on well-established plants 10 months from the cutting stage were all positively successful as against 6 similar inoculations made without incisions, of which 5 were negative and 1 positive. In another instance in June, 11 months after benching, plants of Nina Brener were inoculated by placing bits of a culture of *Fusarium dianthi* in the axils of the leaves and then swabbing the points of inoculation with moist cotton. Infections were positive only when the inoculum was placed in an axil from which a cutting or axillary branch had been torn out.

It appears definitely that injuries are necessary for infection. Natural checking of the base of the stems of the cuttings during and after rooting is a common phenomenon. These openings provide favorable infection courts for the fungus (24, 79). Injuries to the plants in transplanting into the field and back into the greenhouse contribute greatly to the disease, but this seems almost unavoidable if the plants are grown outside.

The incubation period is ordinarily long but under warm atmospheric conditions the disease progresses rapidly. Bickerton (5) reported 92 percent infected plants at a soil temperature range of 70°–80° F. in 23 to 45 days, and 39 percent at 50°–65° in 56 to 75 days, following inoculation of the roots. Under the cool conditions of the winter months, infection remains latent for some time. As the disease appears among scattered plants abundant inoculum is provided for secondary infections in subsequent stages of culture. Thus under favorable conditions the amount of disease may run high among certain classes of stock.

Rhizoctonia Stem Rot

The Rhizoctonia stem rot fungus grows in the soil and attacks one plant after another. Infection is readily induced by placing a culture of the fungus in contact with the stem at the soil line and maintaining moist conditions. Infection is more generally successful by direct insertion of bits of the fungus into incisions in the plant (25). Pieces of Rhizoctonia from culture were inserted in scalpel slits in the stems of Nina Brener carnations in June, 9 months after benching, and in other instances the fungus was placed on the stem at the level of the soil and swabbed with moist cotton. One of 9 inoculations on uninjured stems was positive; 5 of 6 inoculations in scalpel slits in the stem were positive.

Conditions which both favor the fungus and place the plant at a disadvantage contribute to occurrences of the disease. Infection is readily induced by mixing the fungus with the soil in which the plants are growing. Peltier (52, 53) reported that the disease is most progressive at temperatures of 86°–88° F. and soil moisture either too high or too low for the best growth of the plants, and he considered wounding necessary for infection. The fungus enters through cracks in the corky layer of the bark near the surface of the soil. More stem rot is observed among deeply set plants branching below the soil surface than among those with a single stem in the soil. Infection among old plants was high following inoculation of the stem at wounds below the natural soil level (52). Destruction of cuttings and young plants readily follows when the sand or soil is inoculated with the fungus and when favorable temperature and moisture conditions are provided. The fungus is widespread in all types of soil and more virulent in some than in others. The occurrence of carnation stem rot is largely influenced by conditions created by the grower, which are favorable to the fungus and unnecessary for the best growth of the plants; and this was recognized early in the history of American carnation culture. Serious cccurrences of the disease even then were considered the result of deep planting, excessive soil moisture, and imperfect drainage (40, 68).

STOCK PLANTS AND THE SELECTION OF CUTTINGS

The importance of selecting cuttings from healthy stock plants is generally stressed in the literature. The risk of serious losses from ignoring this rule is usually very great, particularly in relation to Alternaria blight, Fusarium root rot, Fusarium branch rot, and carnation rust caused by the fungus *Uromyces caryophyllinus* (Schr.) Wint. These pathogenic organisms exist in the foliage and branches. Starkey (58, 59, 60) reported that at the end of 63 days 83.3 percent of the plants had died from Fusarium root rot as the result of propagating cuttings gathered from diseased branches, and that only 38.1 percent of the cuttings rooted. After 160 days only 7 plants survived. In contrast, 94 to 98 percent of the cuttings from healthy stock plants remained healthy. Wickens (78) noted that healthy cuttings contaminated with the Fusarium root rot organism rapidly succumbed to basal rot.

White (75) found that 42 percent of the cuttings from a bed containing diseased plants were contaminated with fungi of which 7 percent were *Verticillium cinerescens* Wr., the cause of a serious wilt disease of carnations in England. In another instance 22 percent of the cuttings yielded organisms associated with carnation wilt diseases, 38 percent yielded organisms not suspected of causing wilt, and 40 percent of the cuttings were clean. The carry-over of the Verticillium wilt fungus occurs mainly when the cuttings are taken adjacent to visibly diseased areas, but in practice some cuttings are infected even when precautions are taken to avoid the neighborhood of diseased areas (77, 78). The fungus was isolated from parts of shoots well beyond the limits of any microscopically visible internal or external symptoms. Wickens (78) isolated *Fusarium dianthi* freely from branches which externally appeared perfectly sound, but only within the limits of some alteration in the conducting tissue. Bickerton (5) obtained the branch rot fungus from off-colored, and frequently from green cuttings from apparently healthy plants growing adjacent to diseased plants. Sometimes the fungus was found in the shoots of infected plants even in the absence of any visible discolorations of the vascular tissue. Sturgis (65) felt that the outbreak of the disease in his experiments was due to the presence of the fungus in the tissues of the original cuttings.

In the Boston area serious losses from the Fusarium root rot organism have been observed in the propagating house and among young rooted plants in flats or beds in the early months of the year. The axils of the flowering branches from which cuttings are taken provide collecting places and reservoirs for water. Water is a carrier of fungous spores and thus it is not uncommon to note discolored infected tissue at the nodes. The Alternaria blight fungus and the Fusarium root rot fungus are frequently found associated with discolored or decayed tissue at the nodes of the branches. A basal decay of the cuttings follows when cuttings from such sources are planted in sand. The snag in the branch or the point

TABLE 2. RESULTS OF TISSUE TRANSFERS FROM CARNATION CUTTINGS TO ARTIFICIAL CULTURE MEDIA.

Variety	Source	Number of Platings	Number of Isolates		Transfers Dipped in Alcohol and Flamed Before Plating		
					Number of Platings	Number of Isolates	
			Alternaria	Fusarium		Alternaria	Fusarium
Fairy Queen	De Vita	117	11	4	57	0	0
Boston Ward	De Vita	95	0	0	27	0	0
Wardelia	Jahn	84	1	6	64	0	0
My Love	La Montagne	69	1	0	24	0	0
Boston Ward	La Montagne	58	1	1	34	1	0
Boston Ward	Rice	63	1	0	25	0	0
Matchless	Rice	25	3	0	16	0	0
Nina Brener	Farr	97	0	0	40	0	0
Matchless	Brigham	26	0	4	42	0	9
Boston Ward	Brigham				11	0	0
Nina Brener	Brigham				15	0	0
Matchless	Littlefield-Wyman				47	0	0
My Love	Littlefield-Wyman				17	0	0
Scarlet Monarch	Littlefield-Wyman				22	0	0
Nina Brener	Shaw				74	0	1
Total		634	18	15	515	1	10
Percent			2.84	2.37		0.19	1.94

where the cutting has been removed may become infected with the Fusarium root rot fungus and cause the wilting of the branch. Since the dieback of the shoots and wilting sometimes occur in consequence of spore-infected snags or at injured axils in the branches, it is apparent that the cuttings become inoculated on the stock plants with any one of several pathogenic organisms though they may appear healthy and desirable for propagation.

Growers were requested to collect batches of cuttings as if for their own propagation and to submit them to the writer for study. Laboratory examination revealed discolored tissue about the nodes in some instances. Transfers of tissue from the nodes and base of the cuttings were made to sterile culture media in petri dishes. Both Fusarium and Alternaria were occasionally obtained (Table 2).

The greenhouse atmosphere and growing beds of a carnation range are obviously never completely free of pathogenic fungi, however healthy the flowering stock may appear. The avoidance of diseased areas in a range showing more or less disease is not so completely effective in preventing the transfer of contamination as selection in an environment of generally healthy stock. The population of the fungus in the environment of the plants bears some relation to the extent of the disease. Thus a greenhouse kept sanitary by the successful control of disease is obviously important in relation to propagation. The transmission of pathogenic organisms either as hidden infection or as spores lodged on the cuttings can be serious, and unless it is adequately combated, desirable effective control measures in later stages of culture can be defeated.

PREPARATION AND DISINFECTION OF CUTTINGS

Trimming

Carnation cuttings are frequently inserted in the sand without trimming or further preparation. A smooth, horizontal cut with a sharp knife at the base of the cutting to remove the loose remnants of tissue has been advocated (71, 72, 76) on the presumption that a jagged, sloping surface encourages an uneven formation of roots and increases the risk of decay. Our growers also obtain satisfactory results from a clean diagonal cut, which gives a larger area for the growth of roots. Lamborn (39) wrote that the slips can be broken off with the fingers and put directly in the cutting bed without the use of a knife and they will root as certainly as if trimmed and smoothly cut at the end. Rooting the cuttings without trimming them is time and labor saving, but trimming makes it possible to plant more cuttings in a given area of sand. The extra operation of trimming the cuttings is desirable since it offers the opportunity of scrutinizing them and discarding any showing imperfections. There appears to be no evidence against either method so far as disease is concerned.

Soaking in Water

The practice of soaking carnation cuttings in water before they are planted can be the means of spreading disease, especially if the cuttings are infected or come from infected stock plants or contaminated areas in the benches. In water, the cuttings generally may become inoculated by spores freed from a single diseased cutting, and outbreaks of carnation rust in the young stock result from this practice. Creager (22) reported that the soaking of carnation cuttings in water contributed to the spread of bacterial wilt caused by *Phytomonas caryophylli* Burk. among the young stock. Kirby (36) reported that soaking cuttings for one hour caused 18 percent of them to become infected with Alternaria in contrast to 92 percent of those soaked 4 hours.

In view of the continual redistribution of spores among the stock plants in the benches by water, air currents, or even cultural practices, some infection is possible among apparently clean cuttings. It would seem best either to wash the cuttings under a spray of cold water or to soak them briefly in water and then allow the water to drain off. Subsequently they might be kept moist in a cool atmosphere until they can be trimmed and planted. Cuttings soaked in water for several hours do not root well and can be a total failure.

Disinfecting Chemicals

Action on Fungous Spores

The presence of spores of pathogenic organisms on the cuttings suggests the desirability of disinfecting them before they are placed in the sand. A chemical disinfectant for this purpose must meet certain rigid requirements. It must not inhibit rooting or injure the cuttings in any way. The treatment would be advantageous if it could hasten and improve rooting in addition to providing some degree of disinfection. The toxicity of many chemicals to the conidia of the Alternaria blight fungus and of other organisms pathogenic to carnations was studied (Fig. 5).

Small pieces of diseased carnation plant tissue bearing spores of *Alternaria dianthi*, *Fusarium dianthi*, and *Uromyces caryophyllinus* and of tomato leaf tissue bearing spores of *Cladosporium fulvum* Cke. were immersed in solutions of certain chemicals selected for their mild fungicidal properties, in the effort to find a safe treatment offering some degree of disinfection. The small pieces of sporulating tissue were immersed and soaked for a period of 5 to 15 minutes, then washed with fresh water and drained, and then incubated at laboratory temperature.

Solutions of potassium permanganate varying in concentration from saturation to 1-2,000 were tested. This chemical is a mild fungicide, and has some use for that purpose in horticultural practice. A saturated solution was generally and consistently toxic, but as the concentration was weakened in gradual steps to 1-2,000 toxicity was not consistent. The results with the same solution were frequently reversed and this was true of both 1-500 and 1-2,000 solutions; but trials in which germination was completely suppressed were frequent enough at a 1-1,000 dilution to make it desirable for disinfecting carnation cuttings. It was apparent that factors not well understood were present which accounted for complete toxicity in many trials and incomplete toxicity or the absence of it in others.

Spores of Alternaria immersed in drops of potassium permanganate 1-500 to 1-2,000 and incubated for 48 hours, then immersed in fresh water and incubated further, failed to germinate. Likewise when the spores were immersed in fresh solutions for 30 to 100 minutes there was no germination. When the spores were immersed in drops of 1-500 and 1-1,000 solutions on glass slides, dried in the laboratory for 30 minutes, and then incubated in moist Petri dishes, the viability of the spores was lost. By this method a 1-2,000 solution was not toxic.

Small pieces of infected leaf areas bearing Alternaria spores were soaked in solutions of potassium permanganate 1-500, 1-1,000, 1-1,500, and 1-2,000 for 5, 10, and 15 minutes and then washed clean with dribbles of fresh water from a medicine dropper. The mounts were then immersed in a drop of fresh water and incubated for spore germination. The solutions were tested for their toxic effect at regular intervals after preparation. Concentrations of 1-1,500 and 1-2,000 were hardly toxic in the 5 or 10 minute immersion periods, even when the solutions were freshly made. The tests showed almost complete loss of fungicidal value after 7 to 10 days from the date of preparation. The spores of the carnation rust fungus seemed to be much more tolerant of potassium permanganate, but immersion of sori longer than 30 minutes and for as long as 48 hours destroyed the power of the spores to germinate.

When King Cardinal cuttings were dipped in a water suspension of spores of the Uromyces rust fungus and then immersed in water for 15 hours, 32.8 percent showed rust pustules after growing in the sand for 24 days. In contrast, only 3.2 percent of the cuttings immersed in potassium permanganate 1-1,000 for 45 minutes and kept moist over night showed rust. Immersed in potassium permanganate for 15 hours, 1.2 percent of the cuttings showed rust; immersed in water for 45 minutes and kept moist over night, 72.8 percent of them were infected. In other tests the amount of disease was determined from a count of the infections in the blades and stems. Infection at the base of the stem was indicated by decay or discoloration or both. This was regarded as a separate infection and was added to the number of infections found elsewhere on the cuttings to obtain the total. The value of potassium permanganate as a disinfectant is shown in Tables 3, 4, and 7. Beginning with the earliest tests conducted in 1931, the results with potassium permanganate have been outstanding.

Malachite green was consistently toxic in dilutions up to 1-40,000 and strong effect was shown in a range of 1-20,000 to 1-40,000. At weaker dilutions considerable germination was noted. The consistent fungicidal effect of malachite green at these weak dilutions represented a distinct contrast to that obtained from potassium permanganate. The toxic effect of malachite green 1-25,000 to the spores of the rust fungus was more rapid and complete than that of potassium permanganate 1-1,000. Howard (34) found that malachite green at great dilutions is strongly fungicidal to the spores of *Alternaria solani* (Ell. and Mart.) Jones and Grout. A similar effect upon *Alternaria dianthi* is shown here. Nevertheless, the control of disease among artificially inoculated cuttings immersed in malachite green solution has not been satisfactory (Tables 7, 8, 9). More study is needed.

TABLE 3. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF BOSTON WARD CARNATION CUTTINGS AND CONTROL OF ALTERNARIA.

Treatment (5 Minutes)	Number of Cuttings	Percent Rooted	Number Infections Per 100 Cuttings
A			
Mercuric Bichloride 1-1,000	512	0.0	2.3
Uspulun 2.3 gms.-1,000	595	6.5	7.5
Potassium Permanganate 1-1,000	1159	79.8	16.0
Bordeaux 4-4-50	1278	41.4	21.6
No Treatment	676	71.9	50.2
B			
Potassium Permanganate 1-1,000	85	80.0	10.5
Uspulun 2.3 gms.-1,000	142	9.1	6.3
Bordeaux 4-4-50	102	7.8	7.8
No Treatment	96	57.3	28.1
C			
Potassium Permanganate 1-1,000	353	90.0	12.4
Bordeaux 4-4-50	393	52.9	12.2
No Treatment	317	73.8	51.7

TABLE 4. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF MATCHLESS CARNATION CUTTINGS AND CONTROL OF ALTERNARIA. CUTTINGS PREVIOUSLY IMMERSED IN A WATER SUSPENSION OF SPORES OF ALTERNARIA.

Treatment	Number of Cuttings	Percent Rooted	Number Infections Per 100 Cuttings
(5 MINUTES)			
Potassium Permanganate 1-1,000	100	94	56
Same, plus 0.12 percent Fish Oil	100	93	4
Water	50	24	1108
Water*	50	84	0
(10 MINUTES)			
Potassium Permanganate 1-1,000	100	84	16
Same, plus 0.12 percent Fish Oil	50	78	36
Same, plus Kayso 0.5 gms.	50	94	16
Same, plus Saponin 0.5 gms.	50	100	62
Water	100	87	139
Water*	50	100	0
(15 MINUTES)			
Potassium Permanganate 1-1,000 (new)	147	71	38
Potassium Permanganate 1-1,000 (old)	142	79	56
Water	76	43	197
Water*	74	69	16

*Not inoculated.
Fish Oil, Saponin, Kayso added to improve wetting.

Methylene blue solutions of 1-1,000 to 1-4,000 were studied. Solutions of 1-1,000, 1-2,000 and 1-3,000 were most frequently toxic. The results were often reversed, and in this respect methylene blue appeared like potassium permanganate. The immersion of carnation cuttings in a 1-3,000 methylene blue solution did not give satisfactory control of disease.

Solutions of Orange and Yellow Helione* in concentrations of 1-200 to 1-800 were inconsistently toxic. They were toxic at the strongest concentration more frequently than not, but appeared generally not promising.

Effect on Rooting and Disease Control

Guba (28) reported a notable improvement in the rooting of carnation cuttings by immersing them for 5 to 15 minutes in a 1-1,000 solution of potassium permanganate prior to planting. Disinfection of the cuttings was also claimed for the treatment. In subsequent articles on carnation diseases, this treatment of the cuttings has been endorsed repeatedly (29, 30, 31, 32, 33). The recommendation is based on favorable results obtained in laboratory experiments and in commercial propagating houses (Tables 3, 4, 7, 12).

Carnation cuttings immersed in potassium permanganate solution acquire a darker green color and show a greater growth of roots and foliage during their growing period in the sand than untreated cuttings. Such a response in the propagation of carnation cuttings is very desirable.

*Standard Agricultural Chemicals, Inc., Hoboken, N. J.

TABLE 5. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF VIRGINIA ROSE CARNATION CUTTINGS.

Treatment (15 Minutes)			Percent Well Rooted	Percent Not Rooted
Mercuric bichloride	1-1,000	5 minutes*	87.8	4.0
Methylene Blue	1-3,000		89.6	5.1
Malachite Green	1-25,000		61.2	15.3
Orange Helione	1-200		78.3	8.2
No Treatment			89.1	8.4

*Thoroughly washed after chemical treatment and then trimmed.

TABLE 6. EFFECT OF SOLUTIONS OF MALACHITE GREEN ON ROOTING OF CARNATION CUTTINGS.

Treatment (15 Minutes)	Percent Rooted		Percent Rooted				
	Rinsed in Water		Not Rinsed in Water				
	Peter Fisher	Puritan	Nina Brener	Olivette	Peter Fisher	Puritan	Boston Ward
Malachite Green							
1-20,000	35.2	78.5	100	100	58.8	100	97
1-30,000	64.7	100	86.6	97	47	71.4	97
1-40,000	43.7	85.7	82.7	100	47	78.5	92
1-50,000	35.3	100			44.4	85.7	
No Treatment	35.3	100	90.3	100	11.7	92.8	100

TABLE 7. EFFECT OF CHEMICAL SOLUTIONS ON ROOTINGS OF PURITAN CARNATION CUTTINGS.

Cuttings previously immersed in a water suspension of spores of *Alternaria Dianthi* and *Fusarium Dianthi*.

Treatment (1 Hour)	Percent Well Rooted	Percent Not Rooted
Potassium Permanganate 1-1,000	47.9	47.9
Methylene Blue 1-3,000	18.0	65.0
Malachite Green 1-25,000	1.0	91.0
Water	11.4	80.4

Malachite green, in 1-1,000 and slightly weaker solutions, was harmful to rooting. Frequently, the type of rooting following immersion in malachite green solutions 1-20,000 and weaker was not satisfactory; at other times no injurious effect was shown (Tables 5, 6, 7, 8, 9). The root-inducing effect and the greater vigor of the cuttings associated with the use of potassium permanganate solution was not shown with malachite green.

When cuttings were immersed in a 1-1,000 solution of methylene blue, the rooting was not satisfactory. Sometimes there was no harmful effect from a 1-3,000 solution (Tables 5, 7). The results of immersing untrimmed carnation cuttings for 5 minutes in a 1-1,000 solution of mercuric bichloride, followed by washing, trimming, and rinsing in fresh water, were inconsistent (Tables 5, 9).

Cuttings so treated usually rooted less than those immersed in water or not treated at all. Injury seemed to occur even though, after the treatment and rinsing in water, the basal portion of the stem was cut away to the next node before the cutting was planted in sand. For this purpose the use of this material in practice would be hazardous.

Table 8. Effect of Chemical Solutions on Rooting of Nina Brener Carnation Cuttings and Control of Disease.
Cuttings previously immersed in water suspension of spores of *Alternaria dianthi* and *Fusarium dianthi*.

Treatment (15 Minutes)	Percent Rooted	Percent Infected	
		Rooted	Total
Malachite Green			
1-20,000	86.5	13.3	23.3
1-30,000	93.0	15.2	18.7
1-40,000	93.2	18.0	22.9
No Treatment (Water)	92.9	20.6	25.7

Table 9. Effect of Chemical Solutions on Rooting of Nina Brener Carnation Cuttings and Control of Disease.
Cuttings previously immersed in a water suspension of spores of *Alternaria dianthi* and *Fusarium dianthi*.

Treatment (15 Minutes)	Percent Rooted		Percent Infected	
	Good	Poor	Rooted	Not Rooted
Malachite Green 1-25,000	56.0	8.0	43.7	73.3
Same, washed	46.1	23.0	33.3	74.9
Malachite Green 1-25,000 Vatsol 2-25,000	53.8	11.5	5.8	55.5
Same, washed	64.0	8.0	5.5	57.1
Malachite Green 1-40,000	44.0	8.0	23.0	50.0
Same, washed	46.1	15.3	12.5	60.0
Malachite Green 1-40,000 Vatsol 2-25,000	33.3	4.1	11.1	53.3
Same, washed	64.0	4.0	0.0	85.0
Mercuric Bichloride 1-1,000*	46.1	15.3	18.7	50.0
Same, plus Vatsol 2-25,000*	46.7	8.3	7.7	27.2
Water	88.0	0.0	68.1	33.3
Water**	88.0	8.0	2.2	100.0

* Trimmed and washed after treatment.
** Not inoculated.
Vatsol added to improve wetting. Supplied by American Cyanamid and Chemical Corp., Pittsburgh, Pa.

Preliminary tests with organic fungicides indicate the value of Arasan and Fermate* on the control of disease (Tables 10 and 11).

*Tetramethylthiuram disulfide and ferric dimethyldithiocarbamate respectively.

TABLE 10. EFFECT OF CHEMICAL POWDERS ON ROOTING OF OLIVETTE CARNATION CUTTINGS.
Basal section of cuttings dipped in powder, then planted in sand.

Treatment	Percent Well Rooted	Percent Poorly Rooted
Fermate	97.1	0.0
Talc	54.2	11.4
(Dithane)HE-175 10%-Talc 90%	40.0	5.7
Arasan 10%-Talc 90%	88.5	5.7
Spergon 10%-Talc 90%	48.5	14.2
Fermate 10%-Talc 90%	74.2	0.0
No Treatment	62.7	11.4

TABLE 11. EFFECT OF CHEMICAL POWDERS ON ROOTING OF OLIVETTE CARNATION CUTTINGS AND CONTROL OF DISEASE.
Basal portion of cuttings immersed in spore suspension of *Fusarium dianthi*, then dipped in fungicidal chemical powder before being planted in sand.

Treatment	Percent Rooted		Percent Infected
	Well	Poorly	
Fermate	57.1	8.5	8.5
(Dithane) HE-175 10%-Talc 90%	0.0	0.0	85.1
Arasan 10%-Talc 90%	48.5	17.1	14.2
Spergon 10%-Talc 90%	52.7	19.3	11.1
Fermate 10%-Talc 90%	62.3	8.5	2.8
No Treatment	0.0	11.4	85.7

No injurious effect on rooting was shown by Arasan or Fermate, and the control of Fusarium wilt was striking.

The value of adding these materials to hormone powder as a means of combining both root-inducing action and disease control in the same treatment of the cuttings before planting in sand is indicated. Study is required to determine the effect of immersing carnation cuttings in a water bath of these chemicals on the control of other carnation diseases and on rooting.

Hormone Materials

Kirby (36, 37) reported that dusts containing indolebutyric acid or naphthyl acetamide were more effective in disease prevention than a dust containing naphthalene acetic acid, and that all of them and thiourea controlled Alternaria better than potassium permanganate alone. It was implied that these chemicals in talc are more fungicidal than thiourea in talc. The results were based on the condition of Puritan cuttings as they were taken from the sand.

The effect of these hormone materials on spore germination of the same Alternaria organism was studied by the writer. The spores from infected plant material were applied to glass slides with a camel's-hair brush. Subsequently, the slides were dusted with different brands of hormone powders or sprayed with different brands of hormone solutions, corresponding to the concentration recommended by the manufacturer for rooting carnation cuttings. Spores in drops of these hormone solutions were also placed on glass slides and incubated in moist Petri dishes. The following hormonized powders were used:

Rootone (Old Type)	American Chemical Paint Company
Rootone (New Type)	American Chemical Paint Company
Hormodin No. 1 Powder	Merck and Company
Root-Gro	Root-Gro Chemical Company
Thiourea 1-2,500 in Talc	

The following quantities of hormonized solutions were used in ½ pint of water:

Hormodin A	0.6 cc	Merck and Company
Root-Gro Concentrate	12.5 cc	Root-Gro Chemical Company
Auxilin	0.6 cc	Pennsylvania Chemical Corporation

No toxicity to the spores was revealed. Spore germination appeared to be accelerated by all, irrespective of the active ingredient peculiar to each brand. The powders or solutions could not be considered fungicidal and no claims to that effect are made by the manufacturers.

The idea of treating carnation cuttings with hormone powders and solutions was introduced at a time when carnation growers had already adopted the practice of soaking the cuttings in potassium permanganate solution before planting them in sand. Thus the two practices appeared to conflict. It is reported that potassium permanganate inactivates the hormone substance and that when both are used the root-inducing substance should be applied last (22, 23).

Kirby (36, 37) reported the least percentage of diseased cuttings due to Alternaria, the greatest fresh weight, and the best rooting from immersing the cuttings in potassium permanganate solution, then washing them, and subsequently dipping the cut ends in a hormone dust. He found that when the cut ends of carnation cuttings were dipped in naphthalene acetic acid dust, 17 percent of the cuttings showed Alternaria branch rot in contrast to 26 percent of those immersed for 10 minutes in a 1-1,000 solution of potassium permanganate and 60.5 percent of those not treated. When the cuttings were immersed 10 minutes in potassium permanganate solution, washed, and the cut ends then dipped in naphthalene acetic acid dust, the percentage of diseased cuttings was reduced to 5 percent. Since the brands of hormone materials studied are not fungicidal to spores of the organisms pathogenic to carnations, the control reported by Kirby (36, 37) is obviously not due to the action of the dust upon the spores of the Alternaria pathogene. Experimental trials repeating the procedure and materials employed by Kirby gave nothing significant in favor of supplementing potassium permanganate with a hormone chemical (Fig. 8).

Cuttings from Ivory in February were used in another test. The cuttings were grown in sand for 19 days and rooting was classified into groups as good, poor, and not rooted. In a second test King Cardinal, Pelargonium, Wivelsfield Crimson, and Woburn were used and the results were recorded on March 7, 22 days after the cuttings were planted in the sand (Table 12).

Many tests have revealed the virtue of potassium permanganate in accelerating rooting and improving the growth of carnation cuttings in the propagating bench. The value of hormone substances for this purpose is recognized (38, 46). Either treatment is superior to none for promoting growth of roots. Nevertheless, most growers do not regard the hormone materials with favor except for varieties like Pelargonium that are hard to root, and prefer to root their cuttings in the natural way. Injury from the use of hormone materials has occurred frequently.

Table 12. Effect of Potassium Permanganate and Hormone Materials on Rooting of Carnation Cuttings.

Treatment (In the order used)	February 2-21 Percent Rooted Good	February 2-21 Percent Rooted Poor	February 2-21 Percent Not Rooted	February 13-March 7 Percent Rooted Good	February 13-March 7 Percent Rooted Poor	February 13-March 7 Percent Not Rooted
Potassium Permanganate 1-1,000	84	9	7	90.0	7.5	2.5
Potassium Permanganate, Rootone	67	29	4	90.0	7.5	2.5
Rootone	37	59	4	87.5	2.5	10.0
Rootone, Potassium Permanganate	80	13	7	85.0	5.0	10.0
Potassium Permanganate. Root-Gro				90.0		10.0
Root-Gro, Potassium Permanganate				100.0		
Potassium Permanganate, Hormodin A	90		10	90.0	5.0	5.0
Hormodin A, Potassium Permanganate	74	8	18	95.0		5.0
Hormodin A	75	13	12	97.5	2.5	
Potassium Permanganate, Auxilin	73	10	17			
Auxilin, Potassium Permanganate	72	11	17			
Auxilin	68	19	13			
No Treatment	59	35	6	42.5	25.0	32.5

The hormone treatment generally has not encouraged significantly better rooting than the permanganate treatment and the omission of the latter would be unwise if some degree of disinfection of the cuttings is desired. The treatment of the cuttings with both the hormone material and potassium permanganate in some instances gave superior results, irrespective of the order in which they were used; but the contrast between the dual treatment and potassium permanganate alone could not be considered sufficient to warrant the use of both in practice. The good results obtained from extensive tests with potassium permanganate alone warrant its use. If the grower will make fresh solutions every 7-10 days during the propagating season he will find much merit in its use in contrast to no treatment at all. The cuttings must not be rinsed after immersion in the solution; rather, they should be sprinkled overhead with water after they have been inserted in the sand.

PROPAGATION

The art of propagating carnations from cuttings has been described frequently in various bulletins on carnation culture and in the trade papers. The reader is referred to a recent and comprehensive account describing all the details of propagation by McCully (44), a commercial grower in Massachusetts.

Sanitation

The maintenance of sanitary conditions and good management of moisture and temperature conditions in the propagating house are highly desirable. Cleanliness and the sanitary disposal of carnation debris and unrooted litter are very helpful in disease control (Fig. 9). Beuerlein (4), a New Jersey commercial grower, emphasizes cleanliness in and around the greenhouse in view of the relationship of sick plants and carnation litter to the cultivation and spread of disease. This is especially applicable to the propagating house. The Botrytis bud rot fungus, the various parasitic species of Fusarium, and the Alternaria blight fungus multiply on dead carnation debris.

In the preparation of the house for the new rooting season, all of the old sand is removed and the bare benches are washed clean with water. Some cautious growers drench the woodwork and ground with scalding hot water, or with a 1-75 solution of formaldehyde. The exposure of the bare wood to sun and drying weather before resanding is also desirable.

The presence of soil or organic matter in the sand could imply contamination with the Rhizoctonia stem rot fungus which inhabits all types of soil, even virgin soil. Tools should be cleaned before they are brought in contact with the sand, and every effort should be made to keep soil out of the propagating beds. The practice of transplanting the cuttings into soil in flats on the sand bench should not be tolerated.

Treatment of Sand

Frequently the same sand is used for rooting more than one crop of cuttings. Most growers use the sand but once and this precautionary practice is helpful in avoiding trouble, but there are times in the winter months when sand is difficult to obtain or to replace, and the grower is obliged to use the same sand again. Peltier (53) advocated treating the sand with steam and hot water. This practice would seem desirable especially for second cropping sand, to avoid disease which might originate from inoculum in the sand itself. Results reported by Kirby (36, 37) in Pennsylvania are strongly against the use of sand the second time without first sterilizing it. In an experiment reported by him 6 to 8 percent of the cuttings from new sand were infected with Alternaria in contrast to 56 percent from second-crop sand. The harvest of healthy well-rooted cuttings, rooting above 90 percent, should indicate that the same sand is safe for further planting. Nevertheless, commercial practice recognizes that rooting and disease control are improved by the use of new sand.

Some growers drench the sand with 1-1,000 solution of potassium permanganate previous to second use, and the practice is based chiefly on the faith in the chemical that some growers have acquired from its use as a disinfectant for cuttings. The results have been questionable in the absence of sufficient evidence and since the chemical is considered only mildly fungicidal. The results of a test with Virginia cuttings on new sand in March in a grower's propagating house where serious losses of cuttings from *Fusarium culmorum*, the root rot fungus, were occurring may be considered rather typical.

Treatment	Percent Well Rooted (Based on 140)
Potassium Permanganate	
(Cuttings)	96.5
(Sand)	95.3
(Cuttings and sand)	92.6
No Treatment	86.7

The results appeared to show that factors in the grower's practice, not revealed in this test, contributed to his loss. The value of propagating clean cuttings from clean sources was recognized and a greater improvement in the stand would appear to result from treating the cuttings rather than the sand with potassium permanganate. Potassium permanganate is not comparable in its fungicidal effect with the more generally recognized fungicidal chemicals, but it has a unique stimulating effect on rooting and is tolerated, which makes its use especially desirable. The management of the cutting bench with respect to watering, shade, light, and temperature is also of great importance to successful rooting and even more important than the quality of the sand used.

AGE OF PLANTS IN RELATION TO DISEASE AND YIELD

The relation of age of carnation plants to disease and yield of flowers during the first producing year has never been clearly established to the knowledge of the writer. Frequent observations have indicated more disease among the older plants, other conditions being alike. In New England new carnation plants are propagated from cuttings gathered from November to April, and all of the young plants propagated during these months are usually mixed together to constitute the next planting. By April all of the young stock is growing in pots or flats, and that of the earliest propagation has made the greatest growth of root and top. Early in the history of American carnation culture, rooting in February and March was apparently preferred. More recently, according to Wiggin (80), better results are secured from early propagation, i. e., November or December, because a larger plant with more branches is secured.

In transplanting operations and especially in transplanting from the field to the greenhouse benches, the greatest amount of breakage has appeared to occur among the largest or oldest plants. The close association of disease with injuries and unfavorable growing conditions has been established. Differences in yield of cut flowers of carnation plants made from cuttings taken in different months of the rooting season can be shown in some years. In the year 1931-32, Matchless carnations rooted in February and March yielded the greatest number of No. 1 flowers; December plants, the least. In the year 1932-33, February-rooted Matchless plants yielded slightly more No. 1 flowers than plants rooted in other months. In another year when only Matchless plants of January and March cuttings were compared for yield of cut flowers, there was no significant difference. In still another year, December-rooted plants yielded significantly more than plants rooted in January, February, or March, when all were benched on July 15. The March-rooted plants yielded the least. Factors other than the month of propagation appear to be involved.

FIELDING AND BENCHING

The maintenance of the producing stock in the greenhouse much after May 30 would require the fielding of the young plants, and it is also a factor in determining the date of benching. The two classes of stock are managed to correspond to each grower's concept of their respective value under his particular conditions. In the field the carnation stock experiences certain hazards from the weather and from disease, notably Alternaria blight, and a certain amount of abuse and injury in transplanting which also introduces a serious hazard from disease, notably Fusarium branch rot. Experience has taught that a long growing period in the field extending into late July and beyond is dangerous. In the shelter of the greenhouse many of the growth factors are under better control; but temperature conditions in the greenhouse in July and August can also be severe enough to check and suspend growth. Practice generally has taught the value of some outside growing and the importance of benching the stock early in the summer season. Delay in housing the fielded plants increases the amount of disease which can be shown in the yield of flowers (Fig. 10). A limited series of tests is suggestive of the idea.

Our experience in 1932-33 showed a much greater yield from January-rooted plants benched on July 20 than from similar plants benched on July 30. In the same year March-propagated plants benched on July 10 and July 20 yielded the same; those benched on July 1 and June 20 increasingly less. In 1932-33 the effect of time of benching on yield of No. 1 Matchless carnations per square foot of growing area from October to February inclusive is shown in the following table.

	Benched on July 15	Benched on August 10
December Plants	15.0	5.1
January Plants	11.8	3.0
February Plants	13.5	7.1
March Plants	11.3	2.2

In 1936-37, housing on July 7 in contrast to September 4 increased the yield of No. 1 Boston Ward carnation flowers by approximately 42 percent. Early propagation plus late housing would appear to encourage more disease and a depreciation in growth and yield of flowers. If, under the grower's particular conditions, a limited period of outside culture is desirable, the plants should all be housed by the second week in July or even earlier. When Alternaria blight was first recognized as a serious carnation disease (14, 62, 81, 82), it was troublesome only on outside-grown plants. Where losses from blight have been repeatedly common, growers should abandon outside culture entirely.

CONTINUOUS GREENHOUSE CULTURE

Some of the young stock may be carried along in pots after rooting. This method of culture is desirable if the grower has sufficient help to give pot culture the care it requires. There are advantages, notably that less loss is encountered in transplanting and practically no injury. The shortage of labor and the added cost of culture would favor growing the young plants in 4-inch flats, and this is the common practice in New England. A limited stock may be carried along in greenhouse benches spaced 4 x 4 inches and transplanted later into permanent beds as the old producing stock is removed.

If the plants are not going into the field, they must be planted directly from the flats to the benches. While continuous inside growing contributes to the control of certain diseases, nevertheless it does not produce the kind of plant growth derived from a few weeks of outside culture. Since numerous factors are involved in determining the kind of growth under the two sets of conditions, it would not be fair to claim that one method is better than the other so far as flower production is concerned. The loss attendant upon one method might be turned into a gain by the advantage of some other contributing factor. Inside culture for the entire range would deprive some growers of a substantial income from the harvest of cut flowers in June and July, which other growers would regard as a false gain because of loss from disease resulting from the delay in replanting.

SEGREGATION OF YOUNG STOCK

Continuous inside culture raises the problem of plant growth control. The flats of soil planted to rooted cuttings are placed on supports above the flowering beds and along the eaves where growth conditions cannot be satisfactorily controlled and the detection of disease is obscured and delayed. The flats must be taken down in May, and sometimes it is a problem to decide how to handle the plants, especially when prices for carnations are high. Either the plants must be set in the field or in the benches, or they must be carried along in the flats after May 30 until the old plants and soil can be cleaned out and the benches resoiled. Labor shortage requires planting the new stock in old soil, and the continuation of some of the flowering stock for two or even three years. The abuses which the young stock receives, and the loss attendant upon the delay would, in more normal times, justify a plant house wholly for growing the young plants (Fig. 11). A plant house should simplify the classification and segregation of the stock, make it easier to recognize disease and to exclude inferior or unhealthy stock from the planting, and enable the grower to realize more fully the potentialities of healthy, well-grown plants. It would eliminate much of the hard work of lifting the flats onto elevated supports and removing them again for planting.

GREENHOUSE MANAGEMENT

The intelligent management of the greenhouse atmosphere, and the judicious use of water, are intimately involved in the successful control of disease. During the course of these studies frequent instances of serious occurrences of the Alternaria blight disease were observed in places kept excessively wet by water dripping onto the planted beds through leaks in the greenhouse roof. The same condition may arise from careless watering practices and too much water.

Fusarium root rot, Fusarium branch rot, and Rhizoctonia stem rot are favored by high temperatures and a high water table. These diseases are epidemic only in the warmest months of the year.

The grower can encourage the prevalence of carnation foliage diseases in the greenhouse by tolerating continual moist and stagnant conditions. Exchanges of greenhouse air with the outside air are required to avoid, or to remove, moist stagnant atmospheric conditions. Both heating and ventilating require careful regulation to meet the changes created by the outside weather, and the effect of both upon the greenhouse atmosphere can be seriously impaired by the misuse of water.

Some growers believe that carnations do best by an alternate drying and wetting of the soil. Wiggin (80) states that carnations do best when the soil is uniformly moist but not saturated. It is his experience that newly benched plants should be kept as dry as possible without producing a wilted condition. Peltier (53) reported that the temperature should be kept as low as possible and no more water applied than is necessary for good plant growth.

Carnations are grown best at a temperature range of 50°–68° F. Low temperatures inhibit infection and the progress of disease, but they are difficult to maintain in Massachusetts greenhouses because of the warm weather prevailing in the first few months after the fielded plants are benched. Continued low temperatures correlated with a humid atmosphere encourage occurrence of Botrytis bud rot. These conditions are paired when heating is delayed or lacking in the fall months. An epidemic infection of the flowers by Alternaria in November and December, unusual as it is, occurs where both heat and ventilation are not properly managed. Similarly, the only devastating occurrence of *Heterosporium echinulatum* (Berk.) Cke., the fungus causing fairy ring spot, to come to the writer's attention was brought about by confined humid conditions and wet foliage. The same conditions apply to serious occurrences of carnation rust, *Uromyces caryophyllinus* (Schrank) Wint., and to bacterial leaf spot, *Phytomonas woodsii* (Smith) Bergey et al. These diseases become serious only as sound watering and management practices are seriously violated. In every instance the immediate correction of the contributing conditions has checked these diseases.

Figure 1. Alternaria Blight Infection of Carnation Foliage, Stems, and Flowers.

Figure 1. Alternaria Blight Infection of Carnation Foliage, Stems, and Flowers.

Figure 2. Carnation plants Infected with Alternaria Blight.
Showing the devastating effect of disease on the lower foliage while the plants were in the field, and the relatively healthy top foliage representing new growth in the greenhouse after the plants were benched.

Figure 3. Carnation Cuttings Showing Leaf and Stem Infections due to Alternaria Dianthi. Basal stem infections are frequently the cause of failure to root.

Figure 4. Single Spore Infections by Alternaria Blight Fungus, following inoculation of carnation plant with a water suspension of spores.

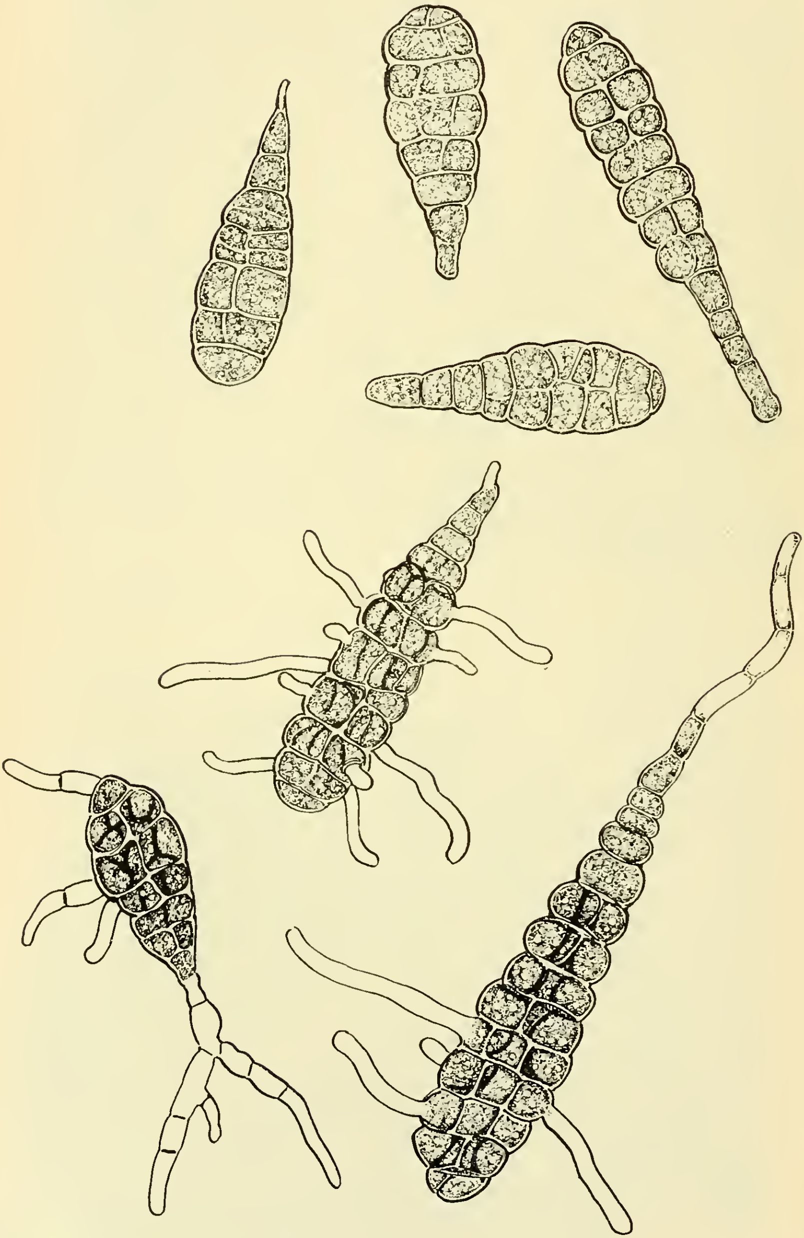

Figure 5. Conidia or Imperfect Spores of Alternaria dianthi; Germinating Spores.

Figure 6. Branch Rot caused by Fusarium dianthi.
Characterized first by wilting and rotting of a single branch and ultimately by the death of the entire plant.

Figure 7. Rhizoctonia solani, the Stem Rot Fungus, destroying Boston Ward plants growing in flats.

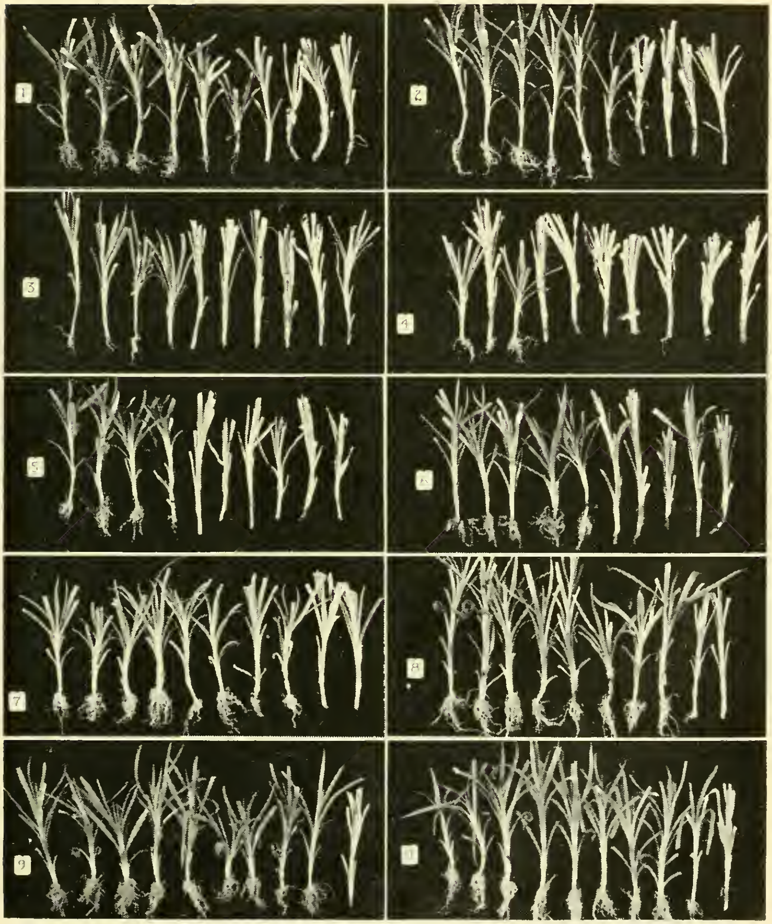

Figure 8. Carnation Cuttings Showing Contrasts in Rooting in Consequence of Treatments with Fungicidal Solutions and Root-Inducing Compounds.

1. Check—No Treatment
2. Thiourea
3. New Rootone
4. Old Rootone
5. Malachite Green 1-25,000, 15 min.
6. Methylene Blue 1-3,000, 15 min.
7. Potassium Permanganate + Old Rootone
8. Potassium Permanganate + Thiourea
9. Potassium Permanganate 1-1,000, 15 min.
10. Potassium Permanganate + New Rootone

Figure 9. Propagation House showing Sand Benches, with cloth curtain on the sides below to confine the heat underneath; cloth screens above to shade the rooting cuttings; ventilators for air exchange; thermometers for registering sand and air temperatures; and a particular regard for neatness and sanitation.

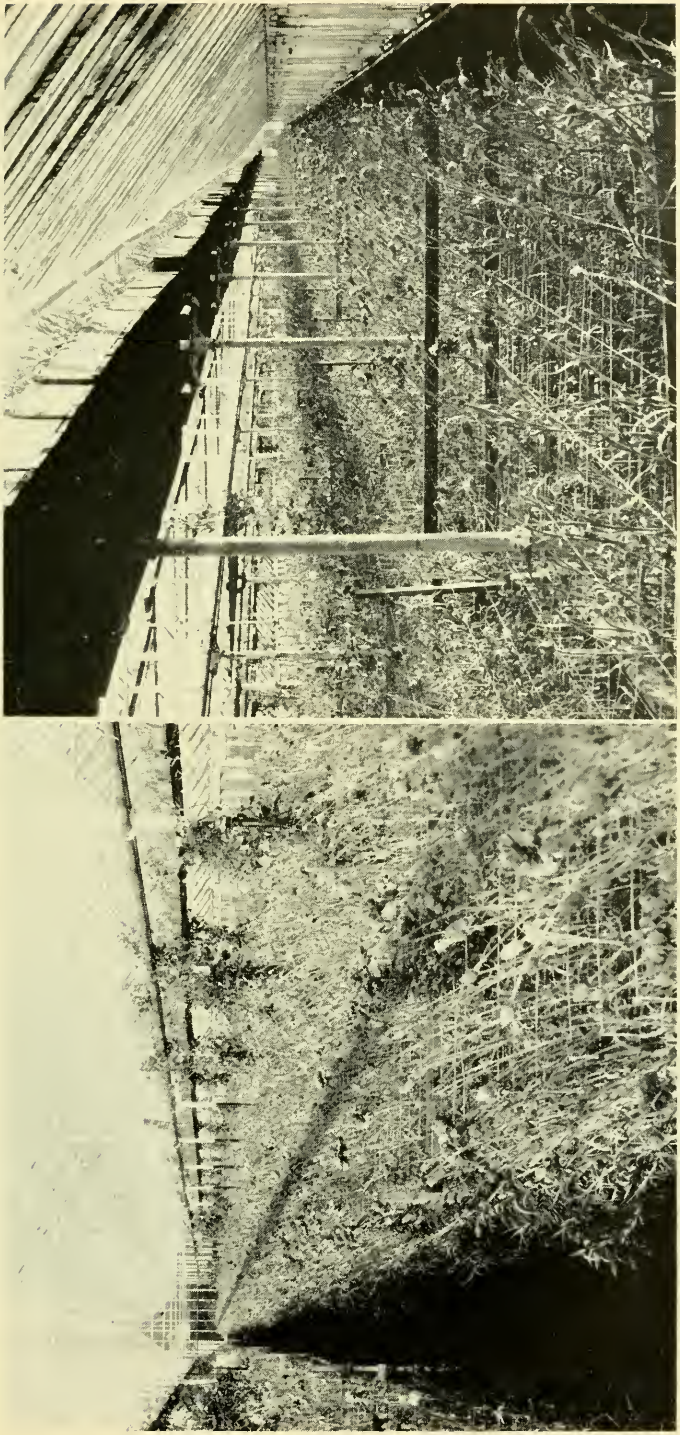

Figure 10. Two Benches in the Same Greenhouse, showing Contrasts in Growth of Carnations and Disease due to Alternaria dianthi.

Left: Transplanted from the field on July 15; Right: on August 20.

Figure 11. Greenhouse Devoted Exclusively to Young Stock.

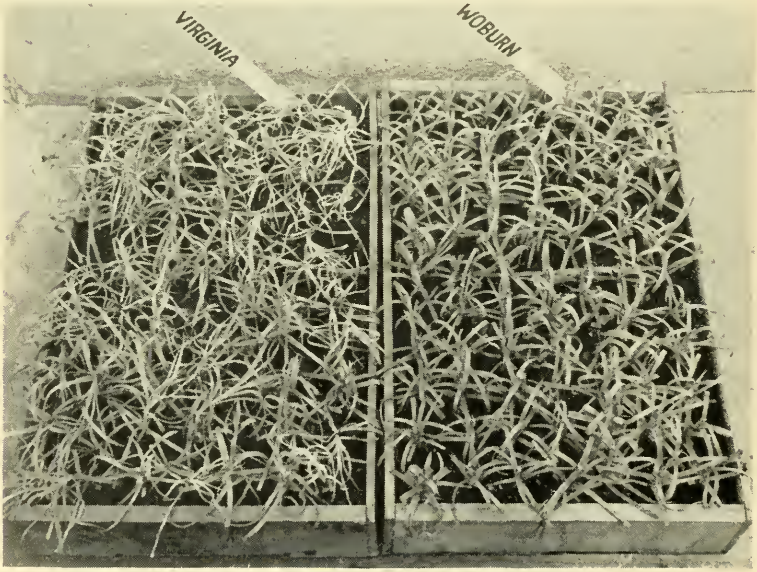

Figure 12. Complete Susceptibility and Complete Resistance to Fusarium dianthi Exhibited by Virginia and Woburn Varieties, respectively.

Figure 13A. Olivette Carnations Transplanted June 1944 in Old Soil Used Once.
Above and below: Left bench, soil not steamed, transplanted from the field.
Right bench, soil steamed, transplanted from flats.
A. S. MacGuffog, Westboro, February 1945.

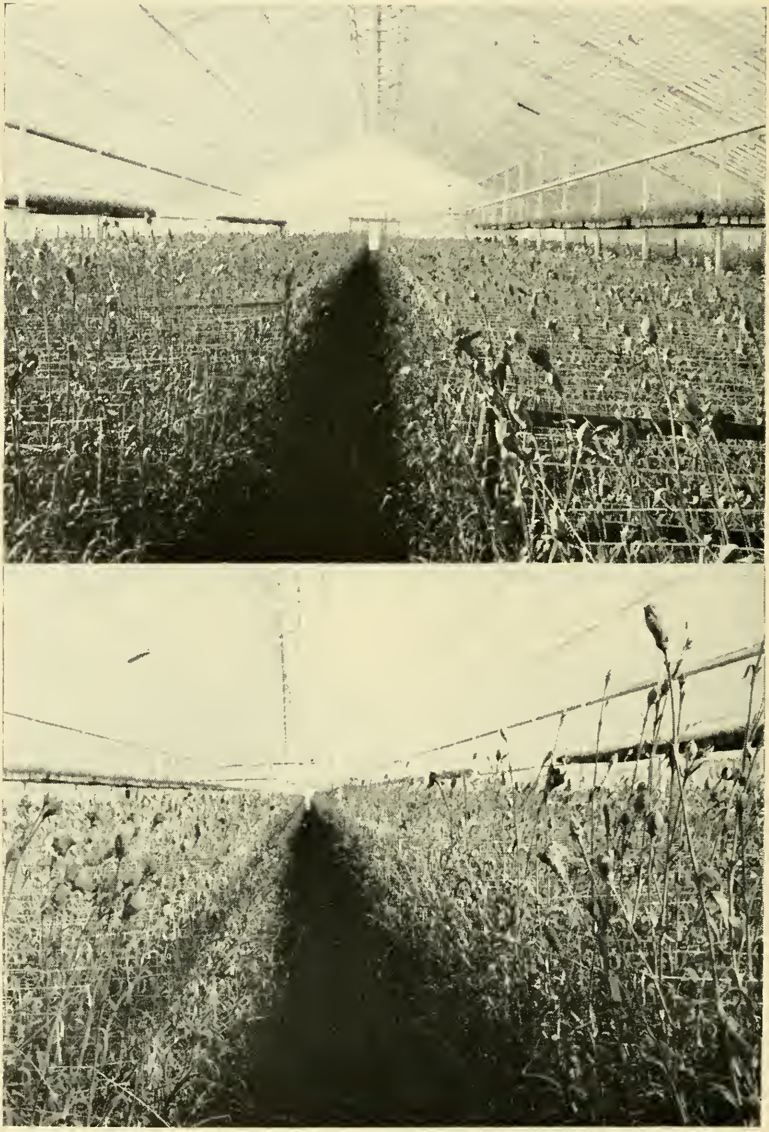

Figure 13B. King Cardinal Carnations Transplanted from Flats June 1944 in Old Soil Used Once.

Above: Left bench, soil steamed; Right bench, soil not steamed.
Below: Left bench, soil not steamed; Right bench, soil steamed.
Photographs taken from opposite ends of greenhouse. A. S. MacGuffog, Westboro, Feb, 1945.

Figure 14. Carnation Plants (Matchless), showing (above) Control of Blight from Spraying with Bordeaux, and (below) Not Sprayed

WATER SYRINGING AND NAPHTHALENE FUMIGATION

The substitution of naphthalene fumigation for the practice of syringing carnation plants with cold water or salt water to control red spider mite has improved the quality of carnations and aided in the control of disease (29). Two or three fumigations at intervals of 5 to 7 days are recommended, using naphthalene flakes at the rate of 2 ounces per 1,000 cubic feet, or a commercial naphthalene base fumigant as directed by the manufacturer. A temperature range of 70° to 80° F. and a relative humidity range of 60 to 80 percent should be maintained during the period of fumigation. One lamp is used for each 7,000 cubic feet, and the heat is adjusted to vaporize one-sixth of the dosage each hour of a 6-hour fumigation period. Fumigation should not be practiced during excessive wind or at temperatures above 90°.

Solutions of salt and nicotine sulfate in cold water, formerly used for syringing carnations, are not lethal to the red spider mite. Some fungicidal value is shown, and the spread of disease is indicated also. In one of the tests which is indicative, an average of 1.17 infections per leaf followed wetting the plants with a spore suspension of Alternaria in a 1-500 solution of 40 percent nicotine sulfate containing 5 percent table salt, in contrast to an average of 3.42 infections per leaf with a spore suspension in water.

Some experiments were carried out to determine the comparative effect of naphthalene fumigation and water syringing on the yield of flowers. The blight disease especially was a factor involved in the contrasts. Six benches in each of two adjoining like sections of a greenhouse of 5,000 cubic feet were planted to 54 Matchless plants each on August 1, 1929. The plants in the comparable benches were dug from the same plots in the field which, from June 21 to July 26 had been sprayed or dusted five times with fungicides. A spray of calcium arsenate and lime caused severe foliage injury and subsequently the plants became badly blighted. Plants treated with 20-80 monohydrated copper sulphate-lime dust were badly blighted and also infested with the red spider mite. Other plots of plants not receiving sulfur were more or less infested. After the plants were benched in the greenhouse, the red spider mite infestation was allowed to increase. One house was syringed regularly with cold water; the other fumigated with naphthalene. With the advance of the season distinct contrasts in growth and disease occurred in favor of fumigation, which are expressed in the yield of Number 1 flowers from October 1929, as follows:

Fungicide	Water Syringing	Naphthalene Fumigation	Percent Increase	Termination of Records
Dusts				
Sulfur	718	810	12.8	June 1
Monohydrated copper sulfate-lime 20-80	383	570	48.9	May 1
Sprays*				
Calcium Arsenate	63	123	95.2	January 1
Chemical Hydrated Lime 1½ lb. Lime-Sulfur 1 gal.	532	763	43.3	June 1
Calcium Arsenate 1½ lb. Bordeaux 4-4-50	577	659	14.2	May 15
Calcium Arsenate 1½ lb. No Treatment	425	728	71.2	May 1

*Materials in 50 gallons.

A further test contrasting naphthalene fumigation and water syringing in adjoining greenhouse sections was conducted in 1930-1931. Each of the benches was planted to 54 Matchless plants grown from cuttings collected from December to March. The differences in the yield of Number 1 carnations from October 1930 to April 1931 inclusive are as follows:

Benching Date	Water Syringing	Naphthalene Fumigation	Percent Increase
May 1	99	311	214.1
July 1	215	568	164.1
July 15	243	396	62.9
August 15	145	159	9.6

More blight developed on the plants as the season advanced which, as might be expected, led to narrower differences in the yields of flowers between the two methods of red spider mite control.

The experiment was repeated in 1933-34. Matchless plants grown from December cuttings were planted June 9, 1933, in benches in each of two greenhouse compartments. The soil of one bench in each house was treated with hot water, the soil of another with 1-50 formaldehyde solution, and the soil of the third was left untreated. Naphthalene fumigation was practiced in one greenhouse compartment throughout the period of the test. In the other the plants were syringed with cold water. Satisfactory control of the red spider mite was not obtained with water, and in December 1933 the compartment was fumigated with naphthalene. The fumigation was repeated as necessary. The contrasts in yields of Number 1 carnations per square foot from October to March, 1934, inclusive, under the two sets of conditions are as follows:

Soil Treatment	Water Syringing	Naphthalene Fumigation	Percent Increase
Hot Water	8.1	10.2	43.6
Formaldehyde	8.6	11.0	27.9
No Treatment	5.6	7.5	33.9

Reviewing the results of the several experiments, the adverse effect of wetting the plants with water in the presence of Alternaria blight is shown in the yield of flowers. In the light of our knowledge of the influence of water on the development of other parasitic organisms attacking the foliage, a similar contrast might be shown in the presence of rust, bacterial spot, or fairy ring spot infection.

The warm temperatures required for naphthalene fumigation cause an acceleration of plant growth and also hasten the wilting symptoms of plants infected with Fusarium or Rhizoctonia. When wilting from such infections is present, more of it can follow under warm greenhouse temperature conditions.

Colonies of both Alternaria and Fusarium in nutrient agar culture plates were exposed in a house of carnations warmed for fumigation with naphthalene for 6 hours on each of 4 successive days in January. Both sets of culture plates were maintained for 4 more days in the greenhouse under conditions considered more nearly normal for carnations.

Average Diameter of Colonies Expressed in Millimeters

FUNGUS	CHECK		NAPHTHALENE	
	4 Days	8 Days	4 Days	8 Days
Fusarium culmorum	3.3	38	10	50
Fusarium dianthi	1.6	28	7	40
Alternaria dianthi	8.0	20	7.3	23

In another test over a period of 3 days in February with 6 hours of fumigation on each day, during which temperatures of 75°-80° F. prevailed in contrast to temperatures of 50°-55° in an adjoining greenhouse section, the difference in the average diameter in millimeters of the colonies on agar plates was as follows at the end of 3 days:

Fungus	Check	Naphthalene	Percent Increase
Fusarium culmorum	1.5	2.0	33.3
Fusarium dianthi	3.5	5.3	51.4
Alternaria dianthi	2.8	3.0	7.1

When the plants are generally healthy, none of these diseases become established under the conditions required for naphthalene fumigation. Spores of Alternaria and Fusarium were exposed for 3 days in February in a greenhouse section fumigated for 6 hours each day beginning at 10 a. m. No spore germination followed, whether the spores were exposed dry or previously sprayed with water. In the latter instance evaporation of moisture followed shortly after exposure. The concentration of naphthalene was not fungicidal. All of the evidence is clearly in favor of fumigation to control the red spider mite.

DISEASE RESISTANCE

No studies have been reported on the genetics of resistance to carnation wilt diseases and the development of disease-resistant types, although many investigators have speculated on the economic importance of such studies wholly on the basis of apparent differences in susceptibility of standard varieties to *Fusarium dianthi*.

Wight (79) advised, "grow resistant varieties" although none are defined. White (72) stated, "The most satisfactory solution of the wilt problem is offered in the possibility of the development of strains of plants immune or highly resistant to disease. There is no reason to doubt that resistant strains of the carnation could be obtained." Van der Bijl (67) stated: "The question of the existence of varieties more or less immune from disease has not received attention though a problem well worth serious consideration and the breeding of disease-resistant varieties may yet be the ultimate solution." Wickens (78) stated: "It is recommended that a search for resistance be made amongst the numerous seedlings raised by specialists in the development of new varieties and that the possibility of the occurrence of resistant sports in existing varieties be not overlooked."

Some conception of the task involved in the development of a commercially desirable type is conveyed by Weston (70): "Not only must the grower strive to grow quality blooms but he must select varieties that grow and produce well. They must have a reputation for giving a high average of good flowers; not be prone to splitting at the sight of dull weather; produce good stems that have some stamina in them; not be below average size and above all possess good color and be free from a tendency to go to sleep under normal conditions"; and by Laurie and Chadwick (40): "The ideal flower is of pleasing pure self color; non-bursting calyx; a diameter of 4 inches, erect wiry long stem; petals hard enough to withstand shipping; serrated, guard petals flat at right angles to calyx, center to stand above calyx one-half the distance to make half a sphere; fragrant, resistant to disease."

However, judging from the limited utility of new carnation varieties in commercial culture, it appears questionable whether the effort required to combine resistance with other desirable commercial qualities is justified. The variety or line of Mrs. C. W. Ward, from which by selection came Boston Ward and then New Deal Ward, although highly susceptible to Alternaria blight and Fusarium branch rot, has enjoyed the unique reputation of many years of utility. The introduction of this variety represented a great achievement. The desirable qualities of Boston Ward or any of its improved selections combined with resistance to *Fusarium dianthi* would appear to represent the nearest approach to the ideal pink variety.

TABLE 13. RELATIVE SUSCEPTIBILITY OF CARNATIONS TO ALTERNARIA DIANTHI.

Resistant		Slightly Susceptible	Very Susceptible
Abundance, Pink	Maine Sunshine	Atlantis	Aida
Achievement	Maytime	Donna Lee	Blush Pink
Antarctic	Melrose	Hazel Draper	Denver
Arctic	Morning Glow	Illuminator	Dorner's Surprise
Aviator	My Love	Jewel	Fairy Queen
Barbara Brigham	My Love, White	Luminosa	Gloria
Barbara Farr	North Star	Ocean Spray	Golden Glow
Beuerlein, Mrs. M.	Olivette	Scarlet Monarch	Guy Allwood
Bonanza	Orange Wonder	Spectrum	Hilda
Break-O-Day	Orchid Beauty	Spectrum, Salmon	Katrine
Chief Kokomo	Paragon	Spectrum Supreme	Laddie
Dairy Maid	Patrician		Marjorie
Dandy	Pelargonium	**Moderately Susceptible**	Matchless
Del Ray	Peter Fisher	Betty Lou	Matchless, Pink
Del Ray, White Sport	Pink Treasure	Delight, Pink	Multiflora
Dimity	Po entate	Delight, White	Nina Brener
Ditchling	Puritan	Fragrance	Rosalind
Donald	Purity	Irene	Rose Charm
Early Dawn	Radiolite	Jane Sutherland	Royal
Early Rose	Satellite	Sceptre	Spicy White
Edna	Scarlet Monarch		Virginia
Eldora Variegated	Senator		Ward, Boston
Eleanor	Sim, Mary E.		Ward, Mrs. C. W.
Golden Wonder	Sophelia		Ward, New Deal
Great Heart	Snow White		Ward, Variegated
Harvester	Sunset Glow		Wardelia
Ivory	Super Supreme		
Joan Marie	Uneeda Pink		
John Briry	Wildfire		
Johnson's Crimson	Wilson, E. H.		
King Cardinal	Winsome		
	Woburn		

Alternaria Spot, Blight and Canker

The reaction to Alternaria blight of the many varieties of carnations current during the progress of these studies was determined from the amount of infection developing on the plants in the field. The contrasts in susceptibility were obtained by counting the number of infections on the stems, foliage, and floral parts of the flowering shoots which were harvested at regular, brief intervals up to early October and after the earliest frosts. Toward the end of the season the very susceptible varieties usually were destroyed by blight. Contrasts in the reaction of the varieties were shown by calculating the average number of infections per flowering shoot for each variety for the season and applying the number to a certain arbitrary range of infections per stem for each particular degree of susceptibility. The range for each classification necessarily was varied somewhat from year to year. The contrasts in the reaction of the varieties to Alternaria blight are purely relative and based on conditions in a limited geographical area. They are supported by extensive observations among plantings of growers and by the experience of growers in eastern New England over a period of several years. The varieties studied were limited to those current to the period from 1928-1940, most of which are now obsolete (Table 13).

The records of the pedigree of named carnation varieties are very incomplete and in many instances totally lacking. Too frequently varieties are announced as hybrids of unnamed seedlings. The earliest published accounts of carnation blight mention Enchantress and Mrs. Thomas Lawson as very susceptible. The

Table 14.—Incomplete Pedigree of Six Varieties of Carnations Resistant to Alternaria Dianthi.

1. IVORY (WHITE)

Seedling No. 598 (white) X Seedling No. 466 (pink)

Seedling No. 253 (flesh pink)

Seedling No. 26 (deep pink)

Enchantress Supreme (salmon) X Matchless (white)

Mrs. C. W. Ward (pink) X Natalie (medium pink)

Enchantress (flesh)

White Perfection X Alma Ward (white)

Mrs. Thomas Lawson (cerise) X Seedling

Prosperity (white) X Seedling

Daybreak X Van Leurens

Belle Washburn (scarlet) X Matchless (white)

Enchantress (flesh) X Red Seedling

2. MAINE SUNSHINE (YELLOW)

Mrs. C. W. Ward (pink) X Crystal White

Snowflake (white) X Matchless (white)

3. PURITAN (WHITE)

Ivory (white) X Sophelia (pink)

Mrs. C. Edward Akehurst (rose-pink) X Matchless (white)

4. PETER FISHER (PINK)

Ivory (white) X Joan Marie (white)

Sophelia (pink)

5. JOHNSON'S CRIMSON

Belle Washburn (scarlet) X Doris (crimson)

Enchantress (flesh) X Red Seedling

Crimson Seedling X British Triumph (crimson)

Crimson Seedling X Lady Bountiful (white)

6. SOPHELIA (PINK)

Mrs. C. Edward Akehurst (rose-pink) X Matchless (white)

TABLE 15.—INCOMPLETE PEDIGREE OF SIX VARIETIES OF CARNATIONS VERY SUSCEPTIBLE TO ALTERNARIA DIANTHI.

1. MRS. C. W. WARD (PINK)

Mrs. Thomas W. Lawson (cerise) X Seedling

2. VIRGINIA (SHELL PINK)

Sceptre (salmon) X Boston Ward (medium pink)

Mrs. C. W. Ward (pink)

3. GOLDEN GLOW (VARIEGATED YELLOW)

Morning Glow (pink) X Matchless (white)

Winona (light pink) X The Queen (white)

William Scott (pink) X Daybreak (flesh)

4. WHITE CLOUD

Daybreak (flesh) X E. A. Wood (variegated pink)

Seedling X Tidal Wave (pink)

5. JANE SUTHERLAND (FLESH)

Prolific (shell pink) X Butterfly

Alice (shell pink) X Rosette (pink)

Mrs. C. W. Ward (pink) X Natalie (medium pink)

6. FAIRY QUEEN (FLESH)

Seedling No. 416 X Seedling No. 315

Seedling No. 10 X Alice (shell pink)

Seedling No. 1 X Seedling No. 261

Belle Washburn (scarlet) X Matchless (white)

Alice (shell pink) X Rosette (pink)

Enchantress Supreme (salmon) X Morning Glow (Var. yellow) variety White Cloud was badly affected by the disease at South Bend, Indiana, in 1902. The parentage of Enchantress is unknown. Mrs. Thomas Lawson is a seedling of Daybreak X Van Leurens, neither of which can be traced further. White Cloud is a seedling of Daybreak X E. A. Wood, and the latter is a seedling of a cross of an unknown seedling X Tidal Wave. Tidal Wave is of unknown pedigree. Some of the more recent very susceptible varieties are Jane Sutherland, Golden Glow, Fairy Queen, and Virginia, and most of these are not too remotely descended from Mrs. Thomas Lawson. Golden Glow is a seedling of Morning Glow X Matchless, and the latter, like Boston Ward (selection of Mrs. C. W. Ward), is very susceptible to Alternaria blight. Matchless is a seedling of White Perfection X Alma Ward. The pedigree of White Perfection is unknown. Alma Ward is a seedling of Prosperity X an unknown seedling. The pedigree of Prosperity is unknown. With such incomplete records, it is not possible to trace the origin of susceptibility to a common ancestry.

In contrast, a high degree of resistance to Alternaria blight is shown by Ivory, Puritan, Peter Fisher, Maine Sunshine, Johnson's Crimson, and Sophelia. Sophelia, which is represented in the pedigree of many resistant varieties such as Joan Marie, Peter Fisher, and Puritan, is a seedling of Mrs. Akehurst X Matchless. The weakness of Matchless was its great susceptibility to Alternaria blight. Some of the pedigree of both Ivory and Maine Sunshine is Mrs. C. W. Ward, a very susceptible type.

It is interesting to note that named varieties originated as sports invariably possess the same reaction to disease manifested by their pedigree. For example, all of the selections and sports of Mrs. C. W. Ward are very susceptible to Alternaria blight. Sophelia has produced several sports, also Peter Fisher derived from Sophelia, all of which are highly resistant to blight.

Records of the pedigree, characters, and originator of carnation varieties have been maintained by the American Carnation Society since its inception at Philadelphia in 1891. It is regrettable that carnation breeders have in many cases failed to declare the pedigree of their named varieties and have disregarded the importance of the register in serving the useful purpose to science and the carnation industry for which it was originally intended.

The pedigree of twelve varieties of carnations has been traced as far back as possible from the Register of the American Carnation Society and from the notes of George Hetzel, breeder for C. B. Johnson, Woburn, Massachusetts, originators of several of the varieties for which histories are given. Tables 14, 15.

Carnation breeders have only rarely considered reaction to disease in the production of new varieties and it is, therefore, not surprising that this factor should have become understood only after the variety had been introduced to the trade. Consequently, many varieties have experienced only a limited commercial production and should never have been introduced. Of more than 100 new varieties of carnations introduced between 1930 and 1940, about 70 percent are resistant or only slightly susceptible to Alternaria blight and about 20 percent slightly to moderately susceptible.

Fusarium Root and Crown Rot

The reaction of carnation varieties to Fusarium root rot could not be established by submerging the roots in a water suspension of spores of *Fusarium culmorum*. Under commercial conditions of culture the disease has been troublesome on King Cardinal, Virginia, Olivette, and Boston Ward. All varieties show susceptibility when the fungus inoculum is placed into knife cuts in the stems of branches and swabbed with moist cotton. Studies at the Colorado Agricultural Experiment Station (15) have not revealed any resistant types among *Dianthus* *caryophyllus* L. although other Dianthus species, not named, are reported to be quite resistant. Numerous species of Fusarium, further divisible into several strains, exist to complicate the problem. The disease appears almost always in devastating proportions in commercial houses in the summer months under the influence of conditions not easily duplicated in experimental trials. Propagation from diseased stock plants definitely causes the continuity of the disease.

Fusarium Branch Rot

Bickerton (5) stated that resistant varieties should be grown in preference to the more susceptible kinds. He determined the degree of susceptibility of 10 varieties of carnations to *Fusarium dianthi* from field observations and root inoculation studies as follows:

SLIGHT	MODERATE	SEVERE
King Cardinal	Sophelia	Chief Kokomo
Maine Sunshine	Virginia	My Love
Patrician		Spectrum Supreme
Peter Fisher		
Puritan		

The reaction of many varieties to the fungus was determined by the same method; namely, dipping the rooted base of carnation cuttings as they are taken from the sand in sterile water containing pure culture inoculum of the fungus and then growing the plants in steam-sterilized soil. Extreme reactions to the fungus were manifested by different varieties, as, for example:

VERY RESISTANT	VERY SUSCEPTIBLE
Dorothy Napier	Barbara Brigham
Eleanor	Joan Marie
Elizabeth Rowe	Marchioness of Headfort
Georgina	Mary Stuart
Hazel Draper	New Deal Ward
Helen Hussey	Nina Brener
John Briry	Northland
Maine Sunshine	Pelargonium
Miller's Yellow	Peter Fisher (regular)
Mrs. C. B. Johnson	Pink Lady (Virginia Rose)
Puritan	Pink Treasure
Tom Knipe	Rosalie
Woburn (Figure 12)	Scarlet King
	Spectrum Supreme
	Virginia (regular) (Figure 12)
	Wildfire

In general, these varieties show a similar performance in commercial culture.

Further study is required to determine more definitely the susceptibility of the varieties to branch rot under variable conditions. Disagreement with the results reported by others might readily be due to the influence of variable genetic strains of the fungus. The analysis and segregation of the progeny resulting from selfing and hybridizing very resistant carnations and the development of commercially desirable types resistant to the branch rot fungus represent a promising field of study.

Rhizoctonia Stem Rot.

No resistance to *Rhizoctonia solani* has been established.

SOIL STERILIZATION

As early as 1897 Sturgis (65) considered that the disinfestation of the soil with heat contributed to the control of Fusarium branch rot of carnations, but his results were negative in view of complications arising from infection inherent in the cuttings. Ward (68) advised the sterilization of the sand in the propagating house and the soil in the benches and the selection of a new field. Van der Bijl (67) reported no beneficial effect from treating the soil with formaldehyde, and did not consider soil sterilization practical under the method of culture peculiar to South Africa.

Peltier (53) reported that formaldehyde used as a soil disinfestant to control Rhizoctonia stem rot was but a partial success, the losses varying from 24 to 53 percent. Steaming the bench soil controlled the disease when the soil was artificially infested, but no losses occurred in the uninoculated and unsterilized sections. The production and quality of the flowers were not affected by heating the soil, nor were they consistently improved. Weinard and Decker (69) found that the loss of plants from Rhizoctonia stem rot in old soils averaged about 4 percent compared with about 3 percent in new soil. The loss of plants on new steamed soil was about 6 percent; on new unsteamed soil about 5 percent. The loss on soil cropped for two years and steamed was about the same as on the same soil unsteamed, or about 6 percent. After 15 years of steaming, 2 percent of the plants were lost compared with 9 percent on the unsteamed plots. It was not surprising to them that steaming the bench soil did not eliminate the stem rot disease since soil was brought from the field on the plants. However, their work showed that soil treated with steam year after year could be kept in a highly productive condition indefinitely and the yield and quality of the flowers greatly improved.

Wickens (78) considered steaming the soil not an adequate control measure for Verticillium carnation wilt in England. Steamed soil sometimes showed greater losses than unsteamed, since cuttings from apparently healthy plants are frequently infected and give rise to diseased plants. Steam sterilization of the soil has met with numerous failures in England (Brown 10). Soil steaming in relation to the control of Verticillium wilt is often discredited from the frequent failure of treated beds to remain free from disease for the complete period of the crop or throughout the second year (White 76). Brown (9) considered heat sterilization of the soil effective, and formaldehyde 1-50 the best chemical. The beneficial effect measured by the survival of the plants was comparable to that of replacing the top soil with clean soil.

White (71) considered the development and extension of soil sterilization essential to the control of Fusarium wilt diseases in carnation nurseries in England. Dowson (4) contended that the control of Fusarium wilt is best accomplished by soil steaming and the growing of healthy plants, although no supporting experiments are shown.

Bickerton (5) reported appreciable control of Fusarium branch rot from the treatment of the field and bench soil with either chlorpicrin or formaldehyde or from the treatment of the bench soil alone with chlorpicrin well in advance of planting. The treatment of the bench soil with chlorpicrin gave a significant increase in flower production even though the plants had previously been grown in infested soil. The value of treating the old soil in lieu of changing was clearly shown.

Most of the New England carnation growers have conducted limited demonstrations with chlorpicrin. Portions of the greenhouse beds were injected with chlorpicrin at the rate of 2 cc. per square foot, well in advance of benching outside-grown plants. In most cases differences in favor of the treated soil were not apparent, but in some cases the differences have been rather striking. Charles Rice of Lexington obtained differences in the yield of carnations on old and new soil treated with chlorpicrin applied in June before planting from the field, and contrasts undoubtedly could have been shown in many of the other demonstrations if the results had been measured in a similar manner, or if the ideal soil conditions necessary to the efficiency of the treatment had existed at the time of application. Some of these are (1) a loose permeable soil, (2) a relatively dry soil holding only enough moisture to partially hold its shape when squeezed in the hand, (3) a soil temperature warmer than 65° F., and (4) a seal of moist soil on the surface, or a cover of paper or burlap for a few days after application, to confine the gas.

The bench plots in the Rice experiments comprised 65 square feet each. The yield of flowers was recorded throughout the year. The gain of flowers indicated in Table 16 represents the difference between the production on new untreated

Table 16. Average Yield of Carnation Flowers Per Square Foot. Old and New Bench Soil Treated With Chlorpicrin.
Charles Rice, Lexington.

Variety	Plot	Yield per Square Foot: September to June 1941-42	Yield per Square Foot: September to May 1942-43	Variety	Plot	Yield per Square Foot: September to May 1942-43	Yield per Square Foot: November to May 1942-43
Puritan	1-0	39.5	32.2	John Briry	1-0	18.2	
	1-1	41.3	33.4		1-1	19.7	
	2-2	41.7	32.6		2-2	19.0	
	3-2	41.0			3-3	19.0	
	3-3		32.7		4-3	17.9	
	4-3		31.2	Gain over	1-0	0.7	
Gain over	1-0	1.8	0.2				
King Cardinal	1-0	30.0	22.7	Pelargonium	1-0	18.9	
	1-1	31.7	23.5		1-1	20.2	
	2-2	30.9	23.4		2-2	19.1	
	3-2	30.7			3-3	21.0	
	3-3		24.0		4-3	19.0	
	4-3		24.1	Gain over	1-0	0.9	
Gain over	1-0	1.1	1.0				
Boston Ward	1-0	37.4	21.0	Olivette	1-0	20.9	17.1
	1-1	41.9	21.8		1-1	22.2	18.6
	2-2	42.5	21.6		2-2	21.0	17.7
	3-2	41.3			3-3	20.7	17.7
	3-3		22.7		4-3	20.5	17.4
	4-3		22.6	Gain over	1-0	0.2	0.7
Gain over	1-0	4.5	1.1				
					2-0		16.5
Virginia	1-0	32.9		Gain over	2-0		1.3*
	1-1	35.1					
	2-2	37.6					
	3-2	36.0					
Gain over	1-0	3.3					

1-0 New Soil, first year of use, not treated
1-1 New Soil, first year of use, first treatment with chlorpicrin
2-0 Old Soil, second year of use, not treated
2-2 Old Soil, second year of use, second treatment with chlorpicrin
3-2 Old Soil, third year of use, second treatment with chlorpicrin
3-3 Old Soil, third year of use, third treatment with chlorpicrin
4-3 Old Soil, fourth year of use, third treatment with chlorpicrin

*Difference between the yield of flowers from untreated soil the second year of use and the average of the yields from the treated plots. The 2-0 plot did not begin to produce flowers until November; hence the November to May production of the other plots is given for comparison.

soil and the average of the production on treated soil. In the year 1941-42 the contrast was significant only among Boston Ward and Virginia varieties, which are very susceptible to all of the wilt diseases. For Virginia the difference was 3.3 flowers per square foot in favor of the treated soil; for Boston Ward, 4.5 flowers. These increases represented a gain of $0.13 and $0.18 per square foot, estimating the value of the flowers at $0.04 each. The other varieties showed smaller contrasts in yield in a range of 1.1 and 1.8 flowers per square foot, or a gross gain of $0.044 to $0.072. With a single exception similar gains are shown between new untreated soil and new treated soil. After deducting $0.01, representing the cost per square foot for material and labor, the gain appears to be worth the effort.

The old producing plants were removed in June, 1942. Two inches of soil in the benches were removed and two inches of cow manure added. Also 4 pounds of bone meal and 2 pounds of 4-12-4 fertilizer were added to each 100 square feet of bench space. Chlorpicrin was again applied at the rate of 2 cc. per square foot.

The contrasts in the yield of cut flowers in the production year of 1942-43 (Table 16) are not significant. The official report of the New England Carnation Growers Association shows that production during 1942-43 was 18 percent below that of the year 1941-42. This drop, and the fact that no flowers were cut in June, accounted for the drop in production from the previous year.

The treatment of the old soil with chlorpicrin increased the yield of flowers only slightly. The difference between the number of flowers from untreated new soil and the average from the treated soil ranged from 0.2 to 1.1 flowers per square foot, representing a gross gain of $0.008 to $0.04. A gain of 1.3 flowers or $0.05 is shown by Olivette, based on the yields on untreated soil the second year of use and on treated soil. After a deduction of $0.01 for costs, the investment appeared to be of doubtful value.

Bickerton (5) reported a net profit of $0.23 to $0.38 per square foot from the treatment of the bench soil with chlorpicrin, and on this basis it was asserted that the treatment would appear to solve the problem of low and decreasing yields of flowers on the same soil used again.

Some growers from custom have preferred steaming, and this, in the judgment of New England carnation growers, is the most popular method. Disinfestation of soil for growing the young stock plants is generally practiced and various ways of steaming the soil are also practiced. Resoiling the benches at the end of the growing season is one of the most costly operations in carnation culture. With serious shortages in man power, the continued maintenance of the old soil in a sanitary and highly productive state by any combination of sterilization and fertilization instead of replacement is highly desirable.

The various reports on the value of soil sterilization in relation to the control of carnation wilt diseases and flower production are not entirely favorable. Examples of bench soil sterilization with steam have been observed in many growers' establishments, but the apparent effect on disease control and growth frequently has been either lacking or inconsistent. Even in instances where disease is prevalent year after year, and where soil sterilization would appear to be desirable, no apparent improvement is shown. In an open discussion on the subject on soil sterilization by experienced and capable New England carnation growers no conclusive evidence of disease control from treating the soil was admitted.* Nevertheless, striking contrasts showing the value of treating old or used soil with steam or chlorpicrin are sometimes apparent (Fig. 13).

*Reported by K. F. McCully, Secretary-Treasurer, New England Carnation Growers Association, in Florists' Review 94 (2426) : 19. May 25, 1944.

Occurrences of carnation wilt diseases are intimately associated with high temperatures, excessively wet soil, inadequate drainage, plant injuries, deep planting, faulty propagation, and infected cuttings. For example, the culture of carnations in raised beds, in contrast to ground beds, has resulted in much better control of the wilt diseases. Soil contamination exists generally where carnations are grown under glass, but it appears to become a factor in the occurrence of disease only when sound cultural and propagating methods are seriously violated.

CONTROL OF ALTERNARIA BLIGHT WITH FUNGICIDES

In general, foliage diseases of economic plants due to Alternaria and closely related pathogenic fungi have yielded to control from protective spraying with copper fungicides. Woods (81, 82) and others (14, 62, 63), in the first published accounts of the disease, suggested spraying the plants with soap and Bordeaux mixture from the time they are fielded in the spring to the time they are well established again in the benches. Over the years since 1927, the writer has advocated spraying the fielded plants with Bordeaux mixture and spreader (28, 29, 30, 31, 32, 33). This treatment was recommended on the basis of fundamental studies and control experiments in the field (Fig. 14) which are reported here for the first time. In the interval, Bickerton (6), working on Long Island, New York, demonstrated the value of field spraying and showed both a significant reduction in infection and a significant increase in production. Other workers and growers, without showing detailed results in support of spraying, have recommended it as a proper treatment for the control of blight.

Toxicity of Chemicals to Conidia

Conidia of the fungus, *Alternaria dianthi* were readily obtained from blighted carnation leaves. Four techniques were followed in determining the toxic effect of the chemicals used: (1) Dry spores were gathered from diseased leaves with a camel's-hair brush and deposited upon the dry chemical residues on glass slides; (2) the spores were first deposited on glass slides and subsequently the fungicide was atomized or dusted upon the spore-bearing surface and the spray allowed to dry, before the slides were placed in a damp chamber for spore germination; (3) the spore-bearing slides were sprayed and immediately placed in moist dishes, and the moist film on the spore-bearing surface was maintained throughout the incubating period; (4) the slides were first sprayed or dusted with chemicals, the sprayed slides were air-dried, and drops of water suspension of spores were then applied to the dry residue.

As may be observed from Table 17, the procedure used has a bearing on the action of the chemical. The presence of water in some instances rendered the chemical deposit soluble, thereby destroying the viability of the spores. This is notably true of the treatments containing copper or calcium arsenate. Spores deposited in the dry residue and in a moist atmosphere germinated; those in the residue in water or in a moist film were killed. Sulfur dust was not fungicidal, and liquid lime sulfur concentrate 1-40 was fungicidal only when the spores were wetted by the spray, suggesting the limited value of lime sulfur as a disinfectant. When a water suspension of spores or dry spores were placed on the dry residue of lime sulfur, spore germination was not destroyed, indicating that the residue after spraying offers no protection against infection. The same might be inferred from the results obtained with a 1-200 solution of potassium sulfide. Lead arsenate was not toxic. Lime was not toxic. All of the dry dust mixtures containing naphthalene were fungicidal under each of the four methods of testing, the toxic action being due to the naphthalene component of the dust mixture. Without moisture on the spore-bearing surface, no effect from copper or calcium arsenate in the confined atmosphere of a Petri dish was shown. In the presence of moisture, naphthalene, copper sulfate, or calcium arsenate exerted a lethal effect upon the spores. The results corroborate the evidence of other investigators claiming the strong fungicidal action of calcium arsenate. The concentration of naphthalene vapor in the small and confined atmosphere of a Petri dish was derived from mixtures containing 30 percent naphthalene. Weaker concentrations might have been adequate. A spray containing 1.6 pints of 40 percent nicotine sulfate (.2 percent) and 40 pounds of salt in 100 gallons of water (5 percent) was not significantly toxic.

Table 17. Toxicity of Fungicides to Spores of Alternaria Dianthi.

Fungicide	Dry Spores Applied to Dry Residue	Dry Spores Treated with Fungicide		Water Suspension of Spores Applied to Dry Residue
		Incubated Dry	Incubated Wet	
	(1)	(2)	(3)	(4)
Dusts[1]				
Sulfur	+	+	+	+
Copper[2] 20, Lime 80	+	+	–	–
Naphthalene 30, Lime 70	–	–	–	–
Naphthalene 30, Sulfur 20, Copper-Lime 50	–	–	–	–
Naphthalene 30, Calcium Arsenate 20, Copper-Lime 0	–	–	–	–
Naphthalene 30, Calcium Arsenate 20, Sulfur 50	–	–	–	–
Sprays[3]				
Hammond's Copper Solution (1-50)	+	+ *	–	–
Potassium Sulfide (1-200)	+ *	–	–	+
Lime-Sulfur (1-40)	+	–	–	+
Bordeaux (4-4-50)	+	+ *	–	–
Lead Arsenate (2 lb.-50 gal.)	+	+	+	+
Calcium Arsenate (2 lb.-50 gal.)	+	+ *	–	–
Calcium Arsenate 2 lb., Lime 2 lb.-50 gal.	+	+ *	–	–
No Treatment (Water)	+	+	+	+

+ Germination. – No Germination. * Germination considerably inhibited.

[1]Figures indicate weight in pounds

[2]Copper in dust mixture derived from monohydrated copper sulfate.

[3]Figures indicate gallons unless otherwise specified.

Laboratory Experiments

Two potted carnation plants of the Jewel variety were used for each treatment. The fungicides were applied on January 9 and the plants were sprayed with a water suspension of spores on January 10. The results were recorded on February 12, 1929 (Table 18). The results were clearly in favor of calcium arsenate and Bordeaux mixture, and each of these materials was more effective in combination with fish oil than alone. Sulfur materials gave poor control. In another experiment with the same variety, Jewel, infections were evident January 27 and the results were recorded on February 11 (Table 19). Bordeaux mixture and calcium arsenate again showed superior fungicidal efficiency. No benefit was shown from the addition of saponin as a spreader.

TABLE 18. CONTROL OF ALTERNARIA INFECTION ON POTTED JEWEL CARNATIONS.

Fungicide*	Number of Leaves	Percent of Infected Leaves	Number of Infections
Calcium Arsenate 1½ lb.-50 gal.	35	45	22
Same, plus Fish Oil ½ pt.	35	17	11
Bordeaux 4-4-50	40	55	27
Same, plus Fish Oil ½ pt.	36	13	5
Lime-Sulfur 1 gal.-40 gal.	28	78	57
Same, plus Fish Oil ½ pt.	27	85	62
Potassium Sulfide 2 gal. -50 gal.	34	82	81
Same, plus Fish Oil ½ pt.	39	89	88
Ammonia 3 pt., Copper Carbonate 6 oz.-50 gal.	28	53	31
Same, plus Fish Oil ½ pt.	31	51	34
No treatment	38	79	101

*Fish oil was added to improve wetting.

TABLE 19. CONTROL OF ALTERNARIA INFECTION ON POTTED JEWEL CARNATIONS.

Fungicide*	Number of Leaves	Percent of Infected Leaves	Number of Infections
Calcium Arsenate 2 lb.-50 gal.	28	7	3
Same, plus Saponin 2/3 oz.	28	14	4
Lead Arsenate 2 lb.-50 gal.	32	81	61
Same, plus Saponin 2/3 oz.	30	80	88
Bordeaux 4-4-50	31	13	4
Bordeaux, Calcium Arsenate	30	10	3
Bordeaux, Lead Arsenate	28	10	3
No Treatment	32	72	140

*Saponin was added to improve wetting.

Dust mixtures of calcium arsenate, lime, sulfur, monohydrated copper sulfate, and powdered naphthalene were compared for their effect upon the control of the disease. Carnation plants, Variety No. 724, were dusted with the following mixtures:

Dust Materials — Parts by Weight

Sulfur
Monohydrated Copper Sulfate 20, Lime 80
Naphthalene 30, Lime 70
**Naphthalene 30, Calcium Arsenate 20, Sulfur 50
*Naphthalene 30, Calcium Arsenate 20, Monohydrated Copper Sulfate – Lime 50
Naphthalene 30, Sulfur 20, Monohydrated Copper Sulfate – Lime 50

The mixtures containing calcium arsenate (marked by asterisks) gave excellent protection against infection, but the mixture indicated by the double asterisk caused injury. The effective ingredient appears to be calcium arsenate, and the importance of adding lime to dust mixtures containing calcium arsenate to avoid injury is indicated by these results and other experience. The copper and sulfur dusts used were not effective.

The results from these exploratory studies on the value of chemical sprays and dusts for controlling the disease on plants in damp chambers provided the basis for further and greater effort in the field under natural conditions of inoculation.

Field Experiments

Thirteen fungicidal treatments were compared in the field in the 1929 experiments on Jewel and Matchless carnations. Ten applications were made, the first on June 21 and the last on September 29. Alternaria blight appeared early in July but the disease did not become serious until September. A record of the prevalence of the disease in the treated plots was made on July 20 prior to transplanting into the greenhouse benches. Calcium arsenate alone or in combination with lime sulfur caused injury which was subsequently followed by more infection. Bordeaux with calcium arsenate was not injurious. A heavy infestation of red spider mite developed on the plants treated with copper-lime dust, and subsequently these plants also became badly infected with blight. Injury from spraying and from the red spider mite clearly disposed the plants to more disease. Unsprayed and uninjured plants showed an insignificant amount of disease in 1929 up to July 30 (Table 20). The remaining plants in the plots in the field continued to receive the fungicidal treatments, and the amount of disease was determined by counting the infections on the cut flowers harvested from September 14 to October 5, The best control was obtained with Bordeaux mixture combined with calcium arsenate; with Bordeaux mixture and fish oil; and with Bordeaux mixture plus calcium arsenate and fish oil. Control was relatively poor with Bordeaux without the fish oil. The greatest amount of

Table 20. Control of Alternaria Carnation Blight in the Field. Jewel and Matchless Varieties. Waltham, 1929.

Fungicide[1]	Number of Infections		
	Per Plant on July 30	Per 100 Stems	
		Sept. 14-Oct. 5	Oct. 28
Dusts			
Sulfur	0.39	131	406
Copper-Lime 20-80	0.69*	318	1,931
Sprays			
Hammond's Copper Solution 1 gal.-50 gal.	0.04	136	364
Potassium Sulfide 1½ gal.-50 gal	0.05	195	442
Lime-Sulfur 1 gal.-50 gal	0.02	184	304
Calcium Arsenate 1½ lb.-50 gal	1.66**	850	1,052
Bordeaux 4-4-50	0.12	142	287
Same, plus Fish Oil ½ pt	0.01	53	167
Bordeaux, Calcium Arsenate	0.00	63	162
Same, plus Fish Oil ½ pt	0.02	54	129
Lime-Sulfur, Calcium Arsenate	0.43***	142	152
Same, plus Fish Oil ½ pt	0.72***	164	197
No Treatment	0.04	519	1,056

[1]Fish Oil was added to improve wetting.

* Heavy infestation of red spider mite.
** Severe injury; fungus secondary.
*** Injury prevalent; fungus secondary.

disease was associated with the use of calcium arsenate, which was injurious by itself; with copper-lime dust, where a serious infestation of red spider mite developed; and with no treatment. On October 28, one month after the last fungicidal application, the final harvest of flowering stems of Matchless carnations was made and checked for the total number of Alternaria infections. The addition of calcium arsenate to lime sulfur or Bordeaux improved the control of blight considerably. Except for injury associated with the use of combined lime sulfur and calcium arsenate, the control of infection compared favorably with that obtained with the Bordeaux-calcium arsenate combinations.

In the summer of 1930, ten materials were compared on plots of 80 plants each, as follows:

Dust Materials — Parts by Weight

Calcium Arsenate 20, Lime 80
Monohydrated Copper Sulfate 30, Lime 70
Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 70
Naphthalene 20, Calcium Arsenate 20, Lime 60
Naphthalene 20, Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 50
Naphthalene 20, Sulfur 15, Monohydrated Copper Sulfate 15, Lime 50

Spray Materials — In 50 Gallons of Water

Hammond's Copper Solution 1 pint
Fungtrogen 3 pints
*Copper Sulfate 2 lb., Sal Soda 3 lb., Fish Oil ½ pint
*Copper Sulfate 2 lb., Caustic Soda 1 lb., Fish Oil ½ pint

Ten applications were made, the first on June 13 and the last on August 22. The disease was observed generally among the plants in the week of June 9. The first application seemed too late, and weather conditions were very favorable for blight. Only Sal Soda Bordeaux and Caustic Soda Bordeaux (indicated by an asterisk) gave satisfactory control of the disease. The results showed the difficulty of controlling the disease in the field in seasons marked by moisture conditions favorable to the fungus.

In the season of 1931, fourteen treatments were compared on Matchless carnations, as follows:

Dust Materials — Parts by Weight

Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 70
Naphthalene 20, Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 50
Naphthalene 20, Sulfur 15, Monohydrated Copper Sulfate 15. Lime 50
Naphthalene 20, Calcium Arsenate 20, Lime 60

Spray Materials — In 50 Gallons of Water

*Bordeaux 4-4-50, Calcium Arsenate 1 lb., Fish Oil ½ pint
*Bordeaux 4-4-50, Calcium Arsenate 1 lb.
*Bordeaux 4-4-50, Fish Oil ½ pint
*Bordeaux 4-4-50
[1]Bordow 8 lb., Fish Oil ½ pint
Bordow 8 lb.
Lime Sulfur 1 gal., Fish Oil ½ pint
Lime Sulfur 1 gal.
Dry Lime Sulfur 4 lb., Fish Oil ½ pint
Dry Lime Sulfur 4 lb.

[1]Dow Chemical Company; not more than 13 percent metallic copper.

The individual plots consisted of 90 plants arranged in 6 rows of 15 plants each. Seven applications were made, the first on June 2 and the last on August 20. The flowering stems were gathered as they blossomed from August 7 to September 20, and the number of infections was recorded at each harvest. Satisfactory control of the disease was obtained only with Bordeaux mixture sprays. Sulfur sprays and all of the dust mixtures gave poor control. Improvement in the control of blight was shown by the addition of calcium arsenate and fish oil to homemade Bordeaux mixture.

In the summer of 1932, further comparisons of fungicidal sprays were made in the field. Six applications were made, the first on June 10 and the last on August 8. The value of the treatments was determined by the counts of the number of infections on the flowering stems gathered over the period from August 15 to September 13. The control of the disease was best with Bordeaux 4-4-50, calcium arsenate 1 pound, and fish oil ½ pint; and plants receiving the Bordeaux combinations appeared greener and relatively healthy throughout the season. Plants from the plots sprayed with combined Bordeaux, calcium arsenate, and fish oil were benched on August 10 after the last field application, and two additional applications were made on a portion of the benched plants. Yield records were taken from October to May and comparisons were made with the yield of plants never sprayed, either in the field or bench. The yield of flowers of the plants sprayed in the field was twice that of the unsprayed plants, and no increase over field spraying was shown by the plants sprayed twice more in the benches.

In 1936, at Waltham and Lexington, comparisons were made between no treatment and combined Bordeaux 4-4-50, calcium arsenate 1 pound, and fish oil ½ pint. The Matchless and Boston Ward varieties were grown in both tests. No perceptible injury from spraying was present. At Lexington there were 405 plants in each plot and the flowering stems were gathered for infection counts from September 22 to October 9. At Waltham infection counts were made from August 17 to September 1. Results of the two experiments were as follows:

Treatment	Number of Infections per 100 stems Lexington	Waltham
Sprayed	5.1	9.8
Unsprayed	255.6	155.0

At Waltham, plants from the sprayed and unsprayed plots were benched on July 7 and September 4. There was no significant improvement in the yield of No. 1 carnations per plant from October 1936 to May 1937, inclusive, in favor of spraying in the summer of 1936; but the contrasts in yield of flowers resulting from early and late housing are especially significant.

Treatment	Benched July 7	Benched September 4
Sprayed	9.7	6.1
Unsprayed	9.6	5.1

In the summer of 1940, plots of the variety Nina Brener were sprayed periodically in the field, and 140 plants from each plot were planted in 48 square foot benches in the greenhouse in July. An additional application was made after the plants were established in the benches. The superior fungicidal effect of Bordeaux with calcium arsenate has been indicated, and a knowledge of the effect of this combination upon the yield of cut flowers after the plants were benched in the greenhouse was considered desirable. There was no blight among the field plantings in 1940; nevertheless, a greater yield of flowers was obtained from the plot sprayed with Bordeaux 5-5-50, calcium arsenate 1 pound, Penetrol ½ pint. Although not a significant difference, the results nevertheless revealed the tolerance of the plants to the best fungicidal treatment for controlling blight. There was no foliage injury from this treatment (Table 21).

A similar experiment was conducted in 1941. The plants were sprayed four times in the field, June 2, 12, 24, and July 3. On July 17, 140 plants from each of the sprayed plots were benched in 48 square foot benches and sprayed further on July 18 and August 5. Dow Potato Spray was included in the tests since it represented a proprietary combined copper and calcium arsenate powder which would appear to be more practical to use than combined homemade Bordeaux mixture and calcium arsenate. For the first and second application it was used at 3 pounds to 50 gallons of water, and then reduced to 2 pounds in 50 gallons; but both were injurious and the treatment was discontinued. Yield records of flowers from September to June, inclusive, showed a very favorable response from field treatments with homemade Bordeaux 4-4-50 combined with 1 pound of calcium arsenate (Table 22). There was no injury. The large excess of lime in Bordeaux 4-4-50 or 5-5-50 exerts a buffering influence upon calcium arsenate, and a deficiency of lime or an excess of calcium arsenate in the mixture can be seriously injurious to carnations.

TABLE 21. YIELD OF CARNATION CUT FLOWERS IN THE GREENHOUSE FOLLOWING SPRAYING TREATMENTS IN THE FIELD IN THE SUMMER OF 1940. Variety, Nina Brener. Waltham.

Fungicide *	Yield, November to April			
	One	Two	Split	Total per Sq. Ft.
Basic Copper Sulfate 2 lb.-50 gal.	207	334	125	13.8
Bordeaux 5-5-50, Calcium Arsenate 1 lb.	300	302	138	15.4
Yellow Cuprocide ¾ lb.-50 gal.	209	328	163	14.5
Cuprocide 54, 1 lb.-50 gal.	235	294	171	14.5
No Treatment	221	264	173	13.7
	Yield, November to May			
Bordeaux 5-5-50, Calcium Arsenate 1 lb.	375	406	145	19.2
Yellow Cuprocide ¾ lb.-50 gal.	289	418	173	18.3
No Treatment	297	348	180	17.1

* Penetrol, ½ pint to 50 gallons, was used with each treatment.

TABLE 22. YIELD OF CARNATION CUT FLOWERS IN THE GREENHOUSE FOLLOWING SPRAYING TREATMENTS IN THE FIELD IN THE SUMMER OF 1941. Variety, Nina Brener. Waltham.

Fungicide *	Yield, November to April			
	One	Two	Split	Total per Sq. Ft.
Dow Potato Spray**	710	307	169	24.7
Yellow Cuprocide ¾ lb.-50 gal.	722	361	210	26.9
Bordeaux 4-4-50	813	391	244	30.1
Basic Copper Sulfate 2 lb.-50 gal.	716	410	212	27.8
Bordeaux 4-4-50, Calcium Arsenate 1 lb.	855	395	227	30.7
No Treatment	704	291	195	24.7

* Penetrol, ½ pint to 50 gallons, was used with each treatment.
** 3 pounds to 50 gallons for the first and second applications; then reduced to 2 pounds to 50 gallons. Both were injurious and the treatment was discontinued.

Discussion and Recommendations

Serious occurrences of carnation blight are limited to susceptible varieties and to seasons marked by frequent rainfall. In field culture, control of the disease is possible only by protecting the plants with fungicides, but carnation growers generally have been handicapped in controlling the disease in the field by lack of power spraying equipment. Frequent and thorough coverage of the plants with a dense driving mist of spray is needed to control the disease. Hand sprayers are both impractical and inefficient. Dusting has never given satisfactory results. The disease is not a problem if the grower will dispense with field culture, at least for his susceptible class of stock. If the grower must field the plants even for the months of May and June only, frequent protection with fungicides would be desirable, particularly in areas along the sea coast or where field culture is prolonged into July.

On the basis of studies at Waltham, growers have been encouraged to use homemade Bordeaux mixture 4-4-50 plus a suitable spreader, such as fish oil, linseed oil, or Penetrol, which have been used at the rate of 1 pint to 100 gallons of spray. Where serious outbreaks of the disease have occurred, the addition of 1 pound of calcium arsenate to 50 gallons of Bordeaux spray has been recommended to strengthen the fungicide. Without the spreader the control of the disease can be unsatisfactory. It is emphasized that good results may be expected only from **thorough plant coverage and frequent application.**

The applications should begin shortly after the plants are established in the field and continue at 7-10 day intervals until the plants are housed. Spraying the plants in the flats just before fielding is practical and can be very desirable. If rainfall is not too frequent the interval between treatments may be extended to two weeks. One or two additional applications may be desirable after the plants are established in the benches. This schedule of treatments has given increases in yields of cut flowers in both blight and non-blight years, and no injurious effect upon the plants has been apparent.

SANITATION BETWEEN PLANTINGS IN THE GREENHOUSE

The sanitary disposal of the carnation stock and litter at the end of the producing season is an important pest control measure. Diseased plants dispersed among the litter are loaded with the inoculum of various pathogenes and at the end of the year the stock usually harbors thrips, red spider mite, and other miscellaneous pests.

In the removal of the old plants a considerable population of insect pests and fungous spores is left behind or redistributed in the houses making it possible for infestations to become established in the new planting. Too frequently the carnation rubbish is deposited outside the greenhouse and left there after the houses are replanted, thus providing a source from which the pests are redistributed throughout the newly planted stock.

The plants and the adhering pests can be destroyed reasonably well just before the cleaning-out operations are started by fumigating with strong concentrations of sulfur dioxide generated from burning sulfur; naphthalene base vapors; hydrocyanic acid gas; or chlorpicrin. Both sulfur dioxide and chlorpicrin are complete pesticides. Naphthalene and hydrocyanic acid gas are more specifically insecticidal and not fungicidal. The use of these fumigants is recommended only for individual isolated houses. The seepage of the fumigant into adjoining or attached houses containing plants can cause damage in spite of all reasonable precautions taken to avoid it. Growers who may be interested in disinfecting the old stock with chemical fumigants between plantings should first consider all of the particulars and hazards involved in their use. After a fumigation of twenty-four hours or longer and the complete destruction of the growth, the houses should be aired well and the litter removed and burned. Such disinfestation of the greenhouse would help greatly in preventing sudden infestations of pests in the newly planted stock.

SUMMARY

The important fungous diseases of carnations in Massachusetts are spot, blight, and canker caused by *Alternaria dianthi* Stev. and Hall; root, crown, or foot rot caused by *Fusarium culmorum* (C. W. Smith) Sacc., *F. avenaceum* (Fr.) Sacc., and other species of Fusarium; Fusarium branch rot or wilt caused by *Fusarium dianthi* Prill. & Delacr.; and stem rot caused by *Rhizoctonia solani* Kühn. Distinctive symptoms of disease are associated with each pathogene and wilting is common to all of them.

Infection of carnation plants by *Alternaria dianthi* readily occurs in a humid atmosphere even in the absence of plant injuries. Injuries to the foliage by drought, infestations of the red spider mite, and other causes contribute to infection in the field.

Fusarium culmorum and related species infect the plants through injuries in the roots, stems, and branches and through snags and adhering remnants of stems and leaves.

Plant injuries are required for infection by *Fusarium dianthi*, which attacks the roots, stems and branches.

Rhizoctonia infection is generally more successful through injuries; but infection is readily obtained by mixing the fungus with the soil and providing warm, moist conditions.

All of these pathogenes attack cuttings in the sand and plants in the various subsequent stages of culture. The cut surface at the base of the cutting is a favored point of attack. The natural cracking or checking at the base of the cutting offers a favorable point of infection especially by the various species of Fusarium.

The optimum temperatures for spore germination and growth of the pathogenes are approximately 75° F. for *Alternaria dianthi*; 77°-80° for *Fusarium culmorum*; 80° for *Fusarium dianthi*; and 86°-88° for *Rhizoctonia solani.*

The incidence of disease in the cuttings and in the young stock subsequent to rooting is intimately associated with either infection latent in the cutting or superficial spore inoculum. Such contamination is derived from unhealthy stock plants or from normal plants adjacent to unhealthy stock plants. The transfer of Rhizoctonia is excluded from this concept.

The use of new and clean sand after each crop of rooted cuttings is recommended, and the potentialities of used sand for rooting further crops of cuttings is indicated.

The direction of the cut through the stem in the preparation of the cuttings is not important in relation to rooting, but a smooth, clean cut leaving no loose remnant of tissue is preferred in relation to disease control. The injured ends of leaf stubs left after trimming the cuttings offer infection courts for Alternaria blight under favorable conditions, but the hazard is usually negligible.

Immersion of the cuttings for 15 minutes in a 1-1,000 solution of potassium permanganate, ¼ ounce to 2 gallons of water, encourages rooting and provides some degree of disinfection of superficial inoculum conveyed by the cuttings to the sand.

Potassium permanganate was the most effective chemical considered in the tests. The various hormone materials used in practice to improve rooting are not fungicidal and no significant advantage was shown from treating the cuttings with both a hormone material and potassium permanganate. Powdering the base of the cuttings with a 10 percent Fermate or Arasan dust gave good control of wilt caused by the fungus *F. dianthi* without harming root action.

All-year culture in the greenhouse is an effective method of controlling Alternaria blight. Fielding the plants increases the hazards from disease. The prevalence of disease increases as transplanting into the greenhouse from the field is delayed beyond the first week in July.

Care in lifting and transplanting to avoid breakage is an important disease control measure. The oldest or earliest-propagated stock is most easily injured and generally less tolerant of changing and unfavorable growing conditions, and more subject to wilt diseases. For disease-susceptible varieties, delaying propagation until January might be advantageous in some years.

Infection and the advance of wilt diseases are favored by excessive watering, overhead watering, warm greenhouse temperatures, and stagnant, moist atmosphere. Such extreme conditions are likely to exist from July to September.

Setting the plants deeper than the roots at any of the stages of culture encourages infection notably by the Rhizoctonia stem rot fungus.

Fumigation of carnations with naphthalene base materials for controlling infestations of the red spider mite represents a notable improvement over the former practice of syringing the plants with strong sprays of water. The change has contributed to better disease control and to an improvement in the quality of the flowers.

Diseased plant remains and plants wilting from disease are potential sources of inoculum and should be disposed of in a sanitary manner.

The young plants and flowering stock require distinct care. The spread and continuity of disease may be controlled by a careful supervision of the young plants. Entire flats of young plants or classes of stock should be discarded in the event of a progressive loss from disease among them. Segregation of the two classes of stock is desirable, and a house devoted wholly to young plants is recommended.

Distinct contrasts in the susceptibility of carnation varieties to *Alternaria dianthi* and *Fusarium dianthi* are shown. The pedigree of several varieties has been traced in an effort to find the source of resistance and susceptibility to *Alternaria dianthi.* The culture of varieties resistant to disease is recommended where a serious disease problem persists.

The subject of soil sterilization with heat and chemicals in relation to disease and weed control is reviewed. The effect of treating new and used soil in the benches with chlorpicrin was not significant when the plants were grown in the field in apparently infested soil. The sterilization of the potting and flatting soil by any acceptable method is very desirable.

Powdered naphthalene, copper compounds, and calcium arsenate are lethal to the conidia of *Alternaria dianthi.* Lead arsenate, lime, and sulfur materials are not toxic. The toxicity of several chemicals to the spores was determined by different techniques.

Good control of Alternaria blight was shown in small-scale tests with Bordeaux combined with calcium arsenate and fish oil, and with dusting mixtures containing naphthalene, calcium arsenate, monohydrated copper sulfate, and lime. In epidemic years significant control of blight in the field was shown by protective treatments with Bordeaux mixture 4-4-50 combined with calcium arsenate 1 pound and Penetrol ½ pint. Increases in yields of flowers are shown. Calcium arsenate alone was injurious. Dusting materials gave unsatisfactory control. Satisfactory results from spraying require frequent treatments with a power sprayer beginning after the plants are fielded in May and continuing to benching time in the greenhouse, or early July. Spraying treatments are desirable for susceptible varieties, but only where field culture is practiced.

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Publication of this Document Approved by Commission on Administration and Finance
3M a 7-45-16568.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 428 OCTOBER, 1945

Annual Report

For the Fiscal Year Ending June 30, 1945

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

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Miner, Gladys I., Botany
Moline, Jessie, Dutch Elm Disease
Parkinson, Leonard R., Home Economics Nutrition
Rodman, Henry B., Feed and Fertilizer Laws
Rosenthal, Judith E., Agricultural Economics and Farm Management
Sanborn, Ruby, Poultry Husbandry
Sherburne, Ruth E., Economics
Southwick, Lawrence, Pomology
Spear, Arthur J., Home Economics Nutrition
White, W. Henry, Botany
‡Wilson, Harold A., Horticulture
Yegian, Hrant M., Agronomy
‡Young, Helen, Floriculture
Zatyrka, Irene E., Pomology

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1944-45

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

The Effect of Public Regulation of Milk Marketing Upon the Organization of the Milksheds of Massachusetts Markets. (Alfred A. Brown, Elaine P. Miller, and Judith E. Rosenthal.) The collection, editing and tabulation of a series of price receipts and sales data for the ten years since milk control began is nearing completion. Efforts have been concentrated on the milksheds and markets in the principal secondary areas of Springfield, Worcester, Lowell-Lawrence, Fall River, and New Bedford.

In addition to contributing some light on the manner in which prices finally develop under public control, the study will provide a reasonably authentic series of data upon which the industry can build in coming years. Study has indicated the shortcomings and inadequacy of existing price records, and current work is directed towards overcoming that deficiency. Although this phase of the work may appear secondary to the major premise, it is important in a program of public pricing. And since milk control appears to be a permanent part of dairy marketing in Massachusetts the contribution of an accurate historical price series appears to be well worth while.

Transportation Requirements of Rural Communities in Massachusetts. (Alfred A. Brown and Elaine P. Miller.) The second part of this study was completed during the past year. The results of the analysis of milk trucking operations have been put to use in the principal dairy areas of the State. Daily truck mileage involved in moving milk from farms to plants had been 23,897. Following the study and conference with the industry this was reduced to 21,458 with a net saving of slightly over 10 percent.

A Study of Farm Real Estate Taxation, Methods of Taxation Reform, and the Effect of Such Measures on Farm Income. (Elaine P. Miller, Alfred A. Brown, and Judith E. Rosenthal.) The transcription of tax and assessment records on farms in the "Sampling Study" and on a selected group of dairy farms has been under way. About two-thirds of the records are in. Preliminary analyses have been made only for dairy farms and an extremely wide range exists between towns in valuations of livestock; cows from $40 to $125, chickens from 50 cents to $1.25, and horses from $25 to $200.

Other indications are that real estate will show much variation in assessment; that there will be little uniformity between real estate taxes paid and personal property taxes paid; that there will be little if any relationship in 1944 between size of farm (in acres) and amount of tax paid.

Development of Statistical Data as Controls to Livestock Production Program. (Alfred A. Brown, Elaine P. Miller, and Judith E. Rosenthal.) All three phases of field work in connection with this study have received much attention. The checking of maps, identification of farm locations, and collection of pertinent data on them have been completed for five counties. Classification of data has been advanced to the point necessary to permit selection of dairy farms.

For the dairy farms picked up in the identification detail, data on livestock numbers have also been secured from AAA milk subsidy records.

In the third sample under consideration, that used by the New England Crop Reporting Service, livestock numbers have been transcribed and tabulated.

Incomplete coverage of the major phase of the work precludes testing of the several samples. Comparison between the major sample and census population on a county or regional (three Valley counties) basis indicates an inaccurate selection. The random sample, selected on a square-inch-grid basis, is over-weighted with small herds.

Loan Performance on Low Income Farms in Massachusetts. (C. R. Creek.) Standard rehabilitation loans which were made by the Farm Security Administration from 1936 through 1943 on 89 cash-crop farms in the three Connecticut Valley counties of western Massachusetts had been repaid in full by 66 farmers by June 1945. Of the remaining cases, 13 were classified as active borrowers who had received loans within the past two years, 5 were collection cases on old loans, and 5 had defaulted on their loans after making some repayments. Payments on these loans were made in large amounts from the sale of onions, potatoes and tobacco. Three years of good yields and high prices for crops enabled these farmers to pay off current and delinquent loans.

Standard loans which were made on 95 livestock and livestock–crop farms during this period were repaid by 53 borrowers by June 1945. Of the remaining cases, 25 were classed as active borrowers, 11 were collection cases, and 6 had defaulted on their loans after making some repayments. These loans were generally set up on a longer schedule of payments than the crop loans and payments were usually made each month from sales of poultry and dairy products. Payments from sales of crops were made by 74 borrowers to repay loans from 1936 to 1945. Sales of livestock and livestock products were the source of repayments on 21 farms. Auctions of livestock and equipment were necessary to close 14 loans, and income from work in industry was used to complete payments on 10 loans. On 62 percent of the farms, loans were repaid from crops; on 18 percent, from livestock enterprises; and on 20 percent, from sales of capital assets and industrial employment.

One or more standard rehabilitation loans had been made between 1936 and 1943 to 184 borrowers and by June 1945 loans were repaid in full on 119 farms or 65 percent; 38 loans or 21 percent were classified as active; and 27 loans or 14 percent were collection and defaulted cases. New loans were made in 1945 to seven borrowers, but not all of the active borrowers received supplementary loans in 1945.

Clearing and Improving Land on Massachusetts Farms. (C. R. Creek and J. F. Hauck.) Practically every farm in Massachusetts contains a few acres of once productive land that has reverted to timber, brush, shrubs, or weeds. Also many farms are divided into small fields of one to five acres by stone walls which were built many decades in the past. Other fields contain boulders and stones which prohibit the use of modern labor-saving machinery.

Within the past five years heavy machinery such as bulldozers, gas shovels, brush-breaker plows, and bog harrows have been used to clear land of trees, stumps, brush, and boulders, remove stone walls, dig drainage ditches, construct erosion controls, and remove old apple and peach trees from orchards. Land has been cleared in present farming units for pasture, poultry range, orchards, cranberry bogs, vegetable crops, potatoes, and field crops. In a few cases the acreage which has been cleared and improved was greatly in excess of the original cleared acreage, but in most cases from 5 to 20 acres of land have been cleared to increase the size of the original farm.

Costs of clearing land with heavy machinery varied greatly depending upon the type and density of timber, stump, or brush cover, the type of soil, the size and adaptability of equipment used, the skill of the operator, and the purpose for which the land was cleared. Records on costs and methods show that stumpland has been cleared ready to plow for as little as $65 per acre and as much as $180. Brush and trees have been cleared for $75 to $140 per acre and boulders removed for $60 to $150 per acre. Stone walls were removed by burying or hauling away for $6 and $9 per rod depending upon size of the wall and methods used. Apple trees were removed from orchards for 25 to 45 cents per tree and usually the value of cordwood cut more than paid for the cost of removal and cutting. Some drainage work has been done on individual farms but much of this land improvement work will be done after Soil Conservation Districts are formed.

Some examples have been noted of land clearing which could not be justified on the economic returns from the land. Where a good type of soil is available in the farm unit for the purpose desired, clearing with modern machinery may be profitable in a period of high prices for farm products. Larger acreages can be brought into production more rapidly by clearing with machinery to take advantage of these higher prices.

Organization and Management of Poultry Farms in Massachusetts. (C. R. Creek.) Poultry farming was less profitable in 1944 than in 1943 according to the summary of Poultry Account Records, chiefly because of lower prices received for eggs and higher prices paid for feed. For the records summarized, net farm income averaged $2350 per farm in 1944, $3660 per farm in 1943, and $2388 in 1942. Labor income per hen was $2.13, $4.20, and $2.85 for an average flock of 863,768, and 691 laying hens per farm. Egg production was 210 eggs per hen in 1944, 196 in 1943, and 206 in 1942 and the average price for all eggs sold was 47, 55, and 42 cents per dozen.

In 1944 the net farm income was $4604 per farm for the one-third highest income farms, which were chiefly breeder type farms, in contrast to $302 per farm for the lowest one-third, which were wholesale egg type farms.The size of laying flock was 1280 and 480 hens on these two groups of farms, while total size of the farm business was 690 and 250 productive man work units. Egg production was 216 and 189 eggs per hen and the average price received was 49.7 and 43.5 cents per dozen. The cost of feed per dozen eggs produced was 23.3 cents on the profitable farms and 29.7 cents on the low income farms. The margin of price received for eggs over cost of feed was 26.4 and 13.8 cents per dozen. It required 83 eggs at prices received to purchase 100 pounds of grain on the higher income farms and 97 eggs on the lower income group. A greater quantity of grain was fed per laying hen on the low income farms than on the more profitable farms and a higher price was paid per hundredweight. All of these factors of size, rate of production, prices received, feeding efficiency, and type of business were jointly responsible for the wide variation in returns from the farm business in these two groups.

A comparison of 15 identical poultry farm accounts for 1942, 1943, and 1944 showed that size of flock increased 16 percent from 819 to 953 hens. Egg production dropped 5 percent in 1943 to 200 eggs per hen but the price received was 56 cents per dozen which was 30 percent greater than in 1942. Feed cost per dozen eggs was 30 percent greater in the latter two years also, while the price received for eggs in 1944 was only 11 percent more than in 1942. The egg–feed ratio was most favorable in 1943 when 5.5 dozens of eggs were required to purchase 100 pounds of mash and scratch grain. The cost of hired labor on these farms increased 56 percent in these three years from $60 to $94 per month. Total labor cost, which included the value of the operator's time and family labor as well as hired labor, increased only 38 percent while the efficiency of labor increased 18 percent as measured by man work units per man. The proportion of eggs sold as hatching eggs was greatest in 1943 at 38 percent of all sales, compared to 26 percent in the other years. Retail egg sales remained uniform in quantity during these years but the proportion of wholesale eggs was lower in 1943. Net farm income was $2890, $4260, and $2940 per farm for these three years. Labor income was $2370, $3715, and $2355, and there was an increase in investment from 1942 to 1944 of $1300 per farm. Farm income was $3.53, $4.74, and $3.08 per hen on these farms.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Brown Root Rot of Tobacco. The object of this project was to determine the effect of the preceding crop on the yield and quality of tobacco. The various preceding crops were planted at three different times. All of the first seeding and some of the second matured; but none of the late seeding. All were plowed under during the following spring when they had been quite completely dehydrated by alternate freezing and thawing. The tobacco crop following the more mature of the preceding crops was not so good as that following the less mature plants. Mature plants contain more lignin and compounds not readily decomposed by microorganisms. Of the many crops grown preceding tobacco, tobacco, sunflowers, Jerusalem artichokes, and potatoes stand out most favorably; while sorghum, sudan grass, and corn are frequently exceedingly unfavorable to the tobacco crop. It is worthy of mention that the more favorable crops to precede tobacco are members of the Compositae and Solanaceae families, while all of the unfavorable ones belong to the Gramineae and Leguminosae families.

Black Root Rot of Tobacco. (C. V. Knightlinger.) In work to improve Havana Seed tobacco for use in the Connecticut Valley, new strains are being produced to effect improvements over Havana Seed 211 and other strains produced thus far. Some of the new strains are capable of producing high yields of tobacco of good type and quality in soils infested with the organism that causes black root rot as well as in soils relatively free from this organism. According to experimental results obtained from small plot tests, some of the new strains seem to possess improvements over Havana Seed 211 in type, quality, and habits of growth. The strains are being tested commercially, and some of them seem to be very promising.

Brown Root Rot of Tobacco. (C. V. Kightlinger.) Brown root rot ordinarily develops on tobacco that is grown immediately following certain other farm crops. Frequently, however, the disease fails to develop under these conditions in the Connecticut Valley. The cause of the disease and the reasons why at times it fails to develop under seemingly favorable conditions are not well known. The purpose of this project is threefold: first, to ascertain the effect on the development of brown root rot of tobacco of the rate at which fertilizer is applied to the preceding crop; second, to ascertain whether brown root rot will develop on tobacco grown continuously when less than the ordinary amounts of fertilizer are used; and third, to study the effects that conditions of low fertility may have on the root ailments of certain farm crops other than tobacco.

Work on the project is still in the preliminary stage of preparing the soil for fuller study of these objectives.

Disinfection of Tobacco Seedbeds. (C. V. Kightlinger.) Fall and spring steaming, chloropicrin, fall treatment with double strength formaldehyde, and spring treatments with single and double concentrations of formaldehyde were tested as soil disinfectants in tobacco seedbeds in 1944. The results were similar to those obtained in previous years.

Fall and spring steaming and chloropicrin were highly effective in the control of weeds. Fall and spring treatments with double strength formaldehyde were somewhat more effective than the spring treatment with single strength formaldehyde, although none of the formaldehyde treatments gave satisfactory control of weeds.

No damping-off or bedrot occurred in the seedbeds during the season; therefore, the comparative effectiveness of the different treatments in preventing seedbed diseases of tobacco could not be determined.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Both the type of ion and the evolutional development of the plant seem to have a part in regulating the intake of the various ions into the plant. The elements proportionately more abundant in sea water than in land waters seem to be more easily introduced into the plant. The more highly developed flowering plants seem to take up elements applied to the soil less than do the less developed types. Under similar conditions less calcium is taken up than potassium, sodium, and magnesium when each is added separately at the rate of 250 p.p.m. Chlorides, bromides, and iodides can be increased by larger percentages in plants than can phosphorus and sulfur when the two last-mentioned elements are applied to soil as phosphates and sulfates. The halides are more abundant in sea water than in land waters.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) When 250 p.p.m. of calcium, magnesium, potassium, or sodium were added singly to plots, the intake of each into plants was increased. When two of these cations were added at the same rate to a single plot, the intake of each was less than when either of the two was added singly.

Preliminary experiments with seedlings of soybeans in water solution indicate that the higher the copper content of the growing medium, the lower is the calcium content of the aerial portion of the plant. These results may not necessarily hold true under field conditions. In field tests 75 pounds of copper sulfate was applied per acre. Plants grown on these plots will be analyzed to determine the effect of copper on the intake of calcium within the plant.

Magnesium Requirement of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) During the past growing season, 1944, no heavy rains fell from the time of planting to the time of harvest. This was conducive to conservation of magnesium of the soil. Only a few species of plants showed the effects of slight deficiency of the element in the soil. This was apparently true throughout the State as no reports were available from extension and research men, or from individuals who usually bring in samples of plants grown on soils deficient in magnesium.

The Ranunculus, Malvaceae, Ulmaceae, Geraniaceae, and Cruciferae showed the deficiency only to a slight degree. No plants usually ascribed to the higher orders gave evidence of the slightest deficiency of magnesium.

Not all plants show the usual symptom of chlorosis. Among these plants are some of the purslanes and a few of the roses — *Portulaca oleracea*, *Rubus villosis*, *Potentilla canadensis*; and the common strawberry shows only an exceedingly limited degree of chlorosis when magnesium is not sufficient for normal growth. The development from apocarpy to syncarpy marks an apparent diminution in need for the magnesium ion.

Long-Time Field Fertility Tests. (Walter S. Eisenmenger and Karol J. Kucinski.) Fifty-five to sixty years ago a series of soil test plots was established to study the effects on the soil and crops of a long-time fertilizer program. Various types of crops have been grown on these plots with the original plan of fertilization being followed each year. For the last three years the crop has been hay. Plots which receive a complete fertilizer and lime are outstandingly superior to all other plots. Check plots which have not received any kind of fertilizer since the inauguration of the tests show complete crop failure, with "haircap" moss coming in during the second season after seeding. In preliminary tests, rabbits fed grass grown on the limed plots showed growth curves superior to those of rabbits fed grass grown on the unlimed plots.

Young Sunflower Plants
The large leaves shade the ground preventing the growth of weeds.

Sunflowers and their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) Results of tests for several years show that sunflowers will grow abundantly in this region, producing good yields on any land which will grow corn. Sunflowers are hardy to light frost, and can be planted when it is safe to plant field corn. The plants are much more resistant to frost when they first come up than at the four or six leaf stage. Field trials have shown that the best spacing is one seed every 18 inches in 36-inch rows for the tall varieties like the Mammoth Russian. For shorter varieties like the Mennonite or Sunrise, 12 inches between plants and 36 inches between rows is recommended. Last year's trials indicate that the shorter-growing Canadian varieties (Sunrise and Mennonite), although yielding about 500 pounds less seed per acre, were superior to tall-growing varieties like Mammoth Russian in ability to withstand wind storms. The labor involved in taking care of sunflowers during the growing season is very little, since the plant starts to grow rapidly and soon shades the ground completely, killing any weeds that may survive the one or two early hoeings. Because of its thick vegetative cover the sunflower plant serves admirably in ridding infested areas of obnoxious weeds.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

Physical and Chemical Properties of Wind-Blown Soils. For several years laboratory tests and field observations have been made to determine why certain soils are subject to wind erosion while others are not. A wind tunnel has been used to supplement field observations.

Because of the unusually small amount of snow cover last winter, 1943-44, dust storms were very severe in the Connecticut River Valley. It was observed at several localities that wind erosion would start as soon as six hours after rainfall. In such cases the soil that was moved by the wind was the very thin top layer and usually contained less than 1 percent moisture, while the immediate sublayer contained 10 to 20 percent moisture. The application of such compounds as urea and lithium carbonate to soils greatly decreased their wind erodibility.

Use of Snow Fencing in Controlling Wind Erosion. One of the problems of Connecticut Valley farmers is the protection of soils and their crops from wind damage. The northwesterly winds which occur during early spring result in considerable losses to soil, seed, fertilizer, and young crops. Farmers have often noticed that certain local areas or spots are much more subject to blowing than the remainder of the field. This may arise from various conditions or a combination of conditions such as the location of buildings, slope of the land, direction of rows, difference in soil texture or drainage, etc. These "blowouts" usually appear sporadically in different years and under certain weather conditions. With the present emphasis on farm production, the farmer does not want to abandon these areas, yet the damage to his seed and young crops such as onions and asparagus may be considerable. To control these local "blowout" spots temporarily until the crop has established itself, some form of windbreak may be used. Trials are being made at the station to see whether so-called highway snow fencing will prove satisfactory for the purpose.

Results from these preliminary studies show that the anchorage of such fencing need not be so complicated as when it is used for prevention of snow drifting of highways. Old iron pipes or wooden stakes 4½ to 5 feet long driven 18 inches into the ground and spaced a rod apart held up the 4-foot-high lath fencing throughout the entire season. If the fencing is placed on the windward edge of the "blowout" at right angles to the prevailing winds and the crop rows are placed parallel to the fencing, very little loss of area or inconvenience in operation will be experienced. Generally one fence row will be sufficient to control "blowouts" of the size commonly found in this section. The cost of snow fencing is about 15 cents a running foot at present, but would be considerably less under normal conditions. This seemingly high initial cost should be prorated with respect to the longevity of the fence.

Erosion Problems Arising from Changes in Land Use. The increase of potato growing in certain localities in Massachusetts has resulted in soil erosion problems. Some operators are already experiencing a decrease in potato yield and have called on the Soil Conservation Service for aid in formulating plans for the protection of their fields. Laboratory tests show that there is an abnormal decrease of organic matter on some of these soils. It was found on several farms in western Massachusetts that the organic matter decrease in six years ranged from 14 to 31 percent with most of the decrease taking place in the first 2 or 3 years. It is deemed advisable, therefore, to encourage potato growers to practice soil conservation methods such as winter cover-cropping, terracing, and contour farming of their hillsides.

Potato Seed Treatments. (C. V. Kightlinger and H. M. Yegian.) Experimental work begun in 1943 was continued in 1944, to ascertain further the comparative tolerance of varieties of potatoes grown commonly in Massachusetts to commonly used disinfecting seed treatments, and also the effectiveness of these seed treatments in controlling rhizoctoniose and scab. The varieties grown were Chippewa, Katahdin, Sebago, Earlaine, Irish Cobbler, and Green Mountain. The seed treatments used were mercuric chloride plus acid, yellow oxide of mercury, Semesan Bel, Sanoseed, Wettable Spergon, Thiosan, and Fermate. At the time of treatment, the seed potatoes were sprouted only slightly.

The inorganic treatments caused little injury to Irish Cobbler and Green Mountain tubers; moderate injury to Katahdin, Sebago, and Earlaine; and rather severe injury to Chippewa. These treatments caused reduction in stands of potatoes in the field, ranging from slight in the case of Irish Cobbler and Green Mountain to rather heavy in the case of Katahdin, Earlaine, and Sebago and heavy in case of Chippewa.

The organic seed treatments had no noticeable injurious effects on the tubers of any of the varieties before planting; but Semesan Bel, Sanoseed, and Thiosan had some detrimental effects on the stands of the Katahdin and Earlaine varieties and worse effect on the stand of the Chippewa, in the field.

None of the seed treatments seemed to increase the vigor of the plants. Careful examination of growing plants and later inspection of mature tubers after digging showed no consistent difference in the amounts of rhizoctoniose that developed from the use of any of the seed, treated or untreated. No scab developed by which to judge the effectiveness of the seed treatments as control measures for this disease.

On the basis of experimental results obtained from two years of testing, it seems that disinfecting seed treatments are of doubtful value as control measures for rhizoctoniose of potatoes at least. Rather heavy reduction in yields of potatoes of the newer varieties occurred, which it seems reasonable to attribute to the poor stands caused by the detrimental effects of some of the treatments on the seed tubers. On the basis of these facts, it seems doubtful whether disinfecting seed treatments are advisable for potatoes, especially for the newer varieties used in these tests.

Potato Variety Trials. (Karol J. Kucinski, Ralph W. Donaldson, Walter S. Eisenmenger.) Because of the favorable growing season last year, all of the potato varieties tested did well, with yields per acre ranging from 510 bushels for Sebago to 347 bushels for Russet Rural.

Based on yields of marketable size, the ranking of potato varieties in the Experiment Station plots during the season of 1944 was Sebago, Pontiac, Sequoia, Chippewa, Green Mountain, Warba, Mohawk, Katahdin, Houma, Irish Cobbler, and Russet Rural.

Corn Improvement Program. (Hrant M. Yegian.) Fifty-five single crosses were made in the early-maturing group, involving all possible combinations of eleven inbred strains. Thirty-six double crosses were also made from the more promising of the previous year's ninety-one single crosses. Ninety-two varieties, mostly hybrids, were tested for their general adaptability and yield. The results were published in mimeographed form with the cooperation of the Extension Service, and are available upon request.

Onion Breeding. (Hrant M. Yegian.) Lots of 100 seeds from crosses between *Allium fistulosium* and *A. cepa* were soaked at room temperature in 0.1 percent colchicine solution from ½ to 120 hours to induce tetraploids. The majority of the seeds soaked from 3 to 5 days had thickened cotyledons and primary roots at the seedling stage indicating chromosomal aberrations, but the leaves and the subsequent adventitious roots produced were normal. No tetraploids were observed in mature plants.

Over 50 percent of the bulbs from the first generation inbred strains having 2, 3, 4, 5, or 6 seed stalks per plants produced 3 or 4 seed stalks. The size of the bulbs, storage temperature, cultural practices, and weather conditions, as well as the genetic constitution of the strains, affect the keeping quality of bulbs, seed stalk development, and amount of seed produced.

Preliminary evidence tends to show that applications of borax at the rate of 30 to 50 pounds per acre did not prevent pink-root or fusarium bulb rot of growing onions, or increase the amount of seed produced by mother bulbs. However, it seems that borax may possibly have some subsequent beneficial effect on the keeping quality of stored onions At least in these trials the sets grown on borax-treated plots produced onions that kept better in storage, had brighter, more uniformly colored skin, and a more presentable appearance than did the onions grown from sets produced on untreated plots.

Seed from an improved strain was introduced last year to be tested by a commercial onion grower. The test is still in progress. However, the strain appears to be promising.

Experiments at Amherst with Hay and Pasture Seeding Mixtures. (W. G. Colby.) One of the principal objectives of these trials was to study the performance of different grass species and strains when seeded in combination with ladino clover alone and with ladino clover and alfalfa. It was hoped that strains of grass could be found which would be more satisfactory when grown with either one or both of these legumes than those now in general use; but even if superior strains were not found, it was thought that much valuable information might be secured which would be helpful in the development of a successful grass breeding program. Significant progress has been made in both directions. In these trials the following strains of orchard grass, meadow fescue, and perennial rye grass gave outstanding performance: orchard grass—S 26, S 37, and Finnish late hay; meadow fescue—Svalof Early and Otofte; perennial rye grass—O.A.C. No. 1 (now called Peron). A description of the experimental layout for this work has been given in a previous report (Mass. Agr. Expt. Sta. Bul. 388:14-15, 1942).

Breeding objectives have been formulated and breeding material has been isolated for further improving one already promising strain of orchard grass. It is probable that similar work will be attempted with certain strains of smooth brome grass.

As these different seeding mixtures have been observed from year to year (the plots are in their fifth harvest season), it has become increasingly evident that the performance of each mixture as well as each strain is influenced by many different factors. Among the most important of these are soil fertility relationships, including fertilizer practices; the nature of the original seeding mixture; the cultural management, including grazing management practices; and finally, the weather. In predicting the performance of a given hay or pasture strain of grass with ladino clover or alfalfa, the influence and relative importance of each of the above factors should be borne in mind.

Field Brome Grass (Bromus arvensis) for Poultry Ranges. (W. G. Colby.) Certain poultrymen have use for a grass which, when seeded in late summer or early fall, can be ranged the following spring on through to midsummer. Then, for the purposes of sanitation, they prefer to plow the land and reseed it for range the next season. Preliminary trials indicate that field brome grass can be successfully used in this way.

In early September 1944, two acres were seeded with field brome grass by a poultryman in Feeding Hills, Massachusetts. Results thus far in 1945 have been most promising. By spring this grass had made a dense matted growth which has since stood up well under heavy ranging conditions. A cover has been maintained even around range shelters and feeding stations. The herbage appears to be reasonably palatable.

The present season has been abnormally wet and this may account for some of the favorable results thus far. If this grass performs satisfactorily in a year with normal rainfall, poultrymen will have available another valuable grass for use on some of their ranges.

Field brome grass (*Bromus arvensis*) is a winter annual which must not be confused with smooth brome grass (*Bromus inermis*) which is a true perennial. Field brome grass has been used to a limited extent in Europe as a forage grass, but, as yet, its use in this country has been confined only to experimental trials. Seed was first secured by the Agronomy department in 1937 from a commercial seedsman in Germany and in 1938 from the Royal Danish Agricultural Society. Seed for these field trials on poultry ranges has been supplied by the Nursery Division of the U.S.D.A. Soil Conservation Service. Seed is not yet available commercially.

Breeding Work with Orchard Grass. (W. G. Colby.) Notwithstanding such desirable characteristics as tolerance to heat and drought, wide range of soil adaptability, good yielding ability, and resistance to lodging, orchard grass has never been popular for either hay or pasture. One reason has been its habit of early maturity. When used in hay mixtures, orchard grass matures from one to two weeks before any of the other common grasses or legumes in the mixture. If it is cut after maturity, it makes coarse, poor-quality hay. Its early maturity also makes it a poor pasture grass. Unless it is grazed promptly in the spring, it will form seed heads and become quite unpalatable.

Strains have been developed which mature from a week to ten days later than commercial strains and several have done well in the seeding mixture trials. However, most of these late maturing strains, including S 26, S 37, and S 143, are very susceptible to winter injury in the seedling stage and frequently suffer serious winter injury in established stands during severe winters.

One strain—Finnish late hay—has been found which is as hardy as commercial orchard grass, even in the seedling stage, yet matures from a week to ten days later. Seed of this strain was obtained in 1938 from a commercial seedsman in Finland. It has shown up well in both hay and pasture mixtures. It combines well with alfalfa and does reasonably well with ladino clover; at least it is much superior to all early-maturing hay strains of orchard grass. For the past two years seed has been increased so that small quantities are available for trial.

In order to further improve the performance of Finnish late hay orchard grass, a space-planted nursery was set out in 1944 using this seed. Late-maturing, winter-hardy plants, with desirable morphological characteristics were selected in 1945. These have been selfed and their progeny will be tested in 1946. It is expected to develop a new strain following the "strain building" procedure.

Trials with New Oat Varieties. (W. G. Colby.) For several years yield trials with new disease-resistant oat varieties have been carried on in cooperation with the U.S.D.A. Division of Cereal Crops. The following varieties have given good grain yields and have shown high resistance to leaf rust: Vicland, Tama, and Clinton. While oats are relatively unimportant as a grain crop in Massachusetts, they are grown quite widely for forage. Varieties resistant to leaf rust are, therefore, more valuable for Massachusetts conditions.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cow's Milk. (J. G. Archibald and C. H. Parsons.) The work with cobalt is still in progress. Extreme difficulties have been encountered in developing a method sufficiently refined to determine the very minute traces of this element present naturally in milk. All of the time devoted to the project this year has been spent in trying out different methods none of which have so far yielded reproducible results.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) A good grade of silage has been produced this past year by mixing corn meal with various grasses at the rate of 150 pounds of meal per ton of grass. The silage kept very well, had a pleasing, mildly acid odor, and has been very palatable to cows. Considerable differences have been noted in the suitability of different grasses for ensilage. Reed's canary grass made only a fair quality of silage; bluegrass alone has not been at all satisfactory; but bluegrass mixed with other grasses has made good silage. In general, silage from a mixture of grasses or of grasses and legumes has been more satisfactory than silage made from single species.

Two technical articles based on this project have been accepted for publication during the past year. One, entitled "Seepage losses from a silo," appeared in the Journal of Dairy Science, Vol. 28, No. 4, April, 1945, pages 321-324. The other, entitled, "Studies in the chemistry of grass silage," will appear in the Journal of Agricultural Research presumably within the next three or four months. Conclusions of the first-mentioned article were that seepage losses in silage are not as serious as losses from other causes, and with good management can be reduced to a very insignificant figure. The most important conclusion in the second paper was that variations in silage quality due to the kind of crop ensiled were more significant than those due to the action of the preservative.

In addition to this work on the formal project, some time has been devoted to checking by observation and analysis the results obtained by a group of farmers who ensiled surplus potatoes furnished to them by the War Food Administration. In general a fair to good grade of silage was obtained, although a few failures have been noted.

Analyses of four lots of potato silage, one ensiled with alfalfa, two with oat hay, and one with sweet corn fodder, show that these silages were higher in protein, carbohydrate, and minerals than corn silage; lower in crude fat and fiber; and much lower in carotene. This last is what would be expected, for potato tubers do not contain carotene; and what little was found came from the relatively small amount of roughage mixed with the potatoes when they were chopped.

The quality of the silages made by mixing alfalfa or sweet corn fodder with the potatoes was excellent; when oat hay was used, the quality was only fair the rather high pH (4.9) indicating an unsatisfactory and insufficient fermentation. More serious than any failure to obtain good silage, however, has been the damage to cutter knives by stones mixed in with the potatoes during harvesting.

The Effect of Feeding Synthetic Thyroprotein to Milking Cows. (J. G. Archibald.) For a period of approximately seven months (April to November, 1944) this project was conducted in the Holstein herd of the Medfield State Hospital. Ten cows fed the hormone continuously for a period of twenty-one weeks, starting about midway of their lactation periods, showed a definite response in milk yield. In general this response took the form not of marked or sudden increase in milk yield, but of greater persistency in milk flow than was to be expected from the production records of these cows in the first part of their lactations. At the end of the fortieth week of lactation, after twenty-one weeks of hormone feeding, average weekly production was 227 pounds per cow in comparison with an expected weekly production, based on previous performance, of 162 pounds per cow.

Four cows fed the hormone in alternate four-week periods for twenty-four weeks showed a definite response in the first two alternate periods, but it was unlike that of cows fed the hormone continuously in that it took the form of sharp increases in yield while the hormone was fed, followed by just as sharp decreases when it was discontinued. By the time the third and last alternate period of hormone feeding had been reached this sharp upward trend was no longer manifest and actual production dropped nearly to the level of expected production.

Of four cows fed the hormone in alternate two-week periods for twelve weeks, only one showed a marked response in milk yield.

Increases in milk production were usually accompanied by some loss in body weight, especially in the group that received this hormone continuously. These losses varied considerably in individual cows; over a period of five months they averaged approximately 50 pounds per cow in the continuous group, 30 pounds per cow in the 4-week group, and 20 pounds per cow in the 2-week group. No adjustment of the rations of these cows was made, but more recent work in the State College herd indicates that such losses can be made good by increasing the grain allowance in proportion to the increased milk yield.

There were no significant changes in the general condition, appearance, or behavior of these cows, neither was the composition of the milk significantly affected. There was some apparent disturbance of the reproductive function in the continuous group, these cows requiring on the average twice as many services for conception as they had required the previous year.

Because of labor conditions at the Medfield State Hospital, work on this project was transferred to the State College herd in the autumn of 1944. In the work in progress here, emphasis is being placed on the effect of the hormone on milk composition. Nineteen cows (seven Ayrshires, six Holsteins, and six Jerseys) were included in the trials conducted during the past winter. All that can be said at this time is that there have been rather marked differences in response to the hormone by the different breeds and also by different individuals within a breed. The project is being conducted in cooperation with Cerophyl Laboratories, Inc., of Kansas City, Missouri, which is furnishing the necessary thyroprotein.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Bacteriological Studies of Rural Water Supplies. (James E. Fuller.) This is a study of the growth and behavior of coliform bacteria at incubating temperatures up to 46° C., in the effort to evaluate the many atypical cultures encountered in testing rural water supplies. The cultures employed in the study were obtained from water samples sent to the laboratory for routine testing. Only typical *Escherichia coli* of sewage type was able to produce gas from lactose at 46° C. Most of the cultures studied proved, on this basis, to be soil-type coliform bacteria of questionable sanitary significance. Good results were obtained from the use of the methyl-red test at 44° C. This procedure seemed able to separate typical *E. coli* (positive at 44° C.) from atypical coliform cultures (positive at 37° C., but negative at 44° C.).

Relation of Chloramine-Resistant Bacteria to Milk Supplies. (James E. Fuller.) Previously published results (J. New England Water Works Assoc., 58: 89-100, 1944) showed a substantial increase in the number of positive presumptive tests (gas production in lactose broth) obtained in routine testing of the water after the chlorine-ammonia treatment was begun. These tests, however, could not be confirmed; that is, they were false presumptive tests. During the past year studies have been made to determine the cause of the false presumptive tests. Results follow:

1. Numbers of Gram-negative bacteria have been isolated that resemble coliform bacteria except for their failure to confirm, that is, to produce gas in lactose broth within 48 hours of incubation at 37° C. 2. By passing the cultures through successive tubes of lactose broth, the ability to produce gas within 48 hours was built up in a number of them. 3. By combining the cultures with one another, or with certain Gram-positive aerobic spore-forming cultures also isolated from the water, it was possible to obtain positive presumptive tests.

The conclusion was that the false presumptive tests obtained from the water supply are caused by coliform bacteria whose fermentative capacity had been so weakened by environment that they were unable alone to produce gas from lactose, but could do it when combined with other cultures. This study has been accepted for publication in the Journal of the New England Water Works Association for September, 1945.

The last phase of the study, now under way, is to investigate the possible effect of these bacteria on milk supplies. Some work has been done to determine their rate of multiplication in milk at several temperatures ranging from room temperature to that of normal refrigeration in an electric refrigerator. The production of acid and curd in milk under these conditions is also being investigated. Work on this phase of the problem has not progressed sufficiently to warrant any statement of results at this time.

Study of Septic Tank Efficiency. (James E. Fuller.) A preliminary statement has been made (Mass. Agr. Expt. Sta. Bul. 417, 1944, p. 17) explaining the origin of this project as a cooperative study with the State Board of Health Division of Engineering. After the Department of Bacteriology took over the project, a part of the tank installation was rebuilt, with the cooperation of the Department of Engineering of the Experiment Station, to eliminate certain faulty features of the original design.

It has not been possible to operate the project continuously, partly because the dormitory that supplies sewage to the tank has been occupied by pre-aviation cadets on a "here today and gone tomorrow" basis, and partly because the installation is not housed, with the result that deep snow and very cold weather necessitated suspension of operation in mid-winter of 1944-45. However, some results have been obtained.

The main object of the project was to study the effect of retention period on the efficiency of the tank in digesting the sewage. The tank has three compartments which receive sewage at rates that provide retention periods of 24 hours, 12 hours, and 8 hours respectively. The tank was put into operation in late August, 1944. Scum formed rapidly in the 12-hour and 8-hour compartments, and the outlets from both were plugged up solidly by early December with scum about 8 inches thick. The scum in the 24-hour compartment formed gradually and more normally and was about 2 inches thick when operation was suspended.

Bacteriological studies of the effluent showed that the coliform bacteria recovered at the beginning of operation were mostly typical *Escherichia coli,* while after about six weeks the type changed to *Citrobacter* which is a member of the coliform group but not so indicative of immediate fecal pollution as *E. coli.*

This indicated that conditions within the tanks changed so as to favor growth of the *Citrobacter* rather than *E. coli*. The bacteriological results were about the same for all three compartments, as to both numbers and types of bacteria recovered.

Laboratory Service, July 1, 1944, to June 30, 1945. (James E Fuller.)

Milk samples, bacteria counts	170
Ice cream samples, bacteria counts	79
Water samples, bacteriological tests	148
Total	397

DEPARTMENT OF BOTANY

A Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. As of July 1, 1945, the Dutch elm disease caused by the fungus *Ceratostomella ulmi* (Schwarz) Buisman, has been isolated from 54 trees in 19 municipalities in Massachusetts as follows-:

Berkshire County	1941	1942	1943	1944	1945
Alford	1			2	
Egremont		3	2	3	
Great Barrington		1	1	6	2
Hancock					1
Lenox					2
Mount Washington				1	
Pittsfield				3	
Richmond					5
Sandisfield				1	
Sheffield		1		5	
Stockbridge				2	
West Stockbridge			1		
Williamstown					1
Hampden County					
Holyoke				2	
Longmeadow				1	
Southwick				2	
Springfield				2	
Westfield		1			
West Springfield				2	

In both Berkshire and Hampden Counties the spread of the disease is favored by the relatively unbroken continuity of elm population in valleys; and the prospect appears that in Hampden County, because of additional complications, the disease if unchecked may become more prevalent than in Berkshire County.

Certain conditions favor control, but not exclusion, of the disease in the eastern part of the State. In general, elms are more restricted there to plantings of ornamental and street trees. Such trees are likely to be better cared for by either private or public agencies. Also, in metropolitan areas, as contrasted with rural areas, elm in woodpiles favorable for breeding of bark beetles which carry the disease fungus, is not so common, and usually there is less movement of elm logs which might be infested with the carrier beetles. Additional factors affecting disease distribution throughout the State are yet to be evaluated.

In all parts of the State where diseased trees are found, surveys are made in the immediate vicinity and recommendations furnished to public and private agencies concerning desirable control measures. Although recommendations are made for particular conditions, they may be summarized as follows:

1. Keep elms as healthy as possible.
2. Spray elms to control elm leaf beetle and other insects.
3. In particular, if elms are cut, remove and burn the bark immediately. The bark beetles which carry the disease fungus breed in the bark of freshly cut elm.
4. Avoid piling elm wood in the open unless it is peeled. Don't transport elm wood with bark attached. Piled elm wood is more dangerous than standing dead trees.

Other methods of disease control are being explored, and, in cooperation with the Department of Entomology, means for control of carrier insects are under investigation.

Other Tree Problems. Fifty-four diseases of thirty species of trees including eight diseases of elm were identified from approximately 350 specimens and inquiries received during the year. The *Cephalosporium* wilt of elm was reported from two additional municipalities in which the disease has been found in Massachusetts. *Verticillium* sp. was isolated from several species of wood plants.

On September 14, 1944, a hurricane struck southeastern Massachusetts with devastating force. Along the coast the water did not invade and undermine property to the extent of the hurricane of September, 1938, but not until long after the excitement of the storm had passed, and in some instances not until the spring of 1945, was the complete effect of salt and wind on trees fully realized. In Barnstable, Plymouth, and Bristol counties thousands of trees were uprooted or shattered. Transportation and communication facilities were suspended or impaired for days or weeks while conditions were righted amid complications of shortages in labor and materials. A visit to the "graveyard" of almost any tree department is a revealing picture of trees lost. As for trees which withstood the storm, in the course of clearing operations they were sometimes left in hopelessly mutilated condition. Inadequate repair of injured trees always paves the way for future failure of damaged limbs. In limbs and crotches a hurricane rends the weak spots and creates additional ones. Viciously enough these in turn often become casualties of lesser storms. Events of recent years serve well to emphasize the need for better tree care and the detection of minor tree defects which may be corrected at limited expense. Neglect of current needed work is an expensive and indeed a deceiving false economy.

In many communities of Massachusetts on April 23 and 24, 1945, early morning frosts injured foliage of trees on which leaves had developed in response to warm spring weather. Damage varied from extensive on fruit trees to limited on some shade and ornamental trees.

Leaf diseases have been unusually prevalent on shade trees during June. The regularity with which rains occurred favored the development and dissemination of fungi involved. In some instances leaves damaged by frost, wind, and fungus infection had already fallen by July first, to a conspicuous extent.

During a severe electrical storm in Amherst on June 15, 1945, the following trees on the State College campus were struck: a large elm south of the tennis court near the cold storage plant, a large elm on Stockbridge Road west of French Hall, a sycamore northwest of Butterfield House, a linden east of North

College, and an ash west of Clark Hall. Damage varied from slight scorching of trunk to debarking of individual limbs and complete demolition of the ash.

In the early summer of 1945, two street trees, in each case located near catch basins into which water drains from near-by hillside streets, showed damage suggestive of chloride injury. During the winter the streets involved are well coated with salt to eliminate ice. Because of heavy snow and spring rains the water levels of basins were rather high this spring. Local conditions suggested that salt, which ordinarily might not be available to near-by trees, had reached their roots as a result of an unusual combination of circumstances.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Work on the propagation of high-bush blueberry by softwood cuttings was continued in cooperation with John S. Bailey, and a second paper was published on the subject.* Cuttings rooted better if taken not later than 2 to 3 weeks before the first berries ripened. Their rooting was most improved and hastened by B-(indole-3)propionic acid, less by potassium indolebutyrate, and least by indolebutyric acid. Powder-dip treatments did not give so good results with blueberry cuttings as did solution-immersion treatments, but there were good results with Spergon–Hormodin No. 2.

Especial attention was given to the effects of combinations of certain fungicides with root-inducing substances, usually in the proportion of 1:1 by volume, for the treatment of cuttings.

In work with Lawrence Southwick it was found that length of life of unrooted softwood cuttings of McIntosh apple was consistently increased by Spergon–Hormodin No. 2 or No. 3, but was not prolonged by Hormodin No. 1 or No. 2 used alone. The life of such cuttings was also lengthened if, after solution-immersion treatment with indolebutyric acid, they were treated with Spergon alone. Mid-June cuttings of McIntosh rooted 33 percent after treatment with naphthaleneacetic acid followed by Spergon–Hormodin No. 2, not at all if treated with naphthaleneacetic acid alone.

Treatments of cuttings of rose with Spergon tended to retard rooting and subsequent growth, but Arasan or Fermate similarly applied gave good results. Thus, in a typical instance, rose cuttings rooted in the following percentages: check, 58; Hormodin No. 1, 77; Arasan–Hormodin No. 2, 93; indolebutyric acid 2 mg./gm. Fermate, 95. For rose cuttings, sand is to be preferred to sand–peat. It was found that the best type of rose cutting has 2 buds, one (upper) leaf with 3 leaflets or, if a 5-leaflet leaf, with the tip leaflet removed.

White pine cuttings, rooting not at all without treatment and relatively poorly with Hormodin No. 3 alone, rooted 64 percent after treatment with Fermate–Hormodin No. 3.

Cuttings of arbor-vitae rooted much better after treatment with indolebutyric acid 8 mg./gm. Arasan, Fermate, or Spergon than after similar treatment with indolebutyric acid in a carrier of talc. Indolebutyric acid 8 mg./gm. Fermate also gave excellent results with *Juniperus chinensis* L. var. *Sargenti* Henry. Cuttings of southern balsam fir rooted better if, after solution-immersion treatment with indolebutyric acid, they were given a powder-dip in Arasan or Spergon.

Probably because the root-inducing substance was too much diluted by the fungicide (there did not appear to be chemical injury), rooting of cuttings of the following species was more improved by treatment with Hormodin No. 3 than by treatments with mixtures of it and the fungicides named below: Colorado

*Doran, W. L. and Bailey, J. S. Propagating the high-bush blueberry by softwood cuttings. American Nurseryman 81:7:10. 1945. (Mass. Sta. Contrib. 554.)

fir and Sawara cypress with Arasan or Fermate; *Abies nephrolepis* Maxim. with Arasan, Fermate, or Spergon.

November cuttings of Norway spruce and Korean fir rooted in larger percentages in sand watered from above than in sand subirrigated; that is, watered only from below.

Rooting of November cuttings of Norway spruce was decidedly improved by treatment with manganous sulfate 0.5 or 1.0 percent solution for 22 hours. Rooting of cuttings of Chinese juniper was much more improved by treatment with potassium nitrate 500 mg./l., 18 hr., preceding treatment with Hormodin No. 3 than it was by Hormodin No. 3 used alone.

Rooting of cuttings of black spruce and of 3 varieties of Norway spruce was improved or hastened by treatments with monobasic potassium phosphate 0.25 or 0.5 percent solution, 21 hours; and in the two cases where comparisons were made, indolebutyric acid was less effective.

Cuttings of Colorado fir and *Juniperus squamata* Lamb. rooted less well if allowed to lose 10 percent of their fresh weight before treatment.

Beach plum cuttings rooted well in 4 weeks after solution-immersion treatment with indolebutyric acid even though they were taken as late in the season as the last of June. For these cuttings taken relatively late, powder-dip treatments were less effective.

November cuttings of a hemlock treated with Hormodin No. 3 rooted 92 percent if from the north side of the tree, 25 percent if from the south side. November cuttings of a Norway spruce treated with manganous sulfate (1.0 percent solution, 19 hr.) rooted 50 percent if from the north side of the tree, 8 percent if from the south. December cuttings of arbor-vitae finally rooted 100 percent in any case, but those from the south side of the tree required 50 to 75 percent more days for rooting. Out of 31 possible comparisons with white pine cuttings taken in March from 3 different trees, cuttings from the north side of the trees rooted best in 17 cases, those from the south side in 7 cases, and there were no differences in 7 others.

Treatments of November cuttings of arbor-vitae (with indolebutyric and indolepropionic acids) which were apparently injurious in sand–sphagnum peat were not injurious in sand–sedge peat. November cuttings of Norway spruce rooted better in sand–sedge peat than in sand–sphagnum peat.

Diseases of Plants Caused by Soil-infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) The effects of certain soil treatments on club-root of cabbage (caused by *Plasmodiophora brassicae* Wor.) were investigated. The disease was not prevented by ammonium sulfate (and lime), calcium cyanamide, or Fermate as used, but it was fairly well controlled by mercurous chloride 0.2 or 0.15 gm. per square foot without injury to growth of plants. Mercuric chloride similarly used retarded their growth. Sodium chloride used alone did not control club-root but 10.0 gm. per square foot appeared to be favorable to growth of plants and mercurous chloride gave rather better control when used with sodium chloride than when used without it. The percentages of infected plants were:

Soil Treatment	Percentage of Infected Plants
No treatment	95
Mercurous chloride 0.15 gram	33
Mercurous chloride 0.15 gram plus sodium chloride 10 grams	13
Mercurous chloride 0.2 gram	20
Mercurous chloride 0.2 gram plus sodium chloride 15 grams	0

Tomato seedlings emerged and grew more slowly if seeds treated with Arasan were planted in untreated soil than if untreated seeds were planted in soil which, immediately after seeding, received an application of formaldehyde, one teaspoonful per gallon of water. And, in untreated soil, tomato seedlings made more growth in their first three weeks if seeds had been treated with red cuprous oxide than if they had been treated with Arasan.

In soil heavily infested with damping-off fungi, principally species of Pythium, and having a relatively low moisture content at the time of seeding, there was usually less damping-off, and final stands of cabbage, tomato, pepper, lettuce, beet, and onion were usually much better if soil was not watered until 4 to 6 days after seeding, than if the soil was first watered immediately after seeding, as it commonly is. Similar postponement of the first watering after seeding also resulted in improved stands of Aubrietia, China aster, and zinnia.

Work done on the control of smut and pink root-rot of onion was with the cooperation of Thomas Sproston, Jr. A paper entitled, "Control of onion smut by fungicides applied to the soil" was presented at the Annual Meeting of the New England Division of the American Phytopathological Society. An abstract of this paper has been accepted for publication by Phytopathology. Onion smut, caused by *Urocystis cepulae* C. C. Frost, was well controlled by 58 pounds Fermate mixed with 1500 pounds of a 5-8-7 fertilizer per acre, applied immediately before seeding. Fertilizer used alone lessened the severity of smut but of course not enough. The percentage of seedlings which, in a typical instance, became infected with smut was 88 percent in a soil without treatment, 56 percent in this soil with fertilizer, and 1 percent in this soil with fertilizer to which Fermate had been added. Fermate so used was not injurious to growth of plants. There were comparable results when Arasan was similarly used. Smut was well controlled by Puratized N5-X and also by the nitrites of sodium and calcium, but Fermate used as above described gave better results. Urea and calcium cyanamide gave fair control but, as used, they caused some injury to onion seedlings.

Soil in which onions had grown poorly and in which they were known to have had pink root-rot, was variously treated before planting onion sets or sowing onion seeds in it. Numbers of onion seedlings which lived, as compared with numbers in untreated soil, were increased 80 percent by sodium nitrite, almost as much by Fermate. Fermate was ineffective, however, in preventing pink root-rot. But with pink root-rot severe on onions from sets in untreated soil (a species of Fusarium was isolated from diseased roots), the disease was at least partly controlled and early growth was markedly improved by copper sulfate 200 pounds or sodium nitrite 400 pounds per acre.

Tomato Leaf Mold Caused by the Fungus Cladosporium fulvum Cke. (E. F. Guba, Waltham.) Previous reports by the writer describe the discovery of resistance to all local strains of Cladosporium among certain primitive tomatoes received from the Division of Plant Exploration and Introduction, U. S. Department of Agriculture, and his progress in crossing these types with the Bay State variety. The Bay State tomato (Mass. Agr. Expt. Sta. Bul. 393) is now very susceptible to a variant strain of leaf mold.

The best approach to desirable types of greenhouse forcing tomatoes appeared among the progeny of successive generations of crosses of Bay State with a primitive type No. 129882 from Peru and No. 112215 from Ecuador.

A further series of crosses was made of selected lines of the above hybrids with Vetomold-121, Bay State, Waltham Forcing, and Marglobe. The crosses with No. 112215 are giving the best performance. The F_3 generation will be grown in several commercial greenhouses for trial in the fall growing season

(1945), and for further selection to pure line the tomato for resistance and high yielding type.

Laboratory prepared dusts containing 5 percent Thiosan, Fermate, Spergon, or Dithane (HE-175), with 95 percent talc are fungicidal to Cladosporium spores. Dusts containing 10 percent active chemical and 90 percent talc gave satisfactory control of spore germination when a water suspension of spores was applied to dusted slides. The Dithane dusts were injurious to tomato foliage. The use of the tolerant dusts would appear to meet the demand for a suitable fungicide for the control of tomato leaf mold in the greenhouse.

Causes and Control of Decay of Squash in Storage. (E. F. Guba, Waltham.) The growing season was unusually dry. Six plots of Blue Hubbard squash were grown, each of an area of 7,350 square feet and comprising 34 hills. Three plots were sprayed five times with Bordeaux 4-4-50 mixture combined with calcium arsenate 1 pound and spreader; three similar plots were not sprayed. The unsprayed out-yielded the sprayed plots, thus confirming the results of the previous year. The residue of the spray persisting on the squash in storage would appear to provide some protection against decay organisms, but storage up to November 1944 showed no significant or consistent contrast among the six harvested lots of squash. Loss from decay was negligible. Shrinkage was greater among the stored squash from the sprayed than from the unsprayed plots. These results, at least in a real dry season, would appear to discourage field treatment with homemade Bordeaux mixture as a disease preventive treatment. Other types of fungicides are suggested for trial.

Interrelation of Wettable Sulfur, Lead Arsenate and Lime in Apple Spraying. (E. F. Guba and E. V. Seeler, Jr., Waltham.) This project is intended to improve upon our knowledge of the apple spraying schedule, involving the substitution of materials to avoid injury, selection of the best types of sulfur to insure the greatest protection against disease, selection of the most efficient fungicide for scab eradication, the effect on the adherence of sulfur of adding lead arsenate and lime, etc. As in the past, detailed reports are compiled and submitted to cooperating leaders.

The year 1944 was an off season for chemical russet injury on Red Delicious and no results were obtained. The usual amount of weather russet injury occurred on Golden Delicious, and as usual the greatest percentage of russeted apples occurred on the unsprayed trees. The season was too dry for an evaluation of the protective action of various sulfur pastes used. The destruction of scab spores on the foliage was best accomplished with lime sulfur 32° Be 2 gallons, Everett Flotation Sulfur Paste 16 pounds, and Fermate 1½ pounds to 100 gallons of water. The results with Wettable Spergon 2 pounds, HE-175 (Dithane) 1½ pounds, and DN-111 1¼ pounds to 100 gallons of water were unsatisfactory.

Effect of Soil Temperature on Leaf Shape of Tobacco. (L. H. Jones.) The effect of soil temperature on the shape of leaves of Havana Seed tobacco has been found to occur in the absence of a mosaic virus. The apparatus provided two constant soil temperatures, a low at 70°F. and a high at 90°F. At the low temperature the leaves developed consistently as the normal ovate shape. At the high temperature the newer leaves appeared yellow spotted, light green in color, narrow, and very pointed, fitting the description of what is called frenching in tobacco. Inoculation of healthy plants with the leaf juice of these frenched leaves failed to result in the development of any symptoms of a mosaic virus, while comparable healthy plants did develop mosaic symptoms when inoculated with the juice of mosaic-affected leaves.

Changing the soil temperatures from the low to high and from the high to low altered the shape of the new leaves formed after the change of temperatures. Those plants which had been growing at the low of 70°F. with normal leaves soon produced frenched leaves at the tip when the soil temperature was raised to 90°F. On the other hand those plants which had been growing at 90°F. soil temperature and had produced frenched leaves at the tip reacted to the dropping of the soil temperature to 70°F. by sending out lateral shoots, the lower leaves of which were frenched but as the shoot grew the leaves developed with less frenching and were practically normal at the tip.

Toxic Effect on Plants by Wood Preservatives. (L. H. Jones.) Continuation of the work previously reported on creosote injury to plants showed that the injury was local. The fumes are evolved from creosote-treated lumber by the high temperature of the sun's rays and pass into the leaves of plants through the stomata. An exposed leaf on a vine or stem may be killed, but the creosote fumes are not transmitted by the vascular system to adjacent parts. However, if the injury is in the region of the growing point, further growth is stopped and the plant will die unless the nature of the plant allows the development of lateral shoots, one of which may become a leader.

No injury resulted from attempts to have creosote or its fumes absorbed through roots of plants in the soil. Seedlings of cabbage protected from creosote fumes by glass shells were uninjured although the creosote fumes were free to enter the soil and be absorbed by roots. One teaspoonful of creosote mixed with the volume of soil in a 3-inch pot failed to give injury even with a recorded soil temperature of 108°F. Creosoted tomato stakes with the creosote slightly above the soil line did no harm to plants, when young or at any time during the season.

Cabbage maggot protectors made of heavy paper impregnated with creosote did not injure cruciferous plants except when the stalks were soft and tender. Unhardened plants were liable to be burned by the fumes where the impregnated paper came in contact with the stalk. Injury also occurred when growers failed to remove translucent hoods before the sun's rays became strong enough to volatilize the gases of creosote in the paper, which were then confined under the hoods. Tests made with these protectors tacked to lath and placed close to radish rows resulted in injury to the radish plants. Even after the radish plant had four true leaves and was four inches high, injury resulted and the leaves were severely injured. Probably the closeness of the leaves did not allow good air drainage and the fumes collected about the leaves.

Lumber with the trade name of Asidbar, impregnated with resins from which the more volatile constituents had been removed, was injurious to seedlings of cabbage and tomato when the lumber was at a higher level than the seedlings. The injury was similar to creosote injury, resulting in a rolling upward and inward of the margins of the cotyledons and first leaves of cabbage and tomato. Death of the seedlings was frequent. Injury did not appear during cloudy weather but followed hot sunny days, indicating that some fumes are evolved by the influence of the sun's rays. Asidbar lumber buried in the soil in close proximity to seeds of tomato and cabbage gave no indication of a toxic effect. In fact the roots of the seedlings developed in contact with the wood, remained white and developed branches in contact with the wood. A recorded soil temperature of 96°F. on a hot day was not followed by any indication of injury from this lumber protected from the sun's rays by the soil covering.

Cuprinol, a copper naphthenate, when used as a wood-preservative paint did not injure plants. Before plants or seeds were used near the painted wood, a week was allowed to elapse in order that the volatile carriers of the preservative might evaporate.

Chlorine Injury to Plants. (M. A. McKenzie and L. H. Jones.) Following investigation of a tree trouble which proved to be of non-parasitic origin, the possible involvement of escaping gas from a nearby chlorinator led to an investigation of the effect of chlorine on woody plants. Available literature on chlorine in relation to plants concerns chiefly chlorine in water used on soil in which plants were growing. In conformity with common opinion, no injury was observed when potted plants were watered with a mixture of chlorine and water applied only to the soil. Injury[1] did occur, however, when an equal quantity of the same mixture was applied directly to the foliage.

Resistance to Fusarium dianthi, Prill. et Del., the cause of a serious carnation wilt disease. (E. F. Guba, Waltham.) The reaction of many standard varieties of carnations (*Dianthus caryophyllus* L.) to *F. dianthi* has been determined by artificial inoculation methods. Selected varieties showing a highly resistant reaction to the branch rot fungus will be selfed and crossed for a similar analysis of the progeny. The wilt-resisting seedlings will be carried to flowering in search of types meeting commercial standards.

Both Arasan (tetramethylthiuram disulfide) and Fermate (ferric dimethyldithiocarbamate) in mixtures of 10 percent with 90 percent talc gave good control of Fusarium wilt in the propagating sand when the basal end of artificially inoculated cuttings was treated with the chemical dust before the cuttings were planted. A mixture of either of these fungicides with hormone dust in the ratio of 10-90 respectively for a combined disease control and root inducing effect is indicated.

Considerable time was devoted to the preparation of a Station bulletin on the subject of carnation wilt diseases and their control.

Miscellaneous Studies. (E. F. Guba and E. V. Seeler, Jr., Waltham.)

Damping-Off Control with Seed-Borne Chemicals. As in previous years the various dry chemical seed treatments were tested for their control of damping-off of vegetable stands. The cold temperatures and abundant rainfall prevailing throughout the vegetable seed sowing season were ideal for these tests. The results will be compared with those of previous years and the preferred treatments arranged in a chart or guide for market gardeners.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Studies on the Quantitative Estimation of Hemicelluloses. (Emmett Bennett.) Hemicelluloses constitute one of the largest single group of substances in plant material, but because of the association with other compounds and the heterogeneity of the substances, their determination is one of the least satisfactory to make. After making other preliminary tests utilizing the charge on the hemicellulosic particle as a basis, it seems more advantageous to start with the holocellulosic material. Preliminary experiments indicate that sodium chlorite can be used effectively in preparing the holocellulosic fraction from non-woody plant tissue for the quantitative estimation of hemicelluloses. This procedure, while long, is simple, requires little attention, and eliminates other more tedious and lengthy operations. The resulting product is substantially free of lignin and contains the hemicelluloses. No statement concerning the actual quantitative estimation is warranted at this time.

[1]Jones, L. H., and McKenzie, M. A. Chlorine gas injures trees. Arborist's News 9:89-90. 1944 (Mass. Agr. Expt. Sta. Contrib. 541).

The Chemical Investigations of Hemicelluloses. (Emmett Bennett.) Hemicelluloses were isolated from corncobs and rye straw by the alkali method. Hypochlorites and bromine were used in purifications. The purified substances were subjected to chemical treatment which would indicate some facts regarding their chemical nature. The results of these investigations seem to indicate the following:

(a) Xylose appears to be the chief sugar present in both preparations. A uronic acid, believed to be glucuronic acid, was also present in both samples. Glucose was present but galactose could not be detected.

(b) As indicated by acetylations, corncob hemicellulose has two free hydroxyl groups. The theoretical acetyl content of $C_9H_{12}O_6$ is 39.81 percent; the prepared product contained 39.73 percent. The theoretical and actual carbon content of the acetate are 49.98 and 49.50 percent respectively. These data indicate that the xylose units probably are linked through the 1, 4 positions and that the preparation was quite pure. Hemicellulose from rye straw does not acetylate satisfactorily.

(c) The "repeating units" appear to be of from 25 to 40 units in length, corresponding to an approximate molecular weight of from 3000-6000.

(d) Hydrolytic and polariscopic studies indicate that the xylose units in both hemicelluloses have a pyranose structure with a beta-type linkage between units.

(e) Alkali-lability numbers are about equal and are comparable to those of commercial samples of corn starch.

(f) Complete hydrolysis of both hemicelluloses could be obtained with 4 percent sulfuric acid in approximately four hours, whereas the usual time is about 15 hours. This shorter time of hydrolysis decreases the destruction of uronic acids.

The Investigation of Agricultural Waste Products.—1, The Chemical Investigation of Lignin. (Emmett Bennett.) The work on this project to date has been devoted to ascertaining the effect of large quantities of pure lignin upon the aerobic decomposition of plant materials of varying composition.

Pure lignin was added to finely ground samples of silage, timothy hay, corn stalks, and oat hay, thoroughly mixed, inoculated with a soil suspension, and allowed to incubate at about 32°C. for several months. The lignin contained 64.2 percent of carbon and 5.6 percent of hydrogen and was added in amounts equivalent to about 14 percent of the plant material. In order to increase the supply of nitrogen for microbial activity one gram of nitrogen in the form of ammonium carbonate was added to each 100 grams of organic material. Controls were used in each case. At definite intervals, representative samples were removed and analyzed for total nitrogen, ammoniacal nitrogen, solids, and pH.

Tentative results indicate that there was a greater loss of organic matter from the corn stalks and oat hay in the presence of added lignin; timothy hay and silage decomposed at about the same rate with or without lignin. In general, ammonification was retarded in the presence of lignin.

Although we have no data on the influence of the products of decomposition on the vigor of the plant, it would seem that added lignin does not materially alter the rate of the aerobic decomposition of plant material if sufficient nitrogen is available.

Factors Affecting the Vitamin Content of Milk and Milk Products. (Arthur D. Holmes.) Milk, which has been described as nature's most perfect food, is of especial importance to the residents of Massachusetts. From the farmers' viewpoint, it is one of the principal agricultural products of the State and it is highly important to the consumer since it is a particularly valuable food which is consumed in such large amounts that a great deal is imported from other areas to supplement that produced in Massachusetts. Obviously many factors affect the vitamin content of milk, but recently attention has been largely centered upon the influence of the ration and the effect of sunshine on cow's milk and a study has been made of the vitamin content of goat's milk collected from numerous areas of the State.

The Ratio of Ascorbic, Nicotinic, and Pantothenic Acids, Riboflavin, and Thiamine in Late Summer Milk. (Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, Katherine Esselen, and Beula V. McKey.) The milk used in this study was produced by the college herd of Ayrshire, Guernsey, Holstein, Jersey, and Shorthorn cows in the late summer when the pasture grasses were fully mature, but before severe frosts had affected their quality. The pasture ration was supplemented with ground grains (14 percent) at the rate of one pound for each six pounds of milk the cows produced. Fifteen samples of milk, which represented 15 days' production, were assayed. The values obtained varied somewhat from day to day, but averaged ascorbic acid 18.4 mg., nicotinic acid 1.1 mg., pantothenic acid 3.66 mg., riboflavin 1.37 mg., and thiamine 0.44 mg. per liter. Judged by the dietary allowances recommended by the National Research Council, such milk would have to be fortified with ascorbic and nicotinic acids to meet the recommended allowance for infant feeding.

Effect of Sunshine upon the Ascorbic Acid and Riboflavin Content of Milk. (Arthur D. Holmes and Carleton P. Jones.) It has long been known that sunshine or strong light tends to destroy ascorbic acid and riboflavin Accordingly, it appeared desirable to determine the extent to which sunshine might reduce the nutritive value of milk by destroying these vitamins. Similar studies had been reported from other laboratories, but unfortunately the authors did not measure the sunshine to which their samples of milk were exposed. Accordingly, milk produced by the college herd was exposed to the action of sunshine for two 30- or two 60-minute periods in ½ pint commercial milk bottles. The intensity of the sunshine was measured with a pyrheliometer equipped with an automatic recording device The "sunshine" varied from a total of 4.8 gm. cal. per sq. cm. on a rainy day to 144.6 gm. cal. per sq. cm. on a bright day. The temperature of the milk varied from day to day depending upon the velocity of the wind, greenhouse effect of the milk bottles, and intensity of the sunshine. The destruction of reduced ascorbic acid was very rapid. Little, if any, was present after 30 minutes' exposure. The riboflavin disappeared more slowly. A 10 percent loss occurred during 60-minutes' exposure on a rainy day and 85 percent disappeared during exposure to bright sunshine for 120 minutes. These data show that milk allowed to stand for more than a short period on the consumer's doorstep exposed to strong light or sunshine, is likely to lose a large amount of its ascorbic acid and riboflavin.

The Vitamin Content of Commercial Winter Goat's Milk. (Arthur D. Holmes, Harry G. Lindquist, Carleton P. Jones, Anne W. Wertz, Katherine Esselen, Beula V. McKey, and Evelyn Fuller.) It has been estimated that the retail value of goat's milk produced in this country exceeds $100,000,000 annually. A large portion of the fluid milk is used for infants, for invalids, and for consumption in the home of the producer. However, a review of the literature revealed very little information on the vitamin content of goat's milk. Accordingly, 18 samples of raw goat's milk from various localities within 100 miles of Amherst were assayed. Data were collected concerning the breed of the goats, their age and stage of lactation, and their ration. The average values obtained were fat

4 percent, bacteria 1300 per cc., ascorbic acid 6.5 mg., nicotinic acid 2.96 mg., pantothenic acid, 3.38 mg., riboflavin 1.25 mg., and thiamine 0.47 mg. per liter. These results show that goat's milk is a very valuable source of the vitamins noted above.

The Variation in the Bacteria, Fat, Ascorbic Acid, and Riboflavin Content of Goat's Milk. (Arthur D. Holmes, Harry G. Lindquist, and Elliott K. Greenwood.) The present curtailed supply of milk and milk products in Massachusetts has stimulated the use of goat's milk instead of cow's milk, particularly in families of foreign birth or ancestry. Coincident with the increase in the number of goats and in the number of consumers of goat's milk, there has been an increasing demand for information regarding the nutritive value of goat's milk. Accordingly, 39 samples of goat's milk were obtained from various localities throughout the State. They were shipped to the laboratory carefully packed in ice and the temperature on arrival was 34°-40°F. Sixty percent of the samples represented a single milking of one animal, but the other samples were composites of milk from herds of 8, 19, 50, and 65 goats. Four breeds of goats were represented, French Alpine, Nubian, Saanen, and Toggenburg. Their ages varied from 1 to 12 years and the stage of lactation varied from 10 days to 36 months. None of the goats received any corn or grass silage. The majority were stall-fed, but 14 of the samples were from goats that also received various herbage varying from buds and twigs of bushes to good Ladino clover, timothy, and red top pasture. The bacteria count varied from 20 to 21,300 per cc. The average for 38 samples was 3,500 per cc. or practically only 1/3 that allowed for certified cow's milk. The fat content varied from 2.2 to 6.5 percent and averaged 4.3. The reduced ascorbic acid of milk from the stall-fed goats averaged 15.1 mg. and that from the goats which received some pasture averaged 20.0 mg. per liter. The riboflavin content of the milk from the stall-fed goats averaged 1.24 mg. per liter, which is identical with that obtained in a previous study. The average riboflavin content of the milk from goats which had access to pasture was 1.02 mg. per liter, which is in accord with another observation that the riboflavin content of cow's milk decreased from 1.43 mg. to 1.26 mg. per liter when a mixed herd of cows was changed from a ration of hay, silage, and grain to a pasture of young, rapidly growing green grass. Apparently the bacteria count, fat, ascorbic acid, and riboflavin content of goat's milk vary considerably with the source of the milk. These results also show that the goat's milk under consideration contained fewer bacteria and less riboflavin, but about the same amount of fat and ascorbic acid as cow's milk.

Influence of Calcium and Magnesium upon Composition of Boston Head Lettuce. (Arthur D. Holmes and Leo V. Crowley.) For many years lettuce has been classed as a protective food since it contains minerals and vitamins which are not present in adequate amounts in carbohydrate-rich and fat-rich foods. While meat and dairy products are relatively rich sources of minerals and vitamins, they are much more expensive and at the present time can be purchased in only limited amounts. Commercial and practical gardeners are of the opinion that frequently the quality and yield of lettuce can be enhanced by supplementing the usual lettuce fertilizers with lime or lime and magnesium. Accordingly, a study was undertaken to determine whether the mineral and vitamin content of lettuce may be significantly influenced by the use of these supplementary fertilizers which were applied at the rate of 150 pounds of magnesium sulfate per acre, 1,000 pounds of limestone per acre, and a combination of 150 pounds of magnesium sulfate and 1,000 pounds of limestone per acre. The use of magnesium sulfate as a supplementary fertilizer increased the magnesium content of the lettuce but it also reduced the calcium, iron, and phosphorus content. The use of magnesium sulfate and lime or lime alone as a supplementary fertilizer tended to reduce the carotene, calcium, iron, and phosphorus content of the lettuce and caused a definite decrease in the magnesium content. The values obtained show lettuce to be a valuable source of carotene, riboflavin, calcium, iron, magnesium, and phosphorus and to be well deserving of its classification as a "protective food" for the human dietary.

CONTROL SERVICES

Philip H. Smith in Charge

The fertilizer, feed, seed and milk testing laws are administered as one service and the operations of each of these, with the exception of the milk testing law, are reported in annual bulletins issued for that purpose.

Under the milk testing law 6,407 pieces of Babcock glassware were tested for accuracy and 85 certificates of proficiency in testing were issued. In addition, all milk depots and milk laboratories in the State were visited at least once, as required by statute, in order to check apparatus and the general conduct of the work. In order to promote greater efficiency in checking on the accuracy of testing, the field men of the Milk Control Board have been deputized to conduct investigations. This is authorized by law.

In addition to regular routine duties, Control Service has been called upon to the extent of time available to assist other departments of the College and Station in conducting work in connection with research problems not originating in the Control department itself. Such service has been rendered during the past year to the Departments of Pomology, Olericulture, Animal Husbandry, Veterinary Science, Agronomy, Poultry Husbandry, Dairy Industry, Waltham Field Station, Food Technology, and Research Chemistry.

Considerable time has been devoted to assays and analyses not directly connected with the requirements of the several acts but for which there appears to be need. Some of the work covered has been assays for riboflavin, carotene, choline, and trace mineral elements in feeds.

Control Service has also examined feeds and fertilizers submitted by citizens of the State and State Institutions. Where such work can be construed to be of general public value no charge is made.

The work of the Seed Laboratory continues to enlarge, not only on account of the temporary increase in War Gardens, but also because of a growing realization on the part of retail seed dealers that good seed is of prime importance if a good crop is to be expected. Each year retailers in growing numbers submit, prior to sale, the seed they expect to offer. During the year a new seed germination room has been installed which greatly facilitates the testing of the larger field and garden seeds.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Hill Fireworm (*Tlascala finitella*). There were plenty of these worms on the heavily vined Burrage bog at South Hanson in June, 1944 Cryolite, 50 pounds to the acre applied as a dust on June 28, gave excellent control of the pest.

Cranberry Spittle Insect (*Clastoptera saint-cyri*). This insect began to hatch on Cape Cod cranberry bogs as early as May 31, in 1944.

Armyworm (*Cirphis unipuncta*). This worm appeared in numbers on many cranberry bogs from which the winter water was let off as early as May 20 in the spring of 1945.

New Insecticides. During the 1944 growing season, tests of sabadilla and DDT as possible controls of various cranberry pests were made in cooperation with the United States Bureau of Entomology, with the following results:

Sabadilla in all cases was used as a 20 percent dust. At the rate of 75 pounds per acre, this dust was fully effective against the black-headed fireworm (*Rhopobota*); and at 100 pounds per acre it controlled the blunt-nosed leafhopper (*Ophiola*) reasonably well. Smaller amounts were not enough. At the rate of 100 pounds per acre, it was wholly ineffective as a treatment for the cranberry fruit worm (*Mineola*), and killed only about two thirds of the cranberry girdler (*Crambus*) moths treated.

No injury to cranberry vines or blossoms from sabadilla was observed. It was not liked by the growers because of its sternutative effects on those handling it. This seems to be a fair stop-gap insecticide for the black-headed fireworm and blunt-nosed leafhopper, but probably will never have permanent value as a cranberry insecticide.

DDT. Fifty pounds of 3 percent dust to an acre was fully effective against full - grown gypsy moth caterpillars and the blunt - nosed leafhopper, lesser strengths not being clearly satisfactory. The 5 percent dust at the rate of 100 pounds to the acre was 80 percent effective against the cranberry fruit worm, but was clearly less satisfactory than derris or cryolite. The 5 percent dust at the rate of 100 pounds per acre, used after the flight of the moths, killed about 75 percent of the small worms of the cranberry girdler on the bog floor. No evidence appeared that DDT is injurous to cranberries at the strengths and in the amounts used. The bee situation is such that it seems dangerous to advocate the use of this material on cranberry bogs even against pests which it controls readily.

Prevalence of Cranberry Insects. The relative general abundance of cranberry insects in the 1944 season was as follows:

1. Gypsy moth infestation relatively fairly heavy throughout the cranberry section of southeastern Massachusetts.

2 Blunt-nosed leafhopper (*Ophiola*) well controlled and rather scarce everywhere on the bogs.

3 Cranberry fruit worm (*Mineola*) extremely abundant and destructive everywhere in southeastern Massachusetts except in Bristol County, more so than for many years. It may be worth noting that a similar insect, the codling moth, was also very abundant in New England this year. The fruit worm was not noticeably prevalent on bogs in Middlesex County.

4. Black-headed fireworm less troublesome than usual.

5. No firebeetles (*Cryptocephalus*) found.

6. Spanworms in general not plentiful.

7. False armyworm (*Xylena*) normal in abundance.

8. Black cutworms (*Euxoa*[1] *ypsilon*) very abundant after summer flooding of bogs to control grubs.

9. Cranberry girdler (*Crambus*) very plentiful and troublesome, due probably to reduced resanding and fall flooding caused by labor scarcity, a war condition.

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[1]Essig, College Entomology, 1942, p. 476.

10. Infestations of cranberry weevil, cranberry spittle insect, and tipworm about normal.

11. Honeybees and bumblebees normally prevalent.

Weather Studies. (H. J. Franklin.) Further studies since Bulletin 402 was published in 1943 have produced additional material which has resulted in the revision of the formulas for use in reckoning minimum bog temperatures with the 7 p.m. weather data.

Winterkilling. Cranberry winterkilling in Massachusetts in the winter of 1943-44 was the most extensive and severe in the memory of the oldest growers, causing an estimated reduction in the 1944 crop of at least 30 percent. On many bogs the vines were all killed down to the ground. The extent of this damage was not surprising, for a much larger cranberry acreage than usual was not flooded when it should have been because of the lack of enough rain to build up water supplies in the fall and early winter.

The severe frost of May 18–19, which cut off all the new growth that had developed on the winterkilled bogs up to that time, and the severe drouth that prevailed most of the summer were very unfavorable to good recovery of the injured vines. In spite of this, the new vine growth by fall was satisfactory on nearly all of the damaged areas. Some growers tried to help their bogs recover by mowing off the dead vines, resanding, or fertilizing, but there is little evidence that any of these measures was definitely beneficial. They had generally resulted in an undesirable growth of runners.

Frost. The frost on the night of May 18–19, 1944, considering the date of its occurrence and the minimum bog temperatures reached (from 14° to 25° F.), was one of the most severe in Massachusetts cranberry history. It killed all the season's new cranberry growth on many bogs and caused the old cranberry foliage on a few small areas to turn dark again as in winter. The extensive injury from this frost was due partly to lack of water for flooding and partly to freezing of the vines over the frost flood on some of the colder bogs. Also, since most of the bogs were very dry and absorbed much more water than usual, many did not get flooded as soon as they should have been. It was difficult to estimate the damage to the 1944 crop because of the extensive injury from winterkilling.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Sterilizing Agents for Dairy Use. (W. S. Mueller, J. E. Fuller, and E. Bennett.) The search for new sterilizing agents which will be practical for dairy equipment was continued during the past year. A sterilizing agent for dairy use should be (1) highly germicidal in the presence of organic matter, (2) non-corrosive to metals and rubber, (3) low in cost, and (4) non-toxic to humans. The germicidal properties of 42 materials obtained from 14 manufacturers have been studied. Where the manufacturer recommended the concentration to be used, the recommendations were followed; otherwise, the material was used in 0.05 percent and 0.5 percent concentrations, and in some cases 1 percent was also used. The sterilizing properties of solutions of the different materials were determined by adding 1 ml. of raw milk to 99 ml. of the solution to be tested. After the milk had been in contact with the solution for 5 minutes, proper dilutions were made and 1 ml. quantities were plated according to the Standard Method for Milk Analysis procedure. Out of the 42 materials, 15 were effective as sterilizing agents, 7 were moderately effective, and 20 were ineffective. The classification of the materials into groups and the germicidal properties of the various groups were as follows:

Group	Effective	Moderately Effective	Ineffective	Total
Germicides and fungicides	6	2	2	10
Wetting agents	3	0	6	9
Surface active agents	3	0	2	5
Dispersing agents	0	4	0	4
Emulsifying agents	0	0	4	4
Detergents	0	1	1	2
Contact insecticides	0	0	1	1
Insecticidal spreading agent	0	0	1	1
Unknowns	3	0	3	6
	15	7	20	42

Of the effective and moderately effective materials, 3 are substituted phenols, 7 are quaternary ammonium compounds, 3 are phosphonium compounds, 8 are alkyl aryl sulfonates, and 1 is an alphatic sulfonate.

All of the effective sterilizing materials were non-corrosive to 18-8 stainless steel, but three were objectionably corrosive to monel metal.

The results to date indicate that, of the 42 materials investigated, three have possibilities of being equal to or better than chlorine for sterilizing dairy equipment, and some may have a place in conjunction with cleansing agents.

Improving the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller.) The only sure means of preventing the oxidation of fat in dairy products is to remove practically all of the oxygen from the container in which the product is packed and to replace it with an inert gas. Because of the difficulties involved, manufacturing procedures would be simplified if the same results could be obtained by the use of an antioxidant. During the past year the value of cacao shell and cocoa powder as antioxidants has been studied.

Sixteen different extracts of cacao shell and cocoa powder were prepared and tested, together with a number of other materials. Two accelerated tests, known as the Swift Fat Stability Test and the Incubation Test, were used, and the materials are listed in decreasing order of effectiveness in butter oil: Caffeic acid, gallic acid, nordihydroguaiaretic acid (N.D.G.A.), propyl gallate, tannic acid, tocopherol, palmetal-l-ascorbic acid, tetrachloropara-benzoquinone, and Viobin. The best antioxidant obtained from cacao products falls near the middle of this group. While the cacao antioxidant was not so effective as some of the other materials studied, it did have some advantages. For instance, it did not impart a foreign flavor to the butter oil, while caffeic acid, gallic acid, N.D.G.A., propyl gallate, tannic acid, and tocopherol, in equal amounts, gave an objectionable flavor; also, it was most effective in the presence of copper, which is significant because some dairy products contain 4 or more p.p.m. of copper when packed for storage.

The antioxidants were used only in accelerated tests, and final conclusions cannot be drawn until long keeping tests have been made on dried ice cream mix, dried milk, butter, and butter-type spreads.

Study of Packaged Ice Cream. (J. H. Frandsen.) Results of scorings this year indicate that bulk ice cream is more palatable than packaged ice cream as generally found on the market. The results are only preliminary, and further studies will be made in an effort to develop a packaged product that will be as palatable as bulk ice cream. When this is accomplished, it will probably result in a very much larger precentage of ice cream being sold in packaged form.

Packaged ice cream can be handled with less shrinkage and less labor than bulk ice cream. Machine-packaged ice cream can be kept at a lower temperature than bulk ice cream, and therefore keeps in better condition after it is sold to the consumer.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Effects of the War and Readjustments in Massachusetts Agriculture. (David Rozman.) Work on this project centered largely on investigation of undeveloped rural land areas as a possible factor in desirable land use adjustment of farming units in the post-war period. An intensive phase of this study was carried out in the towns of Uxbridge, Hubbardston, and Southwick. Further analysis was made of AAA records and other current material in determining the trend and volume of Massachusetts agricultural production.

The preliminary results of the land use factor, especially as derived from an intensive study of the towns of Uxbridge, Hubbardston, and Southwick, indicate that undeveloped areas not in farms offer considerable opportunities for possible readjustment of existing farm units. In some favorably located areas opportunities are also present for a limited number of additional farms. The limiting factors are an irregular distribution of available land, the complicated pattern of land ownership, and the cost of bringing the land into use.

The findings under this project bearing on the major factors involved in agricultural production are of continuous importance in achieving the desirable pattern of Massachusetts agriculture under wartime conditions. They are expected also to pave the way for an orderly transition to peacetime conditions and for placing agriculture in the State on a more stable basis.

In connection with this program of readjustment of Massachusetts agriculture the manuscripts prepared are: (a) 1945 Wartime Production Capacity of Massachusetts Agriculture; and (b) A Post-War Production Pattern for Massachusetts Agriculture.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and H. F. Bergman.) The storage of cranberries was continued during the 1944 season. Berries were stored at 45 degrees in a normal atmosphere and also in a controlled atmosphere where the carbon dioxide content was kept at approximately 10 percent, oxygen at 10 percent, and the balance was nitrogen. Berries similar to those stored at 45 degrees were also stored in an air-cooled screenhouse. The berries were picked and stored on September 9 but the controlled-atmosphere room was not sealed until September 11.

On September 14 the hurricane disrupted power service and service was not restored until September 25. The temperature rose to 53 degrees in the two rooms which were supposed to be kept at 45 degrees.

The storage losses as determined by screening on October 6 were as follows: 45-degree room, normal atmosphere, 4.4 percent; 45-degree room, controlled atmosphere, 2.9 percent; screenhouse, 7.1 percent. Berries stored in the controlled atmosphere had colored less than those stored in normal atmosphere. In comparing loss in the screenhouse with that in the rooms held at 45 degrees, it should be recalled that the temperature in the latter rooms actually rose to 53 degrees between September 14 and September 25.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) The poultry housing studies were continued during 1944-45 with special emphasis on ventilation and arrangement of equipment to permit a reduction in the number of square feet allowed per bird in the pen. The electric ventilation system was rebuilt so as to use a smaller duct, and the outlet from the duct increased in size to reduce drafts across the floor. The main features of circulating a relatively large volume of air across the floor and the introduction of a small amount of fresh air were retained. Windows were kept closed throughout the season, the sole intake of air being through a 6″ pipe in a pen housing 100 birds. Temperatures were kept higher than would have been possible in this uninsulated house with slot or window ventilation. Litter remained good.

In another pen, slot ventilators were baffled, which permitted placing roosts and elevated feed hoppers well toward the front of the house without fear of drafts. The new arrangement permitted increasing the number of birds until only 3 square feet of floor space per bird was allowed in place of the conventional 4 square feet. This was accomplished without sacrificing the health of the birds or loss of egg production.

Hay Drying. (C. I. Gunness, J. G. Archibald, C. H. Parsons.) Equipment was installed in one of the college barns in 1944 for curing hay partially cured in the field. A system of ducts was installed on the barn floor and air blown into these ducts, the air being forced up through the partially cured hay. About 40 tons of hay were cured, the greater portion of which was put into the barn with a moisture content of 45 percent. The hay was cured satisfactorily and indications are that this system can be used in New England with considerable success.

The trial is continued during the current season and another installation has been made for curing baled hay.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb.) Work in connection with the cooperative project with the Dow Chemical Company was continued, both at Amherst and Waltham.

Tests in different blocks of the college orchard and in nearby commercial orchards supported previous results and showed that DN-111 or D-4 properly applied were dependable to a very high degree in subduing summer outbreaks of European red mite. In one of the experimental blocks in which tests were being made of DDT as a replacement of lead arsenate, red mite apparently suffered no inconvenience from repeated applications of DDT and by early July had increased to an average of 175 mites per leaf. DN-111 in one application reduced the population to an average of 1.5 mites per leaf within 24 hours, and no serious later build-up took place.

DN-111 and D-4 applied to beach plums heavily infested with red mite reduced the mites almost to the point of extinction.

In several commercial orchards the owner applied DN-111 following standard directions and secured as satisfactory control as in our own test blocks. This supported our contention that, if the material is thoroughly applied (trees sprayed from the ground), DN-111 can be expected to give a high degree of control, and that D-4 dust will give practically as good results if sufficient time is taken to insure thorough coverage.

Trees of Wealthy, Cortland, and Baldwin varieties were given 5 applications of DN-111 plus wettable sulfur plus lead arsenate between May 20 and August 11. No injury was noted on any variety. The season of 1944 was not of a type to induce spray burn of any type so that while these tests are encouraging they need to be supported by further work in a more normal year.

Tolerance tests of DN-111 and lead arsenate and wettable sulfur were made on peaches, plums, and cherries. Two applications were made: the first, an equivalent of late shuck spray, on May 29, and a later spray on July 13. No injury was noted.

Tolerance tests of both DN-111 and D-4 were made on 10 different types of ornamentals during the period between May 31 and July 18. Considerable foliage injury was observed on several plants following the May application. Unmistakable burning, though less severe, resulted from early June application. Injury was noticeably less following late June application, and very little or no injury resulted, even on susceptible varieties, following July applications.

The scarcity of apple leafhoppers in both early and late season throughout the State made it impossible to run the tests planned against these insects.

At Waltham, dormant applications to apples having a light infestation of overwintering red mite eggs resulted in a reduction of live mites on May 16 from 170 mites per 100 spurs where no treatment was applied to 39 mites per 100 spurs following miscible oil 3.3 percent actual oil, and to 129 mites per 100 spurs following DNOC powder at the rate of 3 pounds in 100 gallons. By August 1 no significant difference in the number of mites was found, indicating that the effect of the dormant spray had been lost.

Studies of Different Forms of DDT. (A. I. Bourne and W. D. Whitcomb.) The work on DDT in its various forms was conducted in cooperation with the Crop Protection Institute, and all of the materials were furnished by the Geigy Company, Inc., New York City. Tests of DDT were made in all of the outstanding field projects and are reported under those projects, and in addition special laboratory and field tests were made on as many particular species of insect pests as possible.

Rose Chafer. In laboratory tests Gesarol A-20 and A-3 gave very promising results against rose chafer. In the first series of tests the materials were applied in a light application to grape foliage, and beetles were then placed on the leaves. In 6 days 90 percent of the beetles on dusted foliage were dead and only 50 percent on sprayed leaves. In a second test, foliage was given a heavy dusting with A-3, and 80 percent of the beetles were dead after 2 days and 90 percent at the end of 3 days. In a series in which the beetles were sprayed or dusted and then placed on grape foliage which was also sprayed or dusted, 90 percent of the sprayed beetles and all of the dusted beetles had died by the second day. In a fourth series, beetles were sprayed or dusted and placed on untreated grape foliage. After 2 days 80 percent of the dusted beetles and 74 percent of the sprayed beetles were dead, and at the end of 5 days all had died. In this time 4 percent of the untreated beetles died in the 2-day period, 2 percent more after 3 days, and 10 percent at the 5-day period.

Japanese Beetle. Gesarol A-20 spray and Gesarol A-3 dust were fully as effective against Japanese beetles as against rose chafer. The beetles seemed to be rendered inactive within a few hours after treatment and no recovery was noted. In all cases the beetles had been treated and then placed on fresh foliage.

In a comparison of DDT with other insecticides, all beetles treated with DDT spray or dust were dead by the second day, while all were alive in lots treated with cryolite spray and copper rotenone dust. In the lot treated with Lethane B-72, 20 percent of the beetles were dead after 2 days and most of the remaining beetles were more or less inactive. During this period of 2 days, only 3 percent of the untreated beetles had succumbed.

Striped Cucumber Beetle. DDT was very toxic to striped cucumber beetles. Within a short time after treatment the beetles became inactive and ceased feeding, and in 24 hours all were dead, while all beetles dusted with rotenone succumbed within 12 hours. DDT was not quite so rapid in its actual killing effects as rotenone; but since all treated beetles ceased feeding and became inactive within a few hours after treatment, from a commercial standpoint they ceased to function as pests so that the actual time of death was of secondary importance. No injury to foliage was noted in laboratory tests. The beetles appeared late in the season when the plants had made considerable growth and no injury from the treatment was observed such as was reported from tests in other states where applications were made in early season when the plants were small and very tender.

Squash Bug. This insect was relatively scarce in the vicinity of Amherst and only laboratory tests on a few specimens were possible. In each series DDT killed young-stage bugs up to and including half-grown nymphs. Later stages were quite resistant, and adult bugs seemed to be only slightly affected.

Black Scale. Gesarol A-20 at a dosage of 4 pounds to 100 gallons proved very effective in the control of black scale on gardenias. The immediate effects were very pronounced and the material showed a definite residual action which prevented reinfestation and from a commercial standpoint eliminated the pest.

Plum Curculio, Codling Moth, and Apple Maggot. Insectary poison studies at Waltham with a commercial preparation of DDT (Gesarol A-20) used at the rate of ¼, ½, ¾, and 1 pound of DDT per 100 gallons of water showed this material to be surprisingly ineffective against the plum curculio on apples. Further studies on a caged apple tree sprayed with the material corroborated the insectary studies with plum curculio, but indicated promising effectiveness against codling moth and apple maggot flies.

Flies. Experiments against adult flies were conducted mainly in the college piggery. On June 21 two pens were sprayed with a solution of 2 gallons of water and 38 cc. of Gesarol SH5, and two pens were sprayed with a solution of 2 gallons of water and 18 grams of Gesarol A-20. An immediate reduction in flies occurred. Dead flies were found on both the treated and the untreated sides. Daily inspections revealed a comparative absence of flies until June 24, when a few were found on the treated side of the piggery during a heavy rain. At the end of a week the flies were present in relatively the same number on both the treated and the untreated sides. Troughs treated with DDT remained free from flies during the experiment.

Experiments against fly larvae in infested manure were conducted. Applications were made on July 19 to 3 pens in the sheep barn. A solution of 1 pint of Gesapon-18 to 10 gallons was employed at rates of 3, 6, and 9 gallons to 27 square yards. In addition 15 square yards of fly-infested soil near the feeders were treated with the material at the rate of 1 gallon of 1 percent solution per square yard. The following day, examination revealed the presence of live larvae in all treatments, both in the sheep barn and at the piggery, indicating that DDT at the concentrations used was not effective. Subsequent examinations bore this out.

The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts. (A. I. Bourne, in cooperation with the Departments of Pomology and Plant Pathology.) The tests in 1944 included studies of the effectiveness in insect control of more accurate timing of applications, the value of nonarsenical insecticides to supplement the standard schedule, and a study of one form of DDT (Gesarol-20) as an orchard spray material.

All materials were used in combination with wettable sulfur to determine their compatibility and effectiveness in disease control. Special emphasis was laid on the emergency codling moth spray interposed between the 2d and 3d cover sprays and intended to fill the gap existing between mid-June and early July. Records were taken from the McIntosh variety. Fruit from these trees was harvested just before the hurricane of September 14–15. Scab proved to be a minor factor and was well controlled in all plots.

Although in the unsprayed check plot 66 percent of the fruit was more or less scarred by curculio, yet the spray applications timed on temperature ranges were sufficiently accurate to hold the pest in check very satisfactorily except in the plots where DDT replaced lead arsenate. DDT failed to check curculio and 35.6 percent of the fruit in this plot showed curculio damage.

Codling moth proved to be a more difficult problem. Following the standard schedule there was 15 percent injury. One application of fixed nicotine reduced codling moth injury by approximately 2 percent. Two applications of fixed nicotine, however, reduced injury by this species to 5 percent, and a modified schedule employing DX-nicotine in combination with reduced dosage of lead arsenate held codling moth injury to approximately 3 percent. An emergency application interposed between the 2d and 3d cover sprays still further reduced codling moth damage to 1.4 percent.

DDT failed to check plum curculio activity to any marked degree and allowed 10 percent codling moth damage but proved slightly superior to the standard schedule against apple maggot.

The addition of magnesium sulfate to the spray combination, to correct magnesium deficiency, caused no injury to leaves or russeting of fruit and had little or no effect upon the toxicity of the sprays to either insect pests or plant diseases.

A heavy deposit-building dust to protect fruit from late-season stings by codling moth showed definite possibilities. Codling moth damage in dusted plots was only slightly more than half that in adjoining sprayed plots. The dust also held scab successfully.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) A large second brood of European corn borer in 1943, coupled with a mild winter and very little snowfall, produced one of the heaviest carry-overs of larvae in Massachusetts in recent years. Relaxing of clean-up measures left much of the corn standing in the fields, and winter mortality was practically nil. There was every indication of a very heavy infestation for the 1944 season. Hot, dry weather throughout May evidently retarded pupation, which was very slow until the period of one or two light rains about mid-May but proceeded rapidly thereafter. However, during the period of moth activity very unfavorable weather intervened and egg laying was seriously retarded. As a result, throughout practically the entire state, the infestation of early sweet corn was not serious and was very much lighter than anticipated.

DDT spray (Gesarol A-20 at 2 pounds to 100 gallons) and dust (A-3) gave almost perfect control.

Black Leaf 155 at the rate of 2 pounds to 100 gallons was sufficiently effective to indicate that against a light infestation this dosage would give good commercial control if the application was properly timed. Black Leaf 155 at 3 pounds to 100 gallons dosage and derris (4 percent rotenone) spray at 4 pounds to 100 gallons gave better than 97 percent control. As indicated above, the infestation was too light to show any significant difference between treatments. The borer population in the unsprayed checks averaged only 1 to 2 larvae per plant.

Potato Spraying Experiments. (A. I. Bourne.) The experimental plots were planted May 9. The young plants appeared within the next 10 to 14 days and averaged 5 to 6 inches in height at the time of the first application on June 12.

During the early season (June and July) the infestation by flea beetles was comparatively light. In late July the number of beetles increased rapidly and continued high until mid-August when the infestation dwindled rapidly and very little scarring of foliage was caused thereafter. There were very few leafhoppers throughout the entire season. Comparatively little damage was caused by European corn borer larvae, and although the potatoes adjoined a plot of field corn the number of second-brood moths hiding during the day in the potato vines was not great. This was in marked contrast to 1943. No late-season damage to potato vines was noted. No serious outbreak of potato aphids occurred. An incipient attack was noted about mid-July and nicotine sulfate was included in the application on July 20. No further steps in control were necessary.

Bordeaux mixture at standard strength of 10-10-100 was applied to the east and middle plots. Calcium arsenate at the rate of 4 pounds to 100 gallons was added to the bordeaux in half of the east plot. DDT (Gesarol A-20) at 2 pounds to 100 was added in one half of the middle plot. Bordeaux at strength of 5-10-100 alone, with calcium arsenate, and with DDT was applied in the west plot. Eleven applications were made at approximately weekly intervals between June 12 and August 28. The new Friend field crop sprayer with a 6-row boom (3 nozzles per row) was used throughout the season and rendered excellent service.

The plants in plots which received the low-copper bordeaux began to ripen and die down in late August and early September. Plants in the plots which received full strength bordeaux for the most part persisted throughout September and many plants were alive and green until they were killed by the frost of October 4–5. The plants suffered considerable damage by the high wind of the hurricane on September 14–15 and from the heavy rain which accompanied it. The injury was aggravated by the period of hot, humid weather which immediately followed the hurricane.

The early ripening of plants in the plots which received the low-copper bordeaux schedule was reflected in the yield, which averaged 320 bushels per acre compared with a yield of 369 bushels per acre in the plots sprayed with standard 10-10-100 bordeaux. The plots in which calcium arsenate and DDT were added to bordeaux (standard strength) yielded approximately 20 bushels per acre more than corresponding plots which received bordeaux alone.

In the series of plots which received standard bordeaux, the addition of calcium arsenate was accompanied by a distinct and immediate reduction of nearly 50 percent in the amount of flea beetle damage. This ratio held through successive weeks. The addition of DDT did not give such noticeable reduction immediately, but showed a cumulative benefit from successive applications which resulted in marked reduction in the number of leaf punctures. Where the low-copper bordeaux alone was applied, practically the same degree of protection against flea beetle was secured as was furnished by standard strength bordeaux. The addition of calcium arsenate or DDT in these plots did not noticeably increase the degree of immediate protection although there was some evidence of beneficial cumulative effects following successive applications.

Control of Onion Thrips. (A. I. Bourne.) Application of a dinitro dust (DN-4) gave 97.5 percent reduction in thrips population but caused slight burning of the plants. Lethane (B-71) dust gave 78 percent reduction with no injury. DDT (Gesarol A-3) dust proved only moderately effective with a reduction of 44 percent. Very heavy applications greatly increased the effectiveness of Lethane and DDT dusts, in both cases giving higher than 88 percent reduction in the number of thrips, which is a very satisfactory control.

Of the sprays applied, nicotine sulfate with Pine Tar soap gave excellent results by providing an effective control of better than 97 percent. Derris powder with the addition of a wetting agent (Ultrawet) ranked very close to nicotine sulfate, causing 95 to 97 percent reduction in thrips population and furnishing very definite residual effects which prevented reinfestation. DDT (Gesarol A-20) spray alone gave 87 percent control, and when used with a wetting agent 91.4 percent control. All of the materials used as sprays proved entirely safe and caused neither immediate burn nor any retardation of growth.

Biology and Control of the Celery Plant Bug. (W. D. Whitcomb and Wm. Garland, Waltham.) The celery plant bug (*Lygus campestris* L.) was much less abundant in 1944 than in the two previous years and the infestation in the experimental plantings at Waltham was extremely light. Nevertheless, considerable "blackheart" developed in the early celery, apparently due to a frost on May 19, 1944, followed by abnormally dry weather. Although many plants on which no bugs were observed in semi-weekly observations developed "blackheart", some correlation between "blackheart" and plant bugs was indicated by the presence of 1 (first generation) or 2 (second generation) more bugs per "blackheart" plant than on normal plants. Yellow varieties of celery averaged about 2 more plant bugs per plant than green varieties; and Summer Pascal, the favorite variety in this area, appeared more resistant to plant bug infestation.

With infestations averaging about 20 plant bugs per 100 plants, 2 or 3 applications of insecticides gave excellent protection. Pyrethrum dust containing .2 percent pyrethrins with and without sulfur, and a commercial thiocyanate dust called B-71 gave perfect control after each application, and a .5 percent rotenone dust was satisfactory.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) Experimental fumigations with chlor naphthalene mixtures to recheck a few critical factors in the use of this material were completed.

Preliminary fumigations with alpha bromo naphthalene showed reasonable toxicity to the common red spider but also gave indications of plant injury. However, this material is considered sufficiently promising to warrant further investigation.

Biology and Control of the Grape Cane Girdler. (W. D. Whitcomb and Wm. E. Tomlinson, Jr., Waltham.) The grape cane girdler was naturally scarce in 1944, and the time allotted to this project was temporarily transferred to other work.

Apple Maggot Emergence. (W. D. Whitcomb.) Apple maggot flies began to emerge in the cages at Waltham in 1944 on June 14, the earliest date since the cages have been in operation. Favorable conditions permitted some of the flies to live until early October and created an unusually long period of activity for this pest.

	Cultivated Soil	Sod
First Fly Emerged	June 14	June 14
25 Percent of Flies Emerged	June 23	June 26
50 Percent of Flies Emerged	July 3	July 3
75 Percent of Flies Emerged	July 14	July 13
Last Fly Emerged	June 26	June 26
Percent of Flies Emerged	66	45

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) Dosage experiments using ¾, 1, and 1¼ gallons of spray per 100 square feet of surface area of the tree were continued with special emphasis on the effect of this factor in controlling the plum curculio in a heavy crop of apples. During the experiments 246,000 apples were examined. The results indicated that the 1¼ gallon dosage was definitely more effective and that the ¾ gallon dosage was unsatisfactory. The 1-gallon dosage was inconsistent, and suggested that the margin was so slight that the results might be affected by factors which were not measured. The influence of dosage on control of the codling moth was even more significantly in favor of the 1¼ gallon treatment.

Cryolite again proved less satisfactory than lead arsenate against the plum curculio in apples.

During the hot weather in late June and early July many dropped apples infested with plum curculio larvae were burned by the sun. Emergence of larvae from normal apples was 39.4 per 100 fruits; from one-half burned apples, 2.66 per 100 fruits; and from completely burned apples 0.20 per 100 fruits.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) Because of the war emergency it was not possible to conduct the oriental fruit moth parasite-rearing project in 1944.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) With normal heavy field infestation by the cabbage maggot, untreated plants of the Early Jersey Wakefield and Charleston Wakefield varieties again showed about 25 percent less injury, and produced 30 to 50 percent more marketable heads than Golden Acre and Super Curled Savoy varieties. Penn State Ballhead also showed considerable resistance.

Tar paper pads and 4 percent calomel–talc dust both gave more than 90 percent control, and corrosive sublimate solution 1-1280 in two applications was satisfactory with 84 percent control. Talc alone gave no protection, and reduced dosages of 2 percent calomel–talc and corrosive sublimate solution 1-2560 in two applications were unsatisfactory against a very heavy attack.

The number of eggs laid on each variety in the period May 6–31 varied from 29 to 14 per plant, with the largest number being found on Charleston Wakefield which showed the least injury, indicating that resistance results from the ability of the plant to resist injury rather than from any repellent action to the flies during oviposition.

Biology and Control of the Red Spider Mite on Greenhouse Crops. (W. D. Whitcomb, Wm. E. Tomlinson, Jr., and Wm. Garland, Waltham.) Applications of two forms of DNOCHP containing 20 and 13.3 percent of active ingredient respectively killed approximately 97 percent each of the red spider on greenhouse roses when reduced to equal amounts of DNOCHP by using 8 and 12 ounces respectively in 100 gallons of water. This indicates that a definite concentration of DNOCHP is necessary, whether applied in one heavy application or several light applications. Proprietary sprays containing naphthalene and azo-benzene both gave excellent control of red spider but caused injury to rose foliage.

A proprietary spray containing the extract of yam bean and one containing B-butoxy-b'thiocyanodiethyl ether were both inconsistent and in general gave unsatisfactory control of red spider on greenhouse roses when used according to manufacturer's directions.

Control of the Squash Vine Borer. (W. D. Whitcomb, Waltham.) Studies of the susceptibility of different genera of the family Cucurbitaceae to attack by the squash vine borer showed the *Cucurbita maxima* was most heavily infested. The varieties Blue Hubbard, Warren Turban, and Buttercup squash averaged 3.31 borer injuries per vine. Six varieties of *Cucurbita pepo*, including pumpkin, gourd, and four types of summer squash, averaged 2.23 borer injuries per vine, with the straightneck summer squash the most heavily infested. *Cucurbita moschata*, represented by the Butternut squash, was not infested and appeared to be immune.

Cucumis sativis, the cucumber; *C. melo*, the cantaloupe; and *Citrullus vulgaris*, the watermelon, also were not infested.

New Insect Pests of Importance in 1944. (W. D. Whitcomb, Waltham.) Outbreaks of the spotted tentiform leaf miner (*Lithocolletis blanchardella* Fab.) occurred in a few orchards in the Nashoba district causing serious injury to apple foliage and accentuating drouth damage. These outbreaks were located in orchards where the infestation was light in 1943. The orchards which were heavily infested in 1943 had little or no infestation in 1944. Six species of parasites were reared from *L. blanchardella*, which apparently explains the absence of the leaf miner following heavy infestations the previous year.

Spraying Log Piles to Prevent Scolytid Infestation of Elm Logs. (W. B. Becker.*) In the spring, between 10 and 21 uninfested elm logs (with bark up to 1 inch thick on xylem up to 11 inches in diameter) were scattered uniformly throughout log piles measuring 4x4x4 feet. Power sprayers were then used to direct various sprays into the piles from the ends of the logs and the top of the pile. At Springfield, a single-nozzle, adjustable-stream spray gun was used at 400 pounds pressure; at Great Barrington, a similar spray gun was used at 100 to 250 pounds pressure; and at Amherst, a six-nozzle spray boom was used with a power sprayer which gave 400 pounds pressure. *The results are based on the number of exit holes per square foot of elm bark found in the logs after late fall.* The figures following each spray mixture indicate the proportion of ingredients and the amount applied per log pile.

	Percent Prevention
At Springfield (practically all the elm scolytids were *Scolytus multistriatus*)	
Orthodichlorobenzene and No. 2 fuel oil (1-8, 20 gals.*)	100.0
Bordeaux and water (1 lb. – 5 gals., 20 gals.)	61.2
Gesarol SH5 (5% DDT in a summer spray oil) and water (1-100, 20 gals.)	78.1
At Great Barrington (*Hylurgopinus rufipes* was the only or predominant elm scolytid present)	
Gesarol SH5 and water (1-100, 35 gals.)	64.3
Orthodichlorobenzene and No. 2 fuel oil (1-8, 8 gals.)	6.3
No. 2 fuel oil alone (8 gals.)	86.0
At Amherst (*H. rufipes* was the only elm scolytid present)	
Gesarol SH5 and water (1-100, 14 gals.)	92.8
Gesarol SH5 and kerosene (1-100, 14 gals.)	93.6
Orthodichlorobenzene and No. 2 fuel oil (1-8, 16 gals.)	100.0

*Approximately 300 cc. per square foot of bark.

Spraying Log Piles to Kill Elm Scolytids. (W. B. Becker.) In midsummer, log piles of the same size used for the prevention sprays, but containing logs from which beetles were ready to emerge, were similarly sprayed with the same equipment. *The percentages given are based on the number of exit holes per brood gallery, as compared with the emergence from unsprayed logs.* The figures following each spray mixture indicate the proportion of ingredients and the amount applied per log pile.

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*The author is deeply indebted to Mr. L. Fletcher Prouty, Assistant Superintendent in the Springfield Department of Public Parks, who provided much material assistance in carrying out all the experiments in Springfield.

	Percent Control
At Springfield (*Scolytus multistriatus* outnumbered *Hylurgopinus rufipes* brood galleries by approximately 5 to 4 and 5 to 1 in the various piles)	
Orthodichlorobenzene and No. 2 fuel oil (1-8, 20 gals.)	88.5
Orthodichlorobenzene, D. I. Lestoil, and water (2.5-1-20, 20 gals.)	46.7
Gesarol SH5 (5% DDT in a summer spray oil) and water (1-100, 20 gals.)	9.3
At Great Barrington (*H. rufipes* outnumbered *S. multistriatus* brood galleries by between 10 to 1 and 3 to 1 in the various piles)	
Gesarol SH5 and water (1-100, 20 gals.)	8.6
Orthodichlorobenzene, D. I. Lestoil, and water (3-75-1.5-30, 20 gals.)	59.6
Elgetol, D. I. Lestoil, and water (1-0.5-50, 20 gals.)	74.7
At Amherst (only *H. rufipes* was present)	
Gesarol SH5 and water (1-100, 15 gals.)	0.0
Orthodichlorobenzene, D. I. Lestoil, and water (1.9-0.8-15.0, 15 gals.)	73.4
Orthodichlorobenzene and No. 2 fuel oil (1-8, 15 gals.)	100.0

Sprays to Prevent Scolytid Infestation of Individual Elm Logs. (W. B. Becker.) At Amherst, the following spray mixtures applied to the entire surface of individual elm logs (up to 9 and 17 inches in diameter with bark up to 9/16 and ¾ inch thick) just prior to beetle flight in the spring gave the indicated percentages of prevention of *Hylurgopinus rufipes* infestation *based on the number of exit holes per square foot of bark* in the late fall, as compared with unsprayed logs. The figures following each spray mixture indicate the proportion of ingredients and the amount applied per square foot of bark service.

	Percent Prevention
Creosote and kerosene, strained (1-4, 138 cc.; also 1-8, 142 cc.)	100.0
Orthodichlorobenzene and No. 2 fuel oil (1-12, 170 cc.; also 1-8, 113 cc.)	100.0
Gesarol SH5 (5% DDT in summer spray oil) and kerosene (1-200, 141 cc.; also 1-100, 136 cc.)	100.0
Kerosene alone (164 cc.)	100.0
Gesarol SH5 and water (1-100, 169 cc.)	78.4
Gesarol SH5 and water (1-200, 131 cc.)	71.7
Dowax, Gesarol SH5, and water (1184-38-3547, 145 cc.)	50.2
Dowax and water (1-3, 159 cc.)	0.0

At Springfield, the following spray mixtures were applied to the entire bark surface of individual logs (up to 7 and 11 inches in diameter with bark up to 7/16 and 3/4 inch thick at ridges) when scolytids were beginning to attack them in mid-June. The indicated percentages of prevention of scolytid infestation *are based on the number of brood galleries which became established per square foot of bark surface*, because of the preliminary nature of the experiment. *Scolytus multistriatus* was the only or predominant scolytid in the logs.

	Percent Prevention
Orthodichlorobenzene and No. 2 fuel oil (1-8, 117 cc.; also 1-12, 110 c.c)	98.3
No. 2 fuel oil alone (105 cc.)	97.7
Cuprinol (a commercial preservative used for wood, rope, etc.) alone (98 cc.)	93.0
Creosote and kerosene, strained (1-8, 84 cc.)	92.6
Creosote and kerosene, strained (1-4, 72 cc.)	90.0
Gesarol SHN20 (20% DDT in an oil) and kerosene (1-100, 94 cc.)	79.8
Creosote, D. I. Lestoil, and water (946-757-3785, 99 cc.)	75.4
Kerosene alone (98 cc.)	72.1
Gesarol A20 (20% DDT in a dry spray concentrate) and water (18 gm.-3578 cc., 76 cc.)	59.9
Dowax and water (1-3, 99 cc.)	57.4
Creosote, Aresklene (a commercial emulsifier), and water (946-47-3785, 88 cc.)	52.7
Kerosene alone (19 cc.)	50.6
Ammonium sulfamate (a weed killer) and water (454 gm.-3785 cc., 90 cc.)	48.6
Orthodichlorobenzene, D. I. Lestoil, and water (473-142-3785, 86 cc.)	19.4
Gesarol SH5 and water (1-100, 67 cc.)	12.2
Zinc chloride and water (189 gm.-3785 cc., 128 cc.)	5.4
Gesarol SHN20 and kerosene (1-100, 19 cc.)	0.0

Sprays to Kill Scolytids Breeding in Individual Elm Logs. (W. B. Becker.) At Amherst, the following spray mixtures were applied to the entire bark surface of individual elm logs (up to 12 and 21 inches in diameter with bark up to 5/8 and 3/4 inch thick) and gave the indicated percentages of control based on the number of exit holes per brood gallery in the late fall. The figures in parentheses following each spray mixture indicate the proportion of ingredients and the amount applied per square foot of bark surface.

	Percent Control
Orthodichlorobenzene and No. 2 fuel oil (1-8, 135 cc.)	99.9
Creosote and kerosene (1-4, 119 cc.)	97.6
Kerosene alone (113 cc.)	91.1
Orthodichlorobenzene D. I. Lestoil, and water (1-0.3-8, 166 cc.)	80.7

The Prevention of Elm Scolytid Infestation by Solar Heat. (W. B. Becker.) At Amherst, freshly cut elm logs lying in a north-south direction in the sun were rolled 180 degrees of their circumference (1) every week and (2) every three weeks during the early season oviposition period (May 18 June 23). After the latter date none were disturbed until after the beetle's active season had ended. Compared with the number of exit holes per square foot of bark in unturned check logs in the sun, 99.7 percent control resulted from weekly turning of logs between 3 and 13 inches in diameter, with bark up to 7/16 inch thick. Turning every three weeks gave 93.5 percent control in logs between 4 and 21 inches in diameter, with bark up to ½ inch thick. *Hylurgopinus rufipes* was the only elm scolytid found in the logs.

At Westfield, similar experiments conducted between June 10 and July 15 with logs up to 7 inches in diameter having bark up to 5/8 inch thick gave 100 percent control with both treatments. *H. rufipes* was much more abundant than *Scolytus multistriatus* in the logs.

At both localities the beetle galleries reached a more advanced stage in the logs which were turned every three weeks than in those turned every week. The larger logs usually had more brood galleries than those of small diameter, those less than 5 inches in diameter having none at all even among the unturned check logs.

Combined Use of Sprays and Solar Heat on Individual Elm Logs to Prevent Elm Scolytid Infestation. (W. B. Becker.) At Amherst, slightly more than the upper half of freshly cut, uninfested elm logs, 3 to 14 inches in diameter, with bark up to 1 inch thick, and lying in a north-south position in the sun, were sprayed in the spring with creosote and kerosene (strained), 1 to 4 by volume, and then rolled over so the sprayed side was turned down. Compared with unsprayed logs similarly placed, 99.8 percent prevention resulted, based on the number of exit holes found per square foot of bark after the beetle's active season had ended. The only area infested was a small patch of bark on the under side of one log, which was not covered by the spray. *Hylurgopinus rufipes* was the only elm scolytid present.

At Westfield, 100 percent control resulted from similar treatment of elm logs up to 7 inches in diameter, with bark up to 3/8 inch thick. *H. rufipes* was much more abundant than *Scolytus multistriatus* in the control logs.

Some logs less than 10 inches in diameter, which were similarly treated at Amherst on July 2, 1943, and which were left exposed to beetle attack through 1944, did not become infested. However, since unsprayed check logs which lay in the sun did not become infested either, it may be assumed that these logs were too seasoned for scolytid infestation by the spring of 1944.

Effect of Dry Storage on Hylurgopinus rufipes Infestation of Elm Logs. (W. B. Becker.) At Amherst, winter-cut logs were piled in three dry structures before *H. rufipes* oviposition began in the spring. These structures were two different barns, the large doors of which were often open, and the basement of a building, the small door of which was usually closed. The logs used were about 18 inches long, between 2 and 8 inches in diameter, and had bark up to ½ inch thick.

Compared with the number of exit holes per square foot in logs piled outdoors in the shade, 96.4 and 99.5 percent control resulted from storing the logs in the barns, and 99.6 percent from storing the logs in the basement. In addition to the possibility of the beetles flying to the logs after they are stored, it must be remembered that *H. rufipes* commonly spends the winter on the trunks of live elm trees and so may be brought indoors on logs cut during that time. The dryness indoors, of course, is unfavorable to the development of those beetles which do become established in the logs.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) The Field Station strains of snapdragons continue to show a high degree of resistance to rust disease in the field and greenhouse. Thirty selections made of resistant lines yielded only seven showing rust, and these showed relatively little rust, being from 10 to 25 percent susceptible. First-generation hybrids of the rust-resistant strains have been much more vigorous than inbred lines. These hybrid types cannot be used for seed production but do give more uniform bloom, flower color, and plant growth. Since at present this type of breeding is practiced on a limited scale with florist's crops, it offers an interesting field of study.

A large flowered, pink snapdragon developed from the Field Station strains was named Helen Tobin, in honor of the wife of the Governor of Massachusetts. Responsibility for distribution of seed of this new variety of winter-flowering snapdragon has been assumed by the Northeastern Regional Unit of the Society of American Florists.

Disease Resistance and Heredity of Carnations. (Harold E. White, Waltham.) Carnation seedling plants have been selected from crosses made between disease-resistant and susceptible varieties of carnations. These plants are to be tested for disease resistance, and promising material will be used for further breeding. Pollination work under glass in winter has not given a satisfactory set of seed on many crosses that have been attempted.

Cultural Treatments of Anemone coronaria. (Harold E. White, Waltham.) Anemone tubers soaked 24 hours in warm water, or sprouted in sand in the propagation house, grew much more rapidly than tubers planted dry in the soil. Flower production was greater on treated tubers than on untreated.

Division of the tubers into too small units resulted in decreased flower production. Better flower production and more plant growth were obtained from fertilizer containing nitrogen than from phosphate or potash alone. Anemones made excellent growth and flowered as abundantly in gravel as in soil.

Effect of Fungicidal Hormones on Carnation and Geranium Cuttings. (Harold E. White, Waltham.) Cuttings of eight varieties of carnations treated with Hormodin Power No. 1 and Stimroot powder showed no difference in degree of rooting. Cuttings treated with Fermate, used dry and as a liquid solution, showed no differences in rooting response. The Stimroot powder contains Spergon, a fungicide, combined with a rooting hormone; while Fermate is a straight fungicidal material. Since cutting-rot disease was not prevalent in the propagation bench, little can be said as to the respective merits of these materials.

Geranium cuttings were treated with Hormodin powder Nos. 1, 2, 3, Telluric rooting powder No. 66, and Rootone. The Hormodin powders No. 2 and 3 contain more rooting chemicals than No. 1, hence are recommended for use on woody plants more difficult to root. The purpose in using the stronger hormone powders was to determine whether over-abundance of callus tissue, or injury brought about by too much hormone powder, might cause greater losses from rot diseases. The percentages of cuttings lost from rot were as follows: Hormodin 1, 50 percent; Hormodin 2, 47 percent; Hormodin 3, 76 percent; no treatment, 56 percent. Results with the other hormone powders were comparable to those with Hormodin 1. The results of these tests indicate that too much root hormone powder, or a highly concentrated powder, may cause cuttings to be more susceptible to rot diseases.

The treatment of geranium cuttings with copper carbonate and malachite green did not reduce cutting-rot losses in the propagation bed.

DEPARTMENT OF FOOD TECHNOLOGY

F. P. Griffiths in Charge

The Nutritive Value of Mushrooms. (W. B. Esselen, Jr., A. Filios, W. H. Fitzpatrick, and E. Weir.) Quantitative data on the amino acid content of mushrooms (*Agaricus campestris*), obtained by microbiological assay methods, showed that they contain approximately 203 mg. of argenine, 458 mg. of isoleucine, 242 mg. of leucine, 144 mg. of methionine, 5 mg. of tryptophane, and 326 mg. of valine per 100 grams on a fresh weight basis.

The total nitrogen content of mushrooms was about 0.5 percent, of which 63 percent was in the form of protein. Purified mushroom protein had a nitrogen content of 11.79 percent. It was concluded that fresh mushrooms contain approximately 2.67 percent of protein. While they are not comparable with such foods as meat and fish as a source of protein, they do compare favorably with some fresh vegetables.

Commercially canned mushrooms (18 different samples) were found to be good sources of the B-vitamins, averaging 0.249 mg. of riboflavin, 1.8 mg. of nicotinic acid, and 0.83 mg. of calcium pantothenate per 100 grams of total can content. The biotin content averaged 6.57 micrograms per 100 grams of can contents.

In the canning of mushrooms, blanching in hot water caused little or no loss of the B-vitamins, but a significant loss occurred during processing. When canned mushrooms were stored for one year, there was some loss of riboflavin but little or no loss of nicotinic acid, calcium pantothenate, and biotin. When fresh mushrooms were cooked by home canning methods, 90.4 percent of the riboflavin, 87.4 percent of the nicotinic acid, 86.4 percent of the calcium pantothenate, and 50 percent of the biotin were retained.

Glass Container Research. (W. B. Esselen, Jr., J. E. W. McConnell, J. J. Powers, A. Filios, C. Dubord, and N. Guggenberg.) Added d-iso ascorbic acid did not affect the flavor of asparagus or grape juice canned by commercial methods. The addition of 20 mg. of d-iso ascorbic acid per 100 ml. to bottled grape juice which had been fortified with 50 mg. of l-ascorbic acid per 100 ml.

completely protected the added l-ascorbic acid from oxidation. If bottled grape juice is fortified with ascorbic acid so that it is equal to citrus juice as a source of vitamin C, the ascorbic acid is well retained during storage. Added ascorbic acid is quite stable in apple juice and cranberry juice during processing.

Ascorbic acid has been shown to function as an antioxidant in processed fruits and fruit juices because increased concentrations of it shifted oxidation reactions away from flavor and color substances and more toward the ascorbic acid in accordance with the Law of Mass Action. Redox potential measurements indicate that ascorbic acids also function as antioxidants because they set up low, highly poised potentials in foods. The poising capacity of a processed food has been found to be of greater relative importance than its actual redox potential in determining resistance to oxidative deterioration.

Storage at 40°F. in the dark significantly retards the development of rancidity in corn and cottonseed oils. A good quality oil can be stored for one year at room temperature without serious deterioration if protected from the light. Amber glass containers are very effective in protecting edible oils against the effects of diffused daylight. Metal containers protect these oils against the effect of light but a slight off-flavor, due apparently to the container, develops during storage. To date no entirely satisfactory antioxidants have been found which are effective in retarding the development of rancidity in edible liquid oils. Many of those which retard rancidity impart an objectionable off-flavor to the oil. The initial quality of an oil is of major importance in governing its keeping quality.

From an investigation of bacterial load on fresh vegetables it would appear that potential home-canning spoilage bacteria such as spore-forming anaerobes and thermophiles are present in relatively small numbers except in occasional samples, and that their numbers are subject to wide variation. Washing and blanching prior to canning are an effective means of reducing the bacterial content of vegetables. The number of putrefactive anaerobes encountered was very low and may account for the fact that in some sections of the country the boiling water bath method of processing has been used successfully by many people.

In experimental packs of orange juice the addition of small amounts of d-iso ascorbic acid enhanced the retention of the fresh fruit flavor during processing and storage.

During the past two years complaints have been received from home canners that the jar rings they used imparted an off-flavor to home-canned foods. This problem has been investigated in cooperation with the War Food Administration and the jar ring industry. Two promising test methods have been developed by which it is possible to determine the tendency of jar rings, made from different types of rubber and other constituents, to impart off-flavors to foods. These methods have been of value in ascertaining the source of off-flavors in jar rings, and may also be of value in maintaining quality control in their manufacture.

Fifteen different varieties of peaches, provided by the Pomology Department, were canned according to home-canning techniques. The canned products were evaluated as to quality after storage for six months. Ideal, Valiant, and Ambergem varieties were graded as very good; Red Rose, Champion, New Jersey 116, Golden East, Golden Glow, Golden Globe, Hale Haven, Summer Crest, and Vedette as good; and New Jersey 66, Delicious, and Radiance, as fair.

Tests were also conducted to determine the effect of different processing methods on the quality of home-canned peaches. The boiling water bath method and processing at 0 to 1 pound steam pressure in a pressure canner gave the best product. Processing at 5 or 10 pounds steam pressure for a short time in a pressure canner resulted in a product inferior to that obtained by the former methods.

The color of home-canned beets was influenced by the variety of the beet used. It is recommended that, for a home-canned product of good red color, the Detroit Red or Detroit Dark Red variety be used.

In controlled processing studies with green beans those processed in a pressure canner were superior in color, flavor, and texture to similar beans processed in a boiling water bath.

Home Freezing — Fruit and Vegetable Variety Studies. (W. B. Esselen, Jr., J. J. Powers, K. Lawler, F. P. Griffiths, and J. E. W. McConnell.) Through the cooperation of the Olericulture and Pomology Departments tests were made to study the suitability of different varieties of Massachusetts-grown peaches and vegetables for home freezing. The products were frozen by accepted techniques and after storage for six months were judged for quality by a tasting panel, on a basis of flavor, texture, and color. Of 15 varieties of peaches Vedette, Valiant, Golden Globe, Red Rose, Ideal, Radiance, and New Jersey 116 were considered very good; Hale Haven, New Jersey 66, Ambergem, Summer Crest, Golden East, Champion, Golden Glow, and Delicious were considered good. On a basis of flavor, Summer Crest, Vedette, and Ideal were preferred.

Seven varieties of green peppers (King of the North, California Wonder, World Beater, Harris Early Grand, Harris Wonder, Waltham Beauty, and Charter Oak) were frozen, both raw and blanched. All varieties yielded a satisfactory frozen product.

Eight varieties of sweet corn were frozen, both on the cob and as whole-kernel corn. When frozen on the cob Seneca Dawn, Span Cross, Early Golden, and Golden Cross Bantam were very good; North Star, Narcross, Sugar and Gold, and Seneca 60 were considered good. In general the cut whole-kernel corn yielded a better product than that frozen on the cob. When cut off the cob in the whole kernel form Early Golden was considered to be excellent; Seneca Dawn, Span Cross, North Star, Golden Cross Bantam, and Narcross were graded very good; and Sugar and Gold and Seneca 60 were considered good.

Twenty different strains and varieties of carrots as represented by Morse's Bunching, Chantenay, Nantes, Long Change, Oxheart, Hutchinson, Danvers Half Long, and Imperator were all satisfactory when frozen.

Tests with summer squash indicated that this vegetable when frozen had only a fair flavor and would not be acceptable to many people.

Fishery By-Products. (F. P. Griffiths.) It was found that the common female sculpin or blow fish could be well utilized as a source of eggs for caviar. Caviar so prepared was very tasty and of excellent quality. About 10 percent of the weight of the fish is roe. The tail portion of the fish may be skinned and makes a very edible food. By utilizing both the roe and the tail, the sculpin should have commercial possibilities.

Venting Community Cannery-Type Retorts. (W. H. Fitzpatrick, J. E. W. McConnell, and W. B. Esselen, Jr.) (Cooperative project with the School Lunch and Distribution Branch of the Office of Supply (CCC), W.F.A.) The so-called No. 2 and No. 3 size retorts used in community canneries are intermediate in size between the pressure canners used in home canning and the large retorts used in commercial canneries. Studies were carried out to determine proper venting procedures for No. 2 and No. 3 retorts. Over 200 venting and heat distribution tests were made on No. 2 size self-heating and steam retorts and a No. 3 size steam retort. The effect of different retort loads of cans and jars on venting requirements was also studied. On a basis of the data obtained, recommendations for venting community cannery retorts have been made to the War Food Administration.

Red Squill Research. (L. R. Parkinson and F. P. Griffiths.) Laboratory tests have confirmed the fact that red squill (a raticide) of low toxicity may be fortified with a concentrate containing the toxic principle of red squill in order to provide a satisfactory commercial product. Such red squill preparations should prove to be very effective for rodent control.

Vitamin D Milk Investigations. (L. R. Parkinson and F. P. Griffiths.) Studies have been continued on the fortification of fluid milk with vitamin D. During the past year 173 samples have been assayed and all but five contained the designated amount of vitamin D. Data obtained during the past three years indicate that the present methods of fortification are reliable and that the producers of vitamin D milk are making every effort to provide a standardized product.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Julia O. Holmes in Charge

A study of Methods for Determination of Riboflavin. (A. W. Wertz, B. V. McKey, K. O. Esselen, and J. O. Holmes.) In a fluorophotometric assay of the riboflavin content of foods, conducted last year, it was discovered that the recommended procedures were not entirely satisfactory with highly pigmented foods such as kale and baked beans. A comparison was therefore made of the biological, microbiological, and fluorophotometric methods currently used in assays for this vitamin. Four foods were studied: beans, milk, kale, and fish. Good agreement between certain modifications of these three methods was found when applied to milk, kale, and mackerel. The microbiological method appeared to give low values for baked beans.

On the basis of the good agreement between the three types of assay procedures, it was concluded that one currently recommended step in the fluorophotometric procedure was responsible for the introduction of a marked error in assay values; namely, the manner in which the comparison was made between the fluorescence of the food extracts and the standardized solution of riboflavin. In every instance in which the fluorescence of the standard was determined apart from the food extract, erroneously low values were obtained; in those instances in which the riboflavin standard was added to the extract, values were obtained which agreed well with those obtained by the biological method and, with the exception of those for beans, with the microbiological method. The conclusion therefore has been drawn that it is imperative that the standardized solution of riboflavin be added to the food extract.

Both the fluorophotometric and the microbiological procedures contained manipulations found to be unnecessary when applied to the foods studied. The enzymatic digestion of the foods appeared to be unnecessary. In the microbiological procedure, the removal of fat from the extracts and the addition of an irradiated extract to the blank and to the standard curve did not affect the values for riboflavin. In the fluorophotometric method the use of florosil on which to absorb the riboflavin conferred no advantages. This was true also for the procedure involving the oxidation of the extracts with $KMnO_4$.

The riboflavin content of frozen baked beans, blanched kale, and steamed fish did not decrease over a six-month period.

Relationship Between Calcification of Eggshell and Carbonic Anhydrase Activity. (Marie S. Gutowska and U. C. Pozzani.) Previous study in this laboratory has shown a direct relationship between the activity of carbonic anhydrase in the shell gland of the hen and the calcification of the eggshell. The administration of sulfanilamide, a strong inhibitor of this enzyme, resulted in an inhibition of eggshell calcification. The present report presents a study of the effect of inhibitors other than sulfanilamide on the action of carbonic anhydrase on eggshell calcification; namely NaCNS, $KMnO_4$, and $MnSO_4$.

Rhode Island Reds of known laying capacity were held in confined laying batteries. The chemicals were administered either subcutaneously or orally. Meldrum and Roughton's manometric method was used for determining carbonic anhydrase activity in the blood and the shell gland. The quality of the eggshell calcification was determined by the eggshell breaking strength.

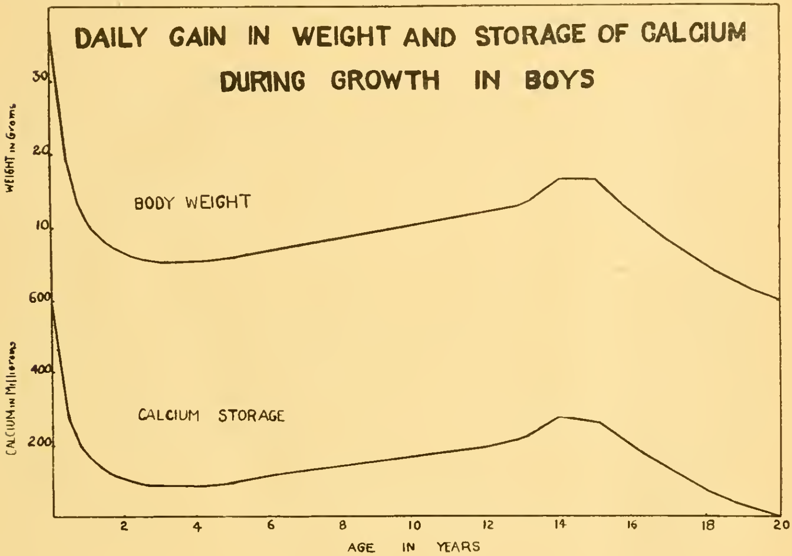
The administration of NaCNS was followed by (a) an inhibition in carbonic anhydrase activity of both blood and eggshell gland, and (b) a lowering in quality of the eggshell. These changes were similar to those observed following sulfanilamide administration. In constrast, $KMnO_4$, although a good in-vitro inhibitor of carbonic anhydrase, had little effect when administered to hens. The administration of $MnSO_4$, either orally or subcutaneously, was followed by an increase in the carbonic anhydrase activity. Finally, a direct relationship was found between carbonic anhydrase activity and well-known seasonal variations in breaking strength of the eggshell.

These studies provide further evidence that the formation of the eggshell is controlled by carbonic anhydrase. It is suggested that this enzyme acts as a catalyst in the shell gland for the decomposition of carbonic acid, thus allowing a greater number of carbonate ions to be released. These carbonate ions unite with calcium and are then precipitated as calcium carbonate, thus forming the eggshell.

The Requirement for Calcium During Growth. (Julia O. Holmes.) Since nutrition literature carries conflicting statements concerning the calcium requirement of children, an attempt has been made to clarify the problem. No data could be found concerning the rate at which calcium is deposited in the human body during growth. Neither could reliable information be found concerning the weight of the skeleton at different ages, an important consideration since 99 percent of the total body calcium is located in the skeleton. A search was therefore made for such information for farm and laboratory animals. Suitable data were found only for Shropshire sheep and albino rats, and included gains in weight of the body and of the skeleton, and increases in calcium content of the body at different ages. When the gains for various intervals during the growth period were expressed as percentages of the total gains made between birth and the attainment of maturity, the percentage gains in calcium were identical with the percentage gains in weight.

Since this relationship between percentage gains in calcium and in body weight was found in two strictly dissimilar types of animals, the assumption was made that the same relationship would occur in all species, including man. If this assumption is valid, it follows, for example, that the child who has accomplished 11 percent of his total growth at the end of the first year has also stored 11 percent of his total calcium. On this basis, the approximate daily storage of calcium which might be expected in boys reared under satisfactory dietary conditions was calculated and is shown in the accompanying chart, together with their daily gains in weight. The storage of calcium by girls is not significantly different during the early years of life. Their pubertal spurt of growth, however, starts earlier than in boys, i.e., at 11 or 12 years of age; and the entire process of growth is accomplished earlier than in boys, probably by the 17th year.

In converting these values for calcium storage into terms of dietary calcium, it must be recognized that infants utilize only about 35 percent of the calcium they eat; preschool children, 20 percent; and older children, 25 percent. The following conclusions can be drawn: (a) during the first six months of life, infants need more calcium than they receive under current dietary practices; (b) the child between two and five years of age would have his calcium needs satisfied by approximately one cupful of milk in addition to an otherwise adequate diet and (c) at the peak of the pubertal spurt the child would need approximately three cupfuls of milk daily. Children previously undernourished in respect to calcium would need somewhat more calcium to bring their bones to a stage of physiological calcification.



DEPARTMENT OF HORTICULTURE
R. A. Van Meter in Charge

Factors Influencing the Hardiness of Evergreens. (C. J. Gilgut, Waltham.) The winter of 1944-45 was one in which there should have been little or no winter injury to ornamental woody plants. There was abundant rain in the fall, there was plenty of snow on the ground, and the temperature did not go excessively low. Yet there was as much winter injury as in the winter of 1943-44 which was preceded by an unusually dry summer and fall and during which there was almost no snow—conditions commonly stated as the cause of winter injury.

Although varying with individual plants, the injury in 1944–45, as in 1943–44, was no more extensive on plants grown with fertilizers to produce an abundant soft growth late in the season than on plants grown without fertilizer to produce a moderate amount of growth with ample opportunity for it to harden before winter.

That winter injury is not avoided when plants are grown slowly without fertilizers is shown well in a block of 128 arbor vitae (*Thuja occidentalis globosa*) set out 5 years ago. The plants received no other treatment than regular cultivation to control weeds, and the amount of current seasonal growth was moderate. They experienced a wet previous summer and fall, a dry previous summer and fall, a winter with almost no snow, a winter with plenty of snow, mild winter temperatures, and severe cold winter temperatures. Records of the winter injury on each plant were made each spring, and it was found that there was no correlation between slow growth and winter injury. Each plant has shown injury at least once, and some have shown it after each winter. In all cases injury appeared in the spring, usually in April and two or more weeks after prolonged strong winds.

To determine whether wax sprays would prevent winter injury, several plants of Globe arbor vitae were sprayed late in the fall with Dowax 1 part to 4 parts of water. None of the plants showed winter injury, although all plants had been injured in previous winters.

Study of Herbaceous Perennial Material. (C. J. Gilgut, Waltham.) In the study of cultural requirements and winter hardiness of herbaceous perennial plants, no mulch was used during the winter. There was a good cover of snow and perhaps for this reason fewer plants were lost from winterkilling than during the previous winter when there was no snow and a hay mulch was put on after the ground froze.

Bearded iris when divided and transplanted about one month after flowering suffered less seriously from winter injury and produced better flowers the following year than when transplanted later in the season.

Professional gardeners, landscape men, nurserymen, and the general public continue to visit the gardens regularly to become better acquainted with the newer and better garden plants. Of the thirty-six new acquisitions placed in the gardens for test, many have not been introduced or disseminated to the gardening public. Numerous requests, by visitors and through the mail, for information on varieties, cultural requirements, fertilizers, and suppression of insect pests and fungous troubles were answered during the season.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Weed Control in Fields of Carrots and Parsnips. (W. H. Lachman.) It has recently been found that certain oils sprayed on fields of carrots and parsnips would destroy weeds without harming these crops. Rather extensive experiments at the college as well as many cooperative tests by vegetable growers throughout the State have indicated the value of this method for controlling weeds.

Oils which, in general, pass the specifications for "Stoddard Solvent" have given good weed control with no deleterious results. Some of the materials which pass these specifications are: Mineral Spirits, Naphtha No. 52, Sovasol No. 5, Stoddard Solvent, Sun Spirits and Varsol No. 2. Another oil, Sovasol No. 75, was found to be a good selective weed killer when mixed with two parts of white kerosene. These oils are used in industry as paint thinners, for dry-cleaning clothes, and as solvents. They seem to be highly selective for members of the Umbelliferae family such as carrots, parsnips, celery, and parsley. The leaves of celery and parsley, however, seem to be more sensitive and under some conditions are severely burned by these oils. The sprays completely destroyed young beet and turnip plants.

Best results were obtained if the oil was applied when the weeds were small and succulent. On a clear, warm day the weeds were often wilted within a half hour after spraying and were dead the next day. Almost all of the common weeds encountered have been completely controlled, with the exception of ragweed, which is particularly resistant to the effects of the oil. Some of the carrot leaves developed a lighter color after spraying, but this disappeared in about a week with no other noticeable effect on the plants. There was no indication of a toxic residue in the soil when these oils were applied at the rate of 80 to 120 gallons per acre, which effected good weed control. The oil costs $.15 to $.20 per gallon, depending on the locality, so that on the average the material to spray an acre costs about $20.00. At the present wage scales it costs approximately $40.00 to hand weed an acre of carrots.

It is desirable to apply the oil as a flat, fan-shaped spray since this gives much more uniform distribution than a cone spray. The Skinner greenhouse irrigation nozzle ST50 was found to be well adapted to delivering the desired type spray. The oil seemed to give best results when applied at about 100 pounds pressure. Higher pressures developed a drifting mist type of spray that was objectionable.

It is suggested that this method of weed control be tried on a small scale at first much the same as with other new developments.

Other details of this method have been published in Massachusetts State College Extension Special Circular 120, and a report also appears in the Proceedings of the American Society for Horticultural Science, Vol. 45.

The Carotene Content of Carrots. (W. H. Lachman.) Ten varieties and strains of carrots were grown during 1944 and were analyzed for carotene during successive stages of maturity as well as after storage in a warm room for three weeks and in cold storage at 32°F. for five months. From the results of the analyses it was rather apparent that the carotene content of carrots increased as the root matured. Carotene appeared to be directly correlated with a deep orange coloration in both the core and cortex of the carrot. Expressed as thousands of Vitamin A Rat Units per pound, the carotene content of the mature carrots ranged from 51.5 to 98.0; from 76.0 to 156.0 after 3 weeks at room temperature; and from 56.5 to 100.0 after 5 months at 32°F. It is noteworthy that the carotene in the carrots was relatively indestructible under various storage conditions, even showing an apparent increase which was no doubt due to moisture loss through respiration and evaporation.

Two bunches of California-grown Long Imperator carrots, purchased on the open market early in April, 1945, were found to have a carotene content of 62.0 thousand Vitamin A Rat Units per pound. These were bunch carrots and rather small. A similar sample, purchased in early May, 1944, analyzed 98.0 thousand units. These carrots were a little larger, which probably accounts for the greater carotene content.

Vegetable Breeding. (W. H. Lachman.) A large number of sweet corn inbreds has been produced by inbreeding open-pollinated varieties. One of the most promising of these, Massachusetts No. 8, is being increased for production by a large seed grower in Idaho. Massachusetts 8 is an excellent inbred line. It has many of the characteristics of Purdue 39 but is about a week earlier, has a larger ear, stiffer stalk, and excellent seed quality.

Number A-13 tomato, a selection from the cross Allred by Rutgers has been sent out for trial in several states and has performed very well in Maine. It has good color and yields well over a long season, but the fruit has a tendency to be soft. This tomato has been back-crossed to Rutgers in an effort to recover more size and solidity.

A number of sweet pepper selections have been made which have excellent type and are particularly resistant to tobacco mosaic. Further testing is necessary to evaluate these selections.

Asparagus Investigations. (Robert E. Young, Waltham.) In a breeding project which has as its objective the improvement of asparagus both as to yield and uniformity, individual plant performance was recorded for 450 plants, representing five selected lines and one commercial strain. As evidence that increases in yield can be obtained by selection, the two highest producing strains in 1944, Nos. 1 and 4, each produced 1.3 pounds of asparagus per plant, compared with 0.76 pound per plant from Mary Washington grown from the best commercial seed. These averages are based on plots containing 75 to 98 plants each. The five-year average for these three plots in pounds of asparagus produced per plant is: No. 1, 1.18; No. 4, 1.22; and Mary Washington, 0.62.

There is a variation from year to year in the average number of spears the plants produced and also in the weight. This appears to be of a biennial nature, being up one year and down the next. Whether there is a correlation between the variation in yield and the weather cannot be accurately determined until the yield records for a greater number of years are available.

There is considerable variation in the production of individual plants in all of the strains. The plants were divided into four groups on the basis of the number of spears produced in 1944: A, 1 to 10 spears; B, 11 to 20; C, 21 to 30; and D, 31 and up. Strain 1 had almost equal distribution of plants in each group; Strain 4 had 9 percent in A, 38 percent in D, and the rest divided equally between B and C; while Mary Washington had 46 percent in the low-producing group A, 32 percent in B, 12 percent in C, and only 10 percent in the high-producing group D. Selection of parent plants on the basis of yield has, in this second generation, greatly reduced the number of plants which produced only a few stalks, and approximately doubled the yield.

For the second consecutive year, there was no rust. There was very little rust from 1937 through 1940, a moderate infection in 1941, and a severe outbreak of the disease in 1942, followed by these last two years when there was none. Weather appears to be the determining factor.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding work has been conducted with broccoli, greenhouse cucumber, celery, rutabaga, New York type lettuce, tomato, carrot, and Butternut squash. While progress has been made in the development of strains of broccoli, carrot, and celery better adapted for local use, it is insufficient to justify detailed discussion.

Trellis Tomato. While Trellis No. 22 and Waltham Forcing tomatoes bred at the Waltham Field Station have wide usage as trellis tomatoes, both are somewhat inferior in table quality. With the desire to retain the cultural and market characteristics of Trellis No. 22 but to improve table quality, crosses were made several years ago with Marglobe, Rutgers, Michigan State Forcing, and Baltimore. Several selections from these crosses, now in the fifth and sixth generation were tested for yield and market adaptability. Earliness is one of the important characters of a good trellis tomato. Two selections, one a cross between Early Trellis and Marglobe, and the other a cross between Early Rutgers and Early Trellis, produced more early fruit than Trellis No. 22, as well as a greater total yield. Trellis No. 22 had a yield of 10.5 pounds per plant; the Marglobe cross 11.0; and the Early Rutgers cross 11.7 pounds. There was no significant difference between the three strains in percentage of No. 1 fruits or in percentage of cracked fruits. Although it has not been possible to keep all the table quality of Rutgers and Marglobe in the two selections, they are an improvement over Trellis No. 22. If the increase in yield is maintained for another year, samples of seed of these selections will be distributed to growers for further testing.

During the harvest season it was noted that one selection, a cross between Trellis No. 22 and Baltimore, did not crack. During the early part of the picking season it had only 1.8 percent cracked fruits as compared to 33 percent for Trellis No. 22. (In this case, a crack is regarded as any split in the skin regardless of size.) The crackless fruit was found to have air pockets surrounding the seed cavity which may offer some explanation as to why cracking does or does not occur.

Greenhouse Cucumber. Seed of two hybrid cucumbers that were reported last year as out-yielding their parent lines 25 percent was distributed to growers for trial, along with two of the inbred lines. Either the hybrids or the strains, or both, were tried in about twenty-five different greenhouses.

Hybrid No. 11 was considered the best by the largest number of growers. Hybrid No. 10 and strain No. 1 produced well for some. Strain No. 2 was too short to be a satisfactory greenhouse cucumber. One grower who kept very accurate records reported that hybrid No. 11 produced 18 percent more cucumbers during the month of March than his own strain.

The problem of producing hybrid cucumber seed for the growers is under consideration, and experiments are being conducted.

Samples of seed of hybrids No. 10 and 11 and strain No. 1 are available to greenhouse growers for further trial and testing.

Rutabaga or Cape Turnip. Bristol White rutabaga, bred for the growers in Bristol County, Massachusetts, has been found by growers in other sections of the country to have wide adaptation. It produced a satisfactory crop in dry weather when other varieties produced woody, inedible roots. Further testing of this variety has been delayed by a seed crop failure resulting from a mosaic disease. However, samples will be available for distribution in 1946.

There has been very little opportunity to have Waltham Yellow rutabaga tested because of the failure of the seed crop.

The characteristics of both of these varieties were given in last year's Annual Report.

New York Type Lettuce (In Cooperation with U. S. Bureau of Plant Industry). The name Waltham Imperial has been given to a selection taken from material supplied by the cooperating agency. This selection is somewhat similar to Great Lakes and was taken from the same breeding material. Two years' trials indicate that under local conditions Waltham Imperial will produce a greater percentage of marketable heads than Great Lakes. In the 1944 spring trials, this strain produced 97 percent marketable heads as compared to 81 percent for Great Lakes.

Since lettuce is so greatly influenced by weather conditions, it is necessary to make tests and comparisons for several years to determine whether the strain is sufficiently broad in its adaptability to produce marketable heads each year regardless of the weather. As soon as a supply of seed can be produced, samples will be distributed to growers for trial.

Other strains and selections were tested and some seemed to be well adapted for summer use. One strain, No. 13, produced 92 percent marketable heads as compared to 46 percent for Waltham Imperial and 45 percent for Great Lakes.

Greenhouse Lettuce. Trials of Waltham Early Forcing lettuce in growers' greenhouses indicate that it is not so good as Bel-May. Some of its characteristics were improvements but others more than offset them. Breeding work with greenhouse lettuce is being discontinued except to maintain a supply of stock seed of the Bel-May.

Butternut Squash. The Butternut squash has become popular on the Boston market during the past few years. The origin of this squash is somewhat obscure. Seed production has been in the hands of local growers. There has been a marked lack of uniformity in this squash, and an increasing desire on the part of growers for a better and more uniform strain. To determine whether any of the strains now in use are superior to others, 18 different strains were secured from both seedsmen and growers for trial. The yield varied from 269 to 562 boxes per acre, the percentage of cracked fruit from 10 to 31, and the percentage of crooked fruit from 1 to 37. Crooked fruits are very objectionable because they are difficult to pack in the bushel box which is the market package for this squash.

Almost all of the strains contained at least one good characteristic but none seemed to combine them all. Breeding work has been started to produce a true high-yielding Butternut squash.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The hurricane of September, 1944, caused damage to the trees on the dwarfing rootstocks. Those on Malling IV and IX suffered most. Those on Malling V and on the standard and near standard stocks showed no injury.

Some trees broke off at the point of union between stock and scion, a few broke below the union, and some were tipped, varying from little to complete prostration. The proportion of trees ruined was small, but large enough with some stock-scion combinations to make the use of them doubtful. We had considered Malling IV to be one of the best semi-dwarfing rootstocks, but this experience suggests its greatest weakness. Most varieties on this rootstock grow rapidly and bear early in life, but they have poor anchorage. Trees on Malling IX are usually poorly anchored and the stock, though large in diameter, is brittle so that the trees tip or the rootstock breaks when subjected to severe winds. It is a good rootstock for the home garden, making low-headed trees which bear at the age of two to four years. Home garden trees are usually located where they have some protection from high winds, and some support such as stakes made from used iron pipe is easily provided.

This experience should not discourage the use of semi-dwarf apple trees, but such orchards should not be planted on poor soils or on wind-swept sites. They should be headed low and pruned rather more severely than standard trees in order to keep them low headed. Perhaps they should be budded 8 or 10 inches high so that they can be planted deeper in the orchard. In this experimental orchard, all the trees were treated alike for purposes of comparison.

The crops of both 1944 and 1945 were much reduced by spring frosts. The amount of bloom is the best indication of potential early production of trees on dwarfing and semi-dwarfing rootstocks. It is evident that the usual habits of varieties appear when they are grown on these stocks but with some modification. Trees on Malling VIII and IX may be expected to bear at the age of two years for Golden Delicious, and four or five years for Northern Spy. Production of some naturally early-bearing varieties as Oldenburg and Wagener seems to be hastened less than that of Golden Delicious. Trees on the semi-dwarfing stocks seem to begin to bear from two to four years earlier, according to variety, than trees growing on seedling stocks.

Lethal Incompatibilities Between Clonal Stocks and Varieties of Apples. (J. K. Shaw and L. Southwick.) The varieties and strains growing on the clonal stocks Spy 227 are now in their third year from the bud. Only three varieties of common apples are growing normally. They are Shotwell Delicious, Paragon (Iowa strain), and strain G of McIntosh. Yates, "Paragon L", and McIntosh strain 12 are alive but making little or no new growth. Golden Delicious trees are nearly all dead, but a few have weak shoots from the base of the tree. Those now completely dead are Delicious, Starking, Richared, Stayman, Stamared, Blaxtayman, Winesap, Arkansas Black, Arkansas, Mammoth Black Twig (Iowa Strain) Turley, Blackmack, and McIntosh strains 1, 8, 39, 45, and R. The ornamental crabs, *Malus atrosanguinea*, *floribunda*, *hupehensis*, *sargenti*, *toringoides*, and Bechtel crab are all growing normally. McIntosh R, Stayman, and Winesap, which failed when budded on Spy 227, are still growing vigorously on the two clonally propagated rootstocks Spy 227-2 and Spy 227-12 which came from seedlings of Spy 227. Further studies planned to throw light on the nature of this lethal incompatibility are being carried on. A second paper reporting on this project appears in Volume 45 of the Proceedings of the American Society for Horticultural Science.

Study of the Bud Sports of the McIntosh Apple. (J. K. Shaw and L. Southwick.) None of the strains reputed to be distinctly striped have yet fruited. Several strains reputed to be uniformly red have fruited, also one random selection considered to be an ordinary McIntosh. This seems to be slightly inferior in color to the strains selected for high color. Those fruiting are growing on very dwarfing stocks while none of the striped strains are on very dwarfing stocks. Spring frosts in 1944 and 1945 have interfered with cropping in this orchard. Further observations are needed before any positive evaluation of these red strains can be made. Doubtless the distinctly striped strains should be avoided.

The orchard of seven strains on three clonal stocks, now in its fourth year of growth, shows no significant differences in vigor of these strains. The present differences in size of the trees seem to be due to environmental conditions and the size of the trees when set.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) Since there was a crop in 1944, further data were collected on two lots of seedling peaches and three were selected as worthy of further trial.

In the spring of 1945, some seedlings from the northern Caucasus region, reported to be very hardy in bud, were set in an orchard to compare their hardiness with that of Elberta and Greensboro.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) This project has been under way for many years and the basis for identifying practically all varieties of apple, pear, plum, and cherry, originating as seedlings, has been established. The apple variety Van Buren, believed to be a bud sport of Oldenburg, is the only variety of such origin that can be distinguished from its parent. The constant appearance of new varieties makes the continuance of this work desirable. Some progress with peaches has been made, but it is doubtful whether it is possible to distinguish some varieties in the nursery. However, most of the nursery mixtures can be detected and many thousands of misnamed peach trees have been eliminated from the trade.

The practice of examining nurseries for trueness-to-name enters its 25th year in 1945. This work is now carried on by members of the College staff under the name of the Massachusetts Trueness-to-Name Inspection Service, sponsored by the Massachusetts Fruit Growers' Association.

A bulletin on pear varieties has been published.

Nature of Winter Hardiness in the Raspberry. (J. S. Bailey, A. P. French, and R. A. Van Meter.) Five canes each of the varieties Marcy, Washington, Taylor, Milton, Chief, and Latham were brought into the greenhouse at about weekly intervals from November 7 to December 21, 1944, for forcing.

Among the canes brought in November 7, those of the varieties Marcy, Washington, and Milton started in 37 to 39 days, while some of the canes of the varieties Latham, Chief, and Taylor never did start. By November 15 all varieties could be forced to grow, but the first three varieties started more readily than the others. By December 1, all varieties except Chief started on the avearge in from 17 to 22 days. Therefore, (1) these varieties are divided into two groups, one of which can be started into growth more readily than the other; and (2) for all but Chief the rest period was over by December 1 and for Chief by December 21.

A Wheatstone bridge apparatus was set up to test the resistance of raspberry canes in the hope of finding a method to tell in the field whether canes are alive or dead. When live canes were tested and then killed by freezing in a cold room, the resistance was less after freezing. As canes dried out the resistance increased. Canes brought in from the field during the winter and tested had either a normal or a very high resistance. The latter indicates that the canes had either been killed by drying or had dried out between the time they were killed and the time the resistance tests were made.

Controlled-Atmosphere Storage of Apples. (L. Southwick and O. C. Roberts, in cooperation with the Department of Engineering.) The 300-bushel controlled-atmosphere room was filled on September 28, 1944, and opened on March 7, 1945. Instead of maintaining the levels of oxygen and carbon dioxide at 2 and 5 percent respectively, necessitating the use of a special air scrubbing apparatus, it was decided to try the English system of 10 and 11 percent, which can be maintained in a tight room by the proper use of ventilation. Actually the carbon dioxide level ranged mostly between 9 and 11 percent. The sum of the carbon dioxide and oxygen always equalled about 21 percent which is the percentage of oxygen in air. The temperature was maintained at 40°F.

The main test was with McIntosh from 25 individual trees. Check lots were stored in the usual way around 32°F. Average firmness of the flesh as measured by a pressure tester on March 6 showed no consistent differences, indicating that the levels of oxygen and carbon dioxide used were not so effective in prolonging storage life of McIntosh apples as the levels previously used; namely, 2 and 5 percent. Furthermore, scald was a real factor varying from very light to very severe, and averaging about 10 percent. Apples from some trees showed from 50 to 75 percent visible scald on removal from the controlled-atmosphere room. This was probably due to the relatively high carbon dioxide concentration. Only occasional scald was found on McIntosh in the regular storage.

Cortland apples from two orchards softened significantly less in the controlled-atmosphere room than in regular cold storage, but scald was much worse.

The possibility of positive scald control by air purification is under study.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) This experiment has now a continuous record for 24 years. Certain changes of treatment of some of the seven 10-tree plots of McIntosh apple trees have been made from time to time. In addition to the comparison between sod-nitrogen and cultivation without fertilizer, the effect of hay mulch and of the addition of phosphorus and potash to nitrogen have been studied.

The sod vs. cultivation question was soon answered. Cultivation without nitrogen does not maintain production. This conclusion has been supported by practical experience. No successful Massachusetts fruit grower now attempts to grow apples without nitrogenous fertilizers.

The application of a hay mulch with no other fertilizer to one of the cultivation plots more than doubled the yield over a six-year period. This practice is increasing in Massachusetts orchards.

The application of nitrate of soda only to a cultivation plot quickly increased yields, but they have not been well maintained.

The answer to the question of the value of phosphorus and potash added to nitrogen is not so clear. There is some indication that when applied to grass sod, yields are maintained better. We dare not say that it has been profitable.

The problem of orchard fertilization is a complicated one and present knowledge is sadly inadequate. We can confidently recommend the use of nitrogen in practically all orchards. In general, the heavier the application (within reason), the greater the yields. But high nitrogen delays maturity, and fruit color may be poor. We can with equal confidence recommend the use of magnesium, potash, and boron when deficiency symptoms appear. But may not a lack of these and perhaps other elements interfere with maximum yields in the absence of clearly defined deficiency symptoms?

Studies of Varieties of Fruits. (J. K. Shaw and Staff.) Among the new peach varieties are a number which look promising. Since most of the peaches described below have fruited only one year, the following evaluations are tentative.

No variety earlier than **Oriole** appears worthy of consideration. Most growers do not like Oriole because of its small size and not too attractive appearance. It has been recommended chiefly because of its bud hardiness.

Fisher, which ripens with Oriole, may be a substitute although its performance in 1944 was not impressive. It is a sport of Valiant and is supposed to be like that variety in every way except ripening date. The fruit was medium to large, round, fairly attractive and yellow-fleshed, but had a tendency to cling. The flesh was a bit stringy and soft when ripe. There was a marked tendency for the fruit to soften at the tip.

While **Golden Jubilee** is an excellent peach, it softens a little too rapidly to suit most commercial growers. There are two possibilities in its season.

Raritan Rose, a cross between J. H. Hale and Cumberland from New Jersey, is a medium to large, well-colored, attractive, white-fleshed, freestone peach. The quality is good, but the flesh tends to be soft and slightly stringy and bruises easily when ripe. It is not impressive but is worth watching if one wants a white-fleshed peach in this season.

Red Haven, a cross between Halehaven and Kalhaven from Michigan, is a large, round, very highly colored, very attractive, yellow-fleshed freestone. Since only a few peaches were borne, the size was probably larger than normal. The flesh was firm and the skin thick and tough so that it should fulfill its reputation of being a good shipper. The quality, while not all that could be desired, was fair to good. The tree is said to be hardy and the fruit buds much hardier than Elberta but not so hardy as those of South Haven or Rochester. It is worthy of trial.

Between Golden Jubilee and Halehaven there are three varieties worthy of attention. **Red Rose** is a large, round, high quality, white-fleshed, freestone. It looks very promising as a white-flesh peach ripening just before Halehaven. The fruit is well covered with red and, therefore, very attractive. It softens slowly and should be a good shipper. **Fireglow,** formerly New Jersey No. 71, is a truly handsome peach of unusually high quality where it can be grown. Unfortunately, the fruit buds are so tender that they will not survive even an ordinary winter. It is not recommended for Massachusetts. **Golden Globe** is a large, round, very attractive, yellow-fleshed freestone of excellent quality. Unfortunately the fruit buds are rather tender to cold. It probably cannot be successfully grown in Massachusetts except in unusually favorable locations.

Sunhigh, a cross between J. H. Hale and 40 CS from New Jersey, is a large, oval, yellow-fleshed freestone. Although the flesh is a bit stringy and a little soft, the quality is good. It ripened with Halehaven in 1944. The trees are still small and the crop was very light.

Triogem, a cross between J. H. Hale and Marigold from New Jersey, is a large, yellow-fleshed freestone of very good quality. It is attractive and has firm flesh and thick, tough skin. It is reported to be a good shipper. It ripened with Halehaven in 1944. It is said to require good growing conditions and considerable thinning, to ripen slowly, and to hang to the tree well. It is well worth a trial.

Between Halehaven and Belle of Georgia, there are four varieties worth considering. **Goldeneast,** a cross between Elberta and New Jersey No. 38 (an Elberta-Greensboro cross), is a large, round, attractive, yellow-fleshed peach of high quality. It is usually a freestone, although it tends to cling slightly in some seasons. It ripens with Halehaven or a little later. However, it is another one of those peaches with fruit buds not hardy enough for best results in Masaschusetts. **Colora,** which ripens with Goldeneast and Halehaven, is a very attractive, yellow-fleshed peach of fair quality and size. It tends to soften rapidly and, therefore, is probably not a good shipping peach. Its outstanding quality for Massachusetts is fruit bud hardiness. One grower in Massachusetts had a few peaches after the winter of 1942-43, when other varieties were frozen out. In spite of its weaknesses, it seems worthy of further trial because of its apparent hardiness. **Pacemaker,** a cross between J. H. Hale and Marigold from New Jersey, ripened three days after Goldeneast in 1944. The fruit is large, round, firm, attractive, but not as highly colored as some, usually freestone with a slight tendency to cling at times. Quality is good to excellent. The trees are said to be semi-dwarf like J. H. Hale, and the flowers are self-sterile. It deserves further trial. **Summercrest,** a cross between Hale and Cumberland from New Jersey, ripened just after Pacemaker, five or six days ahead of Belle of Georgia. The fruit is large, oval, firm fleshed, and fairly attractive, although the color is not all that could be desired, especially if grown on rich soils or given much nitrogen. It is said to color up much better on thin soils or those low in nitrogen. A thick tough skin together with the firm flesh should make it a good shipper. It is worthy of trial.

Polly ripened in 1944 between Summercrest and Belle of Georgia. It is a white-fleshed freestone of very good quality with very soft flesh. It is almost a duplicate of the old Champion. Although it is supposed to be exceptionally hardy in bud, it has not been outstanding in this respect at Amherst. For anyone who wants a white-fleshed peach at this season, a few trees might be considered, but it is much too soft to ship.

White Hale, an open-pollinated seedling of J. H. Hale, is one of a growing list of patented peaches. It is a large, round, attractive, white-fleshed, freestone with considerable red around the pit. It resembles J. H. Hale considerably except in flesh color and in having self-fertile flowers. Quality is good but not best. It seems to soften a little too rapidly for a good commercial sort. Ripened with Elberta in 1944.

Sungold is a medium to large, round to oval, attractive, yellow-fleshed freestone, of high quality. The skin is thick and tough so that it should be a good shipper. It ripens with Elberta. The tree is rather small and dwarfish like Hale. It is said to be very hardy and, therefore, seems worthy of further trial.

Fertile Hale, a whole tree sport of J. H. Hale, is another patented peach. It is a large, round, yellow-fleshed, freestone ripening with Elberta and J. H. Hale. It is only fair in quality and appearance, and resembles Elberta type more than J. H. Hale. Its value is doubtful.

Afterglow, a cross between J. H. Hale and New Jersey No. 27116, which ripens a few days after Elberta, is a large, round to oval, firm, yellow-fleshed freestone, with skin medium tough and thick so that it should be a fairly good shipping peach. The flavor while not the best is better than Elberta. It is not so highly colored as some, but is fairly attractive. It deserves further trial.

Blueberry Culture. (J. S. Bailey.) Although there were no extremely low temperatures during the winter of 1944-45, what appeared to be winter injury was very severe in the spring of 1945. However, the appearance of many apothecia of the mummy berry disease indicated a very heavy infection and suggested that much of what looked like winter injury might be due to the ravages of this disease. Accordingly, an experiment to control it with fermate was started in cooperation with Dr. Sproston of the Botany Department. Although it is now evident that the first spray was not applied early enough, there was some reduction of the primary infection of twigs and blossoms. It is too early to tell how effective fermate will be in preventing fruit infection.

A scale insect, probably a *Lecanium* sp., appeared on some bushes. Application of D289 spray at the rate of 1 quart per 100 gallons on March 29, 1945, when the buds had nearly reached the delayed dormant stage, reduced the scale by at least 80 percent.

In another part of the planting, blueberry bud mite was found. DN 111 was effective in controlling the mites but caused injury to the leaves and spotting of the fruit.

Nutrition of the High-Bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) Because of very severe winter injury during the winter of 1943–44, the crop on the manure plots was exceedingly light. Amount of winter injury was not affected by manurial treatment. Some plants are making much poorer growth than others, but this seems to be the result of the type of soil profile. Most of the field is underlaid by a layer of compact, fine, gray sand into which the blueberry roots seldom penetrate. Where this compact layer is less than six inches from the surface, the plants do not grow well.

To test the effect of potassium on the appearance of chlorosis, a number of rooted cuttings were planted in 1-gallon crocks in the greenhouse. The soil was from a section of the field where chlorosis had appeared and was treated with varying amounts of K_2SO_4. No chlorosis has appeared, even in the untreated soil.

Preharvest Dropping of Apples. (L. Southwick.) Tests were made on Wealthy and McIntosh to determine the comparative effectiveness of sprays and dusts containing higher percentages of active chemicals than "standard." With Wealthy, there was a good correlation between spray or dust concentrations and drop control. For example, in one test, treatments and percentages of preharvest drop were as follows: Check, 36; standard spray, 18; triple concentration spray, 8; standard dust, 16; double concentration dust, 12; triple concentration dust, 4.

With McIntosh, the September 14–15 hurricane wind terminated the tests too early for best results. However, in many cases, control of drop was better with the stronger sprays and dusts. Since the wind broke many spurs, the "hormone" applications were not effective in reducing drop during the hurricane.

The data show benefits from stronger sprays and dusts, but whether the benefits would warrant the increased cost of material is not proven. In any case, with McIntosh and Wealthy, it would seem unwise to use less than standard amounts of commercial materials; in many cases, increased concentrations are justifiable on the basis of insurance alone.

A small test on Duchess showed good results with lower than standard concentrations. This variety is much more easily influenced by "hormone" drop control applications than many varieties including McIntosh.

Plans for using a promising, newly exploited chemical in drop-control tests are underway. It is very possible that more effective materials than naphthalene acetic acid will be found.

Beach Plum Culture. (J. S. Bailey.) This project was concluded and the results published in Experiment Station Bulletin 422, "The Beach Plum in Massachusetts."

Control of the Peach Tree Borer. (J. S. Bailey.) Paradichlorobenzene, ethylene dichloride, and propylene dichloride were applied to peach trees according to standard directions for each. There were so few borers even in the untreated trees, that no indication of their relative effectiveness for borer control was obtained. It is worth noting that none of these materials properly applied caused any injury to the trees.

Magnesium Deficiency in Massachusetts Apple Orchards. (L. Southwick.) The inclusion of 20 pounds of Epsom salts per 100 gallons of spray solution in 3 early-season applications was rather effective in preventing the appearance of magnesium deficiency leaf scorch in the year of application. This treatment seems especially valuable for trees which may be slow in responding to soil applications of magnesium materials. As a temporary measure for controlling scorch, it has a definite place, particularly in mature orchards.

Soil applications of Epsom salts and kieserite were beneficial in young, mulched blocks; but one application of dolomite, kieserite, or Epsom salts was rather ineffective in a seriously deficient bearing orchard under sod culture. The application of commercial magnesium oxide (92 percent MgO) appeared to result in greater increases of magnesium in apple leaves on young trees than the use of Epsom salts applied in similar amounts by weight. Results with magnesium oxide on older trees have not been obtained. Commercial dolomite (magnesium limestone) has seemed to be less beneficial than other materials, even when used in relatively large amounts.

Although some time may elapse before applications become effective, the use of magnesium lime is recommended in most orchards where magnesium deficiency symptoms have appeared. Its use in other orchards is suggested as a means of preventing the deficiency. Prevention is possible and is preferable to allowing the trouble to appear and then trying to correct it. A report of several field experiments will be published in Volume 46 of the Proceedings of the American Society for Horticultural Science.

Thinning Apples with Caustic Sprays. (J. K. Shaw.) Attempts to thin apples in 1944 by spraying with Elgetol at blooming time were partially successful. The trees receiving a second application and those receiving the stronger concentration required less thinning. The apple bloom in 1945 was light, and most of the trees sprayed in 1944 failed to blossom at all. Two or three that had received the heavier sprays had a light bloom, but the sprays were not generally successful in causing annual cropping.

Experiments in 1945 were interfered with by the freeze of April 23. Naphthalene acetic acid sprays applied at concentrations of 10, 20, and 30 p.p.m. apparently reduced set in all cases. Effectiveness seemed to depend more on variety than on concentration. Wealthy and Baldwin were thinned less than Melba and Early McIntosh. Spur leaves seemed to show some dwarfing injury and this also seemed to depend more on variety than on concentration, Melba showing the most injury. This limited experience gives some hope that this material has value as a blossom thinning spray.

Killing Poison Ivy. (L. Southwick.) Following two yearly applications of ammonium sulfamate to poison ivy under apple trees, there is only slight indication of recovery (July 1). If the ivy makes any growth the year following treatment, experience seems to show that it will continue to grow and spread. In short, treatment is needed until there is no recovery. Probably one pound of the chemical per gallon of water is best. Other promising materials are now being developed and further experimental tests are under way.

Chemical Control of Weed Grasses. (L. Southwick.) In the effort to subdue grass growth around the bases of young apple trees in sod, an application of ammonium sulfamate was made on a quiet, hot, humid day in August 1944, to an area about 5–6 feet in diameter. One pound of chemical was used in one gallon of water and a small amount of a special wetting agent was included. A fairly drenching application was made. The grass was killed and showed very little recovery up to July 1, 1945. Apparently no injury to the trees resulted even though the spray got on the trunk bark. This method may prove to be a good substitute for cultivation or hand hoeing around young trees.

A similar test of this material in May 1945 on the sod strip along a row of blueberries resulted in severe damage to the bearing blueberry bushes. Within 2 or 3 days the foliage began to take on a reddish hue and it now appears that the bushes may be killed. Probably the shallowness of the blueberry root system was a factor. This experience shows the necessity for careful testing before toxic chemicals are used in the commercial or home fruit planting.

Further work on weed and grass control is under way with several promising materials.

DEPARTMENT OF POULTRY HUSBANDRY

F. P. Jeffrey in Charge

Broodiness in Poultry. (F. A. Hays.) The major objective is to develop a line of Rhode Island Reds that never exhibits the broody instinct. The mode of inheritance of broodiness is rather well understood, but there are several obstacles yet to be overcome. The majority of the females that carry a broody inheritance exhibit the instinct in the first laying year; yet there are some individuals that fail to display broody behavior even in two or three years of laying that will, if retained longer, become broody. Degree of broodiness is governed by inherited factors. The problem of testing for deferred broodiness and of breed-testing all males is the chief concern at present.

The generation hatched in 1941 consisted of 55 females, one of which exhibited broodiness in the first laying year. The generation hatched in 1942 (106 females) exhibited no broodiness the first year. The generation hatched in 1943, made up of 79 females, actually disclosed four broody individuals—a result which would be expected to occur only when breeding females are not fully tested for deferred broodiness and when breeding males are inadequately progeny tested. The 1944 generation includes 67 females now being tested.

Effectiveness of Selective Breeding to Reduce Mortality. (Regional Poultry Research Laboratory and Departments of Veterinary Science and Poultry Husbandry, Massachusetts Agricultural Experiment Station cooperating.) Results of this project for eight generations hatched from 1935 to 1942 were published in Bulletin 420.

To produce the generations hatched in 1943, 1944, and 1945, the plan of breeding has been changed. A low mortality line has been reproduced from yearling males and females within the line so that inbreeding has been necessary. A high mortality line has been reproduced from young males and females within the line and inbreeding has been practiced. The sole basis of selection in both lines has been the mortality rate. Results thus far suggest that selective breeding may be effective in producing two lines that differ significantly in mortality rates to the age of 18 months.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) In Bulletin 423 it was shown that at least sixteen different factors may affect egg production. These factors are in part environmental, but probably in greater part are governed by inheritance. Among the most important new characters are spring, summer, and fall intensity. Of considerable importance also are spring and summer pause duration. Special attention is now being given to the inheritance phase of spring, summer, and fall intensity.

The primary sex ratio in chickens has been studied for the first time and evidence of a 50-50 sex ratio reported.

A line of birds carrying only autosomal gene E′ for early sexual maturity has been developed. Such females attain sexual maturity at from 190 to 200 days of age. When sex-linked gene E was present with gene E′, the mean age at sexual maturity was reduced to 170-175 days. When neither gene for early sexual maturity was present, the age at sexual maturity ranged from 200 to 300 days.

A Study of Fertility Cycles in Males. (F. A. Hays.) Results reported for the hatching season of 1944 suggest that sex hormones may have some value in stimulating males that are at least 36 months old to active spermatogenesis. They had no value for younger males. This test was repeated in 1945 using a higher dosage of sex hormone and more artificial illumination. Results were entirely negative in this second test and fertility stood at the same level in hormone-treated, artifically lighted, and control pens.

A Genetic Analysis of Rhode Island Red Color. (F. A. Hays.) Colorimetric studies on feather pigment from three generations indicate that dense pigmentation in darker colored birds is due to several recessive genes. Further study is being given to this phase of the problem.

Secondary and Adult Sex Ratio in Relation to Hatchability. (F. A. Hays.) High and low hatchability lines were started in the spring of 1945. A complete record of sex is being secured on all dead embryos from the ninth day on and upon all chicks up to the adult stage of sexual maturity.

A Study of Egg Characters of the Domestic Fowl. (F. P. Jeffrey.) Nine hundred and sixteen pedigreed R. I. Red pullets from 161 dams and 22 sires have been classified as to egg weight, degree of shell color, egg shape, percentage egg shell, condition of firm albumen, shade of shell color, and incidence of blood spots, meat spots, blemished yolk, and fishy odor. Correlation analyses will be run to determine whether any significant relationships exist between any of these ten characters. Each character will be tested for heritability on the basis of sire progenies.

Methods of Feeding. (John H. Vondell.) Eight pens of R. I. Red pullets were fed as follows: four pens were hopper fed (free choice) mash, whole corn, oats, and wheat; two pens were hopper fed mash and hand fed scratch feed; and two pens were fed complete all mash. The feeding methods were compared for the following factors: egg production, mortality, egg weight, body weight, feed consumption per bird, feed to produce a dozen eggs, protein intake, and costs and returns. The test ran from December 1 to September 1.

Average egg production varied less than 4 percent for the three methods, and egg weight less than 1 percent. Mortality averaged 19 percent for the hopper-fed pens, 17 percent for the scratch and mash, and 13 percent for the all-mash. The scratch and mash ration seemed to maintain body weight best, with the all-mash ration poorest. Feed consumption ran 71.27 pounds per bird for the all-mash, 75.81 for the hopper-fed, and 79.05 for the scratch and mash. The hopper-fed birds required 6.39 pounds of feed per dozen eggs, the all-mash 6.47 pounds, and the scratch and mash 6.61 pounds. The protein intake averaged 14.08 percent for the hopper-fed birds, 16.28 percent for the scratch and mash, and 16.68 percent for the all-mash. Net return per bird over feed cost was $2.77 for the hopper-fed, $2.58 for the scratch and mash, and $2.38 for the all-mash.

The test is being continued.

Comparison of Four Strains of Broiler Chicks. (John H. Vondell.) Four strains of commercial broiler chicks were kept under identical conditions and grown through 13 weeks. One strain proved vastly superior in growth, feed efficiency, and dressed grade. The return above feed cost for the four strains was $72.93, $86.39, $78.99, and $106.05.

Poultry Housing Projects. A. (C. I. Gunness and W. C. Sanctuary.) The non-insulated pen previously described (Bulletin 417:67) produced favorable results in terms of litter condition, ceiling condition, and general welfare of birds. This test was not complicated this past winter by water coming through foundations during heavy rains. Adequate drainage prevented the trouble.

B. (W. C. Sanctuary.) Of the two pens under comparison, one (No. 28) was especially arranged to increase housing capacity. The nests were on the rear wall, the pits (roosting quarters), water fount, and hoppers were elevated to give more floor space, and the rear ventilators were near the floor. The other pen (No. 27) had the usual placement of equipment, with floor pit and hoppers on the floor and the rear ventilators (of the same area as those in pen 28) as high as the ceiling would permit. The birds were allowed only three square feet of floor space per bird in each pen.

Both pens were equipped with the baffled window ventilators, and no change in ventilation adjustments was made for the second winter. With no addition of litter after early November, because none was to be had, little building up of litter was possible. The moisture content of the litter became as high as 41 percent, with some caking of the surface. The air was drier in these pens (75 percent humidity) than in other pens which were less crowded.

To June 9, 1945, the birds in pen 28 had laid 8 eggs more per bird than those in pen 27, and the mortality was 3 less than in pen 27. The preceding year, with no crowding, both pens laid practically the same.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1944–45 season, a record number of flocks (529) and samples (975,041) have been tested. The percentage of reactors detected among chickens was 0.12. It is encouraging to note that progress in eradication is being made, as is indicated by the fact that 93 percent of all birds tested are in 100 percent tested, non-reacting flocks.

Furthermore, there was a considerable increase in turkeys tested during the past season, due in large measure to the recent marked expansion in the turkey industry. Unfortunately, the pullorum status in turkey flocks in Massachusetts is not so encouraging as it is in chickens. However, this situation may be improved by working in closer cooperation with the flock owners and through more effective education regarding pullorum disease eradication and prevention.

It has been extremely difficult to meet the testing demand during the past year. Most of the flocks, however, were tested without serious delay. This was made possible by the willingness of the testing personnel to put forth extra effort in the collection and testing of the samples.

A detailed report of the 1944–45 testing season has been published in Control Series Bulletin 124.

2. *Diagnostic Service.* A total of 3801 specimens was received during 1944 in 716 consignments, of which 360 were delivered in person. The specimens were classified as follows:– 3221 chickens, 451 turkeys, 23 quail, 22 fish, 21 ducks, 13 rabbits, 12 bovine semen, 8 foxes, 7 swine, 6 guinea pigs, 3 each of canine feces and geese, and 1 each of the following: canary, canine, feline sputum, goat, goat feces, horse meat, ovine semen, pheasant, pigeon, porcine semen, and sheep.

Coccidiosis (121), tumors (70), infectious bronchitis (49), fowl paralysis (36), internal parasites (32), pullorum disease (31), and fowl cholera (29) were the disease disturbances encountered most frequently. The tumors were classified on the basis of gross examination as follows: 26 lymphocytoma, 14 myelocytoma, 9 hemangioma, 8 embryonal nephroma, 3 fibrosarcoma, 2 each of carcinoma and heart tumor, and 1 each of chondrosarcoma, hematoma, leiomyoma, and myxoma.

The tumors identified as hemangioma represent an interesting problem which is of consequence in some flocks. One owner reported a loss of 25 out of 200 pullets between the ages of five and eight months. Sporadic cases only are noted in most of the cases directed to our attention. Affected birds show a small raised opening in the skin which bleeds recurrently. The site of bleeding has been observed on various parts of the body, including the feet, legs, breast, and head of different birds. Afflicted birds usually die within a month from loss of blood. In some cases there is metastasis of the tumor to the liver, spleen, kidneys, and other internal organs. It is possible to salvage a bird by excising the tumor in the skin if metastasis has not occurred.

The incidence of fowl cholera was greater than in any previous year and infection was detected on 19 new premises. Fowl typhoid was observed much more frequently than in any year since 1939 and occurred in widely separated places within the State. One case of avian tuberculosis was identified. No paratyphoid infection in chickens was brought to the attention of the laboratory. There has been an increase in the incidence of avitaminosis A during the past two years and a dermatitis syndrome believed to be due to deficiency of pantothenic acid and biotin has been observed more frequently.

Additional field observations have been made on a disease disturbance in chicks caused by exposure to coal-tar creosote oil, which was reported last year. It appears probable that strong coal-tar disinfectants, so-called gas house tar, and kerosene improperly used may cause the same type of injury.

The 451 turkeys were received in 84 consignments which represents the largest number ever received at the laboratory in one year. Coccidiosis, enterohepatitis, pullorum disease, and paratyphoid were the diseases encountered most frequently. An examination of the records for the past ten years reveals that diseases which were unidentified or were directed to the attention of the laboratory only infrequently at the beginning of the period are now of major importance to the turkey industry. A list of such diseases includes coccidiosis, hexamitiasis, infectious sinusitis, moniliasis, paratyphoid infection, pullorum disease, swine erysipelas, trichomoniasis, ulcerative enteritis, and so-called unknown disease (blue comb).

Two cases each of fowl cholera and fowl typhoid were identified in turkeys during the year. A considerable number of cases revealed heavy infestations in the lower digestive tract with motile protozoa which were identified as trichomonads. The observations suggest that these protozoa are pathogenic for turkeys and in a number of cases it has appeared that they were responsible for diarrhea, retarded growth, and mortality in poults. The infections with trichomonads are sometimes combined with coccidiosis and hexamitiasis, but frequently the trichomonads appear to be the principal cause of disease outbreaks. Microorganisms apparently belonging to the aerobic actinomycetes group were recovered from two outbreaks of respiratory disease in turkeys.

3. *Flock Mortality Studies.* From the Experiment Station flock hatched in the spring of 1943, 368 morbid and dead birds have been examined—227 females and 141 males. Cannibalism (56), reproductive disorders (50), tumors and leukemia (46), fowl paralysis (21), and kidney disorders (17) were the conditions most frequently encountered among the females. Cannibalism (81), bacterial and mycotic diseases, principally staphylococcosis, (17), and kidney disorders (12) accounted for 70 percent of the diagnoses among the males. The tumorous conditions in the population were identified on the basis of gross examination as 17 lymphocytoma, 8 leiomyoma, 5 each carcinoma and embryonal nephroma, 4 each myelocytoma and unidentified, 3 hemangioma, 2 leukemia, and 1 each cyst-adenoma and neurogenic sarcoma. The majority of cases identified tentatively as fowl paralysis failed to show gross lesions. Diagnoses of cannibalism and reproductive disorders among the females were most frequent during a period of six months, which began about three months after production started.

Erysipelothrix rhusiopathiae was identified in one seven-months-old male. The liver and spleen were slightly swollen and the heart muscle showed pale areas.

4. *Infectious Bronchitis* During 1944, 232 flocks representing approximately 400,000 birds were enrolled in the infectious bronchitis control program. These flocks were located in Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, and Plymouth counties. The procedure of the program was much the same as in 1943, except that the service was placed on a fee basis.

The results on the whole were satisfactory although in a few instances respiratory symptoms developed following the recovery from the infectious bronchitis inoculation. The cause of the disturbance was not definitely identified. It appeared that in some of these cases the infection was either an atypical form of infectious bronchitis or some other respiratory infection which has not been identified up to the present.

In some flocks complications resulted from the fact that birds of an undesirable age were inoculated. Also the condition of the flock and the season of the year had a definite influence on the results. The most satisfactory results are obtained when the birds are 10 – 14 weeks of age, in good health, and inoculated on range in June, July, and August when the weather is apt to be favorable.

This control program is in need of many refinements. Work is in progress to develop an immunizing procedure which will eliminate the possible hazard of dissemination.

5. *Farm Department Brucellosis Control and Eradication.* The laboratory tested 369 bovine and 33 porcine blood samples by the standard tube agglutination method during the 1944 calendar year.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon in Charge

The members of the research staff of the Waltham Field Station are assigned to this branch by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to reports of these departments for results of investigations conducted at this Station.

Soil Testing Service. Commercial vegetable growers, mushroom growers, florists, nurserymen, and vendors of loam brought in 2918 samples of soil for testing and interpretation. For home gardeners, 3291 samples were tested.

PUBLICATIONS

Bulletins

417 Annual report for the period ending June 30, 1944. 78 pp. August 1944.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

418 The propagation and identification of clonal rootstocks for the apple. By J. K. Shaw. 23 pp. illus. August 1944.

There is a demand, far exceeding the supply, for clonal rootstocks for growing dwarf and semi-dwarf apple trees. This bulletin tells how they are grown and how the different kinds may be identified, thus helping to keep these rootstocks true to name.

419 Trellis tomatoes. By Robert E. Young. 19 pp. illus. November 1944.

The tomato is one of the most important vegetable crops in Massachusetts, and the details of its culture are of significant economic interest. This deals with the operation of a practice which has been growing in favor.

420 Mortality studies in Rhode Island Reds. By F. A. Hays. 20 pp. illus. November 1944.

Mortality from all causes is one of the most important problems of poultrymen. This report is intended to add something to the very limited information on the role of breeding in reducing mortality.

421 The identification of pear varieties from non-bearing trees. By Lawrence Southwick, A. P. French, and O. C. Roberts. 51 pp. illus. November 1944.

The identification of varieties before fruit trees leave the nursery is important if disappointments in the orchard are to be avoided. This bulletin considers the characteristics by which nursery pear trees may be identified and records descriptions of 47 varieties and photographs of 41 varieties.

422 The beach plum in Massachusetts. By John S. Bailey. 16 pp. illus. December 1944.

The beach plum industry on Cape Cod and the islands of Nantucket and Martha's Vineyard has developed to the point where there is a demand for improved plums and better methods for growing them. This bulletin reports work done to satisfy this demand.

423 Factors affecting annual egg production. By F. A. Hays. 12 pp. December 1944.

Modern methods of poultry breeding are based on specific characters that affect egg production. This study was undertaken for the purpose of developing more accurate methods of selecting birds for breeding purposes where the primary object is increased egg production.

424 The culture of set onions in the Connecticut Valley. By W. G. Colby, C. J. Gilgut, and H. M. Yegian. 16 pp. illus. April 1945.

The weather conditions peculiar to the Connecticut Valley and cultural practices influenced thereby have a definite effect on the yield, appearance, and keeping quality of onions. These practices and their influence are discussed here.

425 Grass silage. By J. G. Archibald and C. H. Parsons. 11 pp. illus. April 1945.

The storing of grass and legume crops as silage has become an accepted practice. This bulletin, a revision of an earlier issue, reports the most recent findings on the subject.

426 Botulism and home canning. By William B. Esselen, Jr. 28 pp. April 1945.

In order to answer some of the many questions which have been raised concerning botulism and home-canned foods, a summary of available information is presented.

427 Carnation wilt diseases and their control. By E. F. Guba. 64 pp. illus. June 1945.

Wilt diseases cause serious losses in greenhouse carnation culture in Massachusetts. This bulletin is intended to help the carnation grower understand these diseases and to acquaint him with proven control measures.

Control Bulletins

120 Twenty-fourth annual report of pullorum disease eradication in Massachusetts. By the Poultry Disease Control Laboratory. 12 pp. July 1944.

121 Inspection of commercial feedstuffs. By Feed Control Service Staff. 28 pp. September 1944.

122 Inspection of commercial fertilizers and agricultural lime products. By Fertilizer Control Service Staff. 28 pp. September 1944.

123 Seed inspection. By F. A. McLaughlin. 41 pp. December 1944.

Meteorological Bulletins

661-672, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

NUMBERED CONTRIBUTIONS

497 Performance studies on home dehydrators. By W. B. Esselen, Jr., S. G. Davis, and M. A. Ewing. Food Res. 9 (5):341-347. 1944.

501 Corn distillers' by-products in poultry rations. I. Chick rations. By Walter L. Nelson, F. E. Volz, Raymond T. Parkhurst, and Leonard R. Parkinson. Poultry Sci. 23 (4):278-286. 1944.

507 Ratio of soluble sugars, pectic materials, and hemicelluloses to nitrogen-free extract of some common vegetables. By Emmett Bennett. Food Res. 9 (6):462-464. 1944.

508 The significance of inherited characters affecting egg production. By F. A. Hays. Poultry Sci. 23 (4):310-313. 1944.

509 Influence of calcium and magnesium upon composition of Boston head lettuce. By Arthur D. Holmes and Leo V. Crowley. Food Res. 9(5):418-426. 1944.

510 The value of starfish meal in the poultry starting ration. By Roy E. Morse, Francis P. Griffiths, and Raymond T. Parkhurst. Poultry Sci. 23 (5): 408-412. 1944.

511 Preventing surface darkening in certain home-canned foods. By J. J. Powers and C. R. Fellers. Jour. Home Econ. 37 (5):294-296. 1944.

513 The ratio of ascorbic, nicotinic, and pantothenic acids, riboflavin and thiamin in late summer milk. By Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, Katherine Esselen and Beula V. McKey. Jour. Dairy Sci. 27 (10):849-855. 1944.

514 The determination of tannic substances in commercial cocoa powders. By W. S. Mueller and J. W. Kuzmeski. Jour. Dairy Sci. 27 (11):897-901. 1944.

515 The effect of institutional cooking methods on the vitamin content of foods. I. The thiamine content of potatoes. By Anne W. Wertz and C. Edith Weir. Jour. Nutr. 28 (4):255-261. 1944.

516 Retention of vitamin C in foods by the use of natural gas atmosphere in dehydration. By H. L. Titus, Owen J. Brown, Jr., John Wertheim, Laurel M. Skofield, Roy E. Morse and Francis P. Griffiths. Chemical Products, November-December, 1944.

517 Some aspects of the metabolism of the Ebenezer onion. By Emmett Bennett. Plant Physiol. 20 (1):37-46. 1945.

518 Home canning. I. Survey of bacteriological and other factors responsible for spoilage of home-canned foods. By R. G. Tischer and W. B. Esselen, Jr. Food Res. 10 (3):197-214. 1945.

519 Home canning. II. Determination of process times for home-canned foods. By W. B. Esselen, Jr., and R. G. Tischer. Food Res. 10 (3):215-226. 1945.

520 Corn distillers' by-products in poultry rations. II. Laying and breeding rations. By Raymond T. Parkhurst, Carl R. Fellers and John W. Kuzmeski. Poultry Sci. 24 (1):8-19. 1945.

522 Sulfur compounds as disinfecting agents for dairy equipment. By W. S. Mueller, Emmett Bennett, and James E. Fuller. Jour. Dairy Sci. 27 (12): 1007-1009. 1944.

524 Effect of ascorbic acid injections on the amount in the blood plasma of laying hens. By G. Howard Satterfield, Thomas A. Bell, F. W. Cook, and Arthur D. Holmes. Poultry Sci. 24 (2):139-141. 1945.

526 The serial passage of an avian lymphoid tumor of the chicken. By Carl Olson, Jr. Cancer Res. 4 (11):707. 1944.

527 The vitamin content of commercial winter goat's milk. By Arthur D. Holmes, Harry G. Lindquist, Carleton P. Jones, Anne W. Wertz, Katherine Esselen, Beula V. McKey, and Evelyn Fuller. N. E. Jour. Med. 232:72-76. 1945.

528 Male sex hormones and artificial light as activators in the spermatogenesis of adult males. By F. A. Hays. Poultry Sci. 24 (1):66-71. 1945.

529 The fractionation of phosphorus compounds in certain vegetables. By Emmett Bennett. Jour. Nutr. 28 (4):269-271. 1944.

530 Effect of high-temperature–short-time pasteurization on the ascorbic acid, riboflavin and thiamin content of milk. By Arthur D. Holmes, Harry G. Lindquist, Carleton P. Jones, and Anne W. Wertz. Jour. Dairy Sci. 28 (1):29-33. 1945.

531 Ascorbic acid, riboflavin and thiamine content of chocolate milk. By Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, and W. S. Mueller. Amer. Jour. Dis. Children 69:157-159. 1945.

532 Carbonic anhydrase in the calcification of the egg shell. By Marie S. Gutowska and Carl A. Mitchell. Poultry Sci. 24 (2):159-167. 1945.

533 Uncommon pathological conditions in chickens and turkeys. By K. L. Bullis and H. Van Roekel. Cornell Vet. 34 (4):313-320. 1944.

534 Vitamin K content of dairy and cacao products. By W. S. Mueller and Anne W. Wertz. Jour. Dairy Sci. 28 (2):167-168. 1945.

535 The species specificity of a lymphoid tumor of the chicken. By Carl Olson, Jr. Cornell Vet. 34 (4):278-280. 1944.

536 The immunizing action of a lymphoid tumor in chickens. By Carl Olson, Jr. Amer. Jour. Vet. Res. 6 (19):103-106. 1945.

537 d-Isoascorbic acid as an antioxidant. By W. B. Esselen, Jr., J. J. Powers, and R. Woodward. Indus. and Engin. Chem. 37:295-299. 1945.

539 A second report on some lethal rootstock-scion combinations. By J. K. Shaw and L. Southwick. Amer. Soc. Hort. Sci. Proc. 45 (1944):198-202. 1945.

541 Chlorine gas injures trees. By Linus H. Jones and Malcolm A. McKenzie. Arborist's News 9 (12):89-90. 1944.

542 Effect of sunshine upon the ascorbic acid and riboflavin content of milk. By Arthur D. Holmes and Carleton P. Jones. Jour. Nutr. 19 (3):201-209. 1945.

543 The use of oil sprays as selective herbicides for carrots and parsnips. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 45 (1944):445-448. 1945.

544 Methyl bromide as a fumigant for rats and mice in apple cold storages. By Robert M. Borg and Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 45 (1944):146-150. 1945.

546 The primary sex ratio in domestic chickens. By F. A. Hays. Amer. Nat. 79:184-186. 1945.

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554 Propagating the high-bush blueberry by softwood cuttings. By W. L. Doran and J. S. Bailey. Amer. Nurseryman 81 (7):10. 1945.

555 Vegetables as a source of spoilage bacteria in home canning. By Celeste Dubord and William B. Esselen, Jr. Jour. Home Econ. 37 (4):221-224. 1945.

557 A study of methods of clarification and blends of Massachusetts apples for apple juice. By William B. Esselen, Jr. Fruit Prod. Jour. and Amer. Food Mfr. 24 (6):165-168, 189. 1945.

560 The requirement for calcium during growth. By Julia O. Holmes. Nutr. Abs. and Rev. 14:597-612. 1945.

563 Revealing study of plant bands. By Linus H. Jones. Horticulture 23 (12):316. 1945.

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Feeding the dairy goat. By J. G. Archibald. Amer. Dairy Goat Yearbook 3:87-92. 1945.

Distribution of the Dutch elm disease in Massachusetts. By Malcolm A. McKenzie. Newsletter, Mass. Tree Wardens' and Foresters' Assoc. (mimeo.) February 15, 1945.

Present status of the Dutch elm disease in Berkshire County. By Malcolm A. McKenzie. May Cuttings from the Berkshire Garden Center 5:1:6. 1945.

Dairy products builders of health and economic welfare. By J. H. Frandsen. The Milk Dealer 33 (12):54-55, 1944; The Milk Plant Monthly, October 1944, pp. 51 and 58.

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Effects of different insecticides on honeybees. By F. R. Shaw and A. I. Bourne. Gleanings in Bee Culture 72 (4):125. 1944.

Report on castor insecticides. By A. I. Bourne. A. I. F. News 2 (6): April 1944.

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The protective value of asphalt laminated paper against certain insects. By Harvey L. Sweetman and A. I. Bourne. Jour. Econ. Ent. 37:605-609. 1944.

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How to sell home freezers. By Francis P. Griffiths. Quick Frozen Foods 7 (5): 32-33. 1944.

Research on Massachusetts apples and apple products. 1927-1944. By Department of Food Technology. Mass. Fruit Growers' Assoc. Rept. 51st Ann. Meeting, January 1945. pp. 27-35.

Relationship between calcification of eggshell and carbonic anhydrase activity. By Marie S. Gutowska and U. C. Pozzani. Federation Proceedings 4 (1):91-92. 1945.

Rebuilding Poland's poultry industry to provide eggs for children's health. By Marie S. Gutowska. World's Poultry Sci. Jour. 1 (1):17-21. 1945.

Nutrition research in Poland. By Marie S. Gutowska. Bulletin of the Polish Institute of Arts and Sciences in America. 1945.

Calcium and phosphorus. By Julia O. Holmes. A treatise appearing in Dietotherapy—Clinical application of modern nutrition, edited by M. Wohl. pp. 147-188. Saunders, 1945.

New developments in nutrition research. By Julia O. Holmes. An address before the National Dairy Council Summer Conference, Chicago, June 1944. Milk Plant Monthly, February 1945.

The Butternut squash. By Robert E. Young. Flower Grower, April 1945. p. 192.

Chemical weeding of carrots and parsnips with oil sprays. By W. H. Lachman. New England Homestead 118 (1):10-11. 1945.

Weed control in vegetable growing. By W. H. Lachman. New England Homestead 118 (5):4. 1945.

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Tree lessons from the hurricane applied to Dutch elm disease control. By Malcolm A. McKenzie. October 1, 1944.

Don't cut elm. By Malcolm A. McKenzie. January 2, 1945.

Progress reports issued under the National Cooperative Project, Conservation of Nutritional Value of Foods.

The effect of institutional cooking methods on the vitamin content of food.

I. The thiamine and ascorbic acid content of potatoes. By A. W. Wertz and C. E. Weir. Mass. Agr. Expt. Sta. Prog. Note 1, 3 pp. 1944.

II. Thiamine, nicotinic acid, and panthothenic acid content of beans. By A. W. Wertz, B. V. McKey, K. O. Esselen, and J. O. Holmes. Mass. Agr. Expt. Sta. Prog. Note 2, 3 pp. 1944.

III. Thiamine, riboflavin, nicotinic acid, and pantothenic acid content of fish. By A. W. Wertz, B. V. McKey, K. O. Esselen, and J. O. Holmes. Mass. Agr. Expt. Sta. Prog. Note 3, 4 pp. 1944.

Extension Publications

The following Extension Leaflets and Circulars were prepared wholly or in part by members of the Experiment Station staff:

Mexican bean beetle. By A. I. Bourne. Mass. State Col. Ext. Spec. Cir. 15 (mimeographed). Revised, 1944.

Apple maggot. By A. I. Bourne. Mass. State Col. Ext. Spec. Cir. 9 (mimeographed). Revised, 1944.

Control of weeds in carrot and parsnip fields with oil spray. By W. H. Lachman. Mass. State Col. Ext. Spec. Cir. 120. 1945.

Control of cutworms. By A. I. Bourne. Mass. State Col. Ext. Leaflet 70. Revised, 1944.

Apple Pests. By A. I. Bourne, O. C. Boyd, O. C. Roberts, and W. D. Whitcomb. Mass. State Col. Ext. Leaflet 189. Revised, 1944.

Pest control in the home garden. By A. I. Bourne and O. C. Boyd. Mass. State Col. Ext. Leaflet 171. Revised, 1944.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 429 DECEMBER 1945

Annual Molt in Rhode Island Reds

By F. A. Hays and Ruby Sanborn

The primary objective of this study was to determine the value of molting behavior as a guide in selecting breeding stock. Attention is given to both males and females in exhibition-bred and production-bred Rhode Island Reds.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

ANNUAL MOLT IN RHODE ISLAND REDS

By F. A. Hays and Ruby Sanborn

OBJECTIVES OF THE EXPERIMENT

This study had five primary objectives, as follows:

1. To discover typical molting characteristics in Rhode Island Red males and females.
2. To compare molting behavior in exhibition-bred and production-bred stock.
3. To determine physiological relationships between molting and fecundity characters.
4. To discover possible inherited factors governing annual molt.
5. To disclose possible relationships between molting behavior and antecedent egg production.

The term "annual molt" as used here applies only to the shedding of feathers in the different feather regions and does not consider the regeneration of new feathers, since the time required to develop new feathers has been thoroughly studied by such workers as Rice, Nixon and Rogers (1908) and Marble (1930), as well as by Lillie and associates at the University of Chicago.

REVIEW OF LITERATURE

Bennett (1852) stated that hens continue to lay with few interruptions to the end of the summer, when the natural process of molting causes them to cease laying. Molting occurs annually beginning in August and continuing through the three following months.

Rice, Nixon and Rogers (1908) studied the molting process from hatching through adult life. They observed that hens seldom lay during the annual molt; that there was a wide variability in time of onset of molt and duration of molt; that hens starting to molt late, completed the process in a shorter period and also generally laid more eggs than those starting to molt early; and that a decline in body weight occurred during molt.

Sherwood (1922) examined, among other things, the molting of wing primary feathers in 128 White Leghorn females hatched during February and March. Their mean annual first-year egg record, from October 1 to September 30, was 127. The molt record on wing primaries, taken on October 4 following the completion of the first laying year, showed that an average of 5.086 wing primary feathers had been shed on this date. He reported a highly significant negative correlation of $.522 \pm .043$ between the number of wing primaries shed and the previous annual egg record.

Kempster (1925) noted that in White Leghorns early molting females were inferior layers not only in the first year but also in the second. On November 1 a group of females was examined for stage of molt. Those showing no trace of molt were the best layers in both the first and the second year; those in full molt ranked second; while those that had completed the molt were the lowest producers. He also showed that birds that stopped laying early were poor layers in both their first and their second laying year.

Marble (1930), in a very complete study of molting behavior in relation to egg production in White Leghorns, observed that molting of body feathers precedes molting of wing and tail feathers. He was probably the first worker to show clearly that many hens continue to lay while shedding wing primary feathers. He noted also that wing secondaries and main tail feathers are not usually molted until after laying ceases, and that molting of wing primaries was generally very orderly. Low producing hens molted earlier and stopped laying earlier than high producers. He observed that the period of non-production during the shedding of the wing primary feathers is very important in its effect on annual egg production, but the absolute length of time consumed in shedding the ten wing primary feathers is not important in its relation to preceding egg production.

Hays and Sanborn (1930), in a study of the non-productive period associated with annual molt in Rhode Island Reds, showed that intense layers and persistent layers generally stopped laying for a shorter period while in annual molt. They found a significant negative correlation between previous egg production and the length of the non-productive period during molt. Family mortality had no significant effect on molt duration. Second-year egg production was greatly reduced by a long period of non-production following the first-year record.

Greenwood (1936) found evidence that molting is affected by the activity of the gonads, and that time of molt has a genetic basis in females. His data also suggest that the thyroid gland may be responsible for the onset of molt.

Lippincott and Card (1939) stress the importance of late molting and also of the ability to lay and molt at the same time. They point out that hens probably do not lay while molting unless they are increasing or maintaining their body weight.

Hays and Sanborn (1939) showed that the length of the laying year in Rhode Island Reds could be increased about 100 days by selective breeding. Their data indicate that the length of the laying year is the most important character affecting annual egg production and that it is governed by inheritance.

Jull (1940) stressed the importance of late molting in relation to egg production and called attention to the fact that late molting generally means a short period of non-production.

Lerner and Taylor (1941) reported an intimate negative correlation between the date of last egg at the close of the first laying year and the duration of the period of non-production associated with annual molt. Their data included the records of 289 Single Comb White Leghorn females, giving a value of −.525 for the correlation coefficient and linear regression.

Hays (1943) pointed out that late molting does not reduce subsequent hatchability, a fact of very great importance in poultry breeding.

EXPERIMENTAL PLAN

Observations on males and females hatched in March and April of the preceding year began on July 25 and continued at bi-weekly intervals, usually to near the end of the calendar year. Most observations included the following feather regions: neck (cervical), breast (pectoral), thigh (femoral), lower leg (tibial), back (dorsal), and wing primaries. In recording the progress of molt, the grades suggested by Marble (1930) were used. The "0" grade indicated that no feathers had been shed; the "slight" grade indicated the beginning of molt; the "medium" grade indicated that about half of the feathers had been shed; the "large" grade indicated well-advanced molt; and "complete" indicated that all feathers had been dropped. The number of wing primaries shed was recorded at each observation. Each bird was also weighed on each day of observation.

During the first three years, observations were made on three generations to secure data on the molting behavior of the stock. The birds used included both production and exhibition Rhode Island Reds. Observation confirmed that the molting of the wing primaries was the most regular, as Marble (1930) had already observed in Leghorns.

Since the ability to lay while molting wing primary feathers varied widely, an attempt was made in 1941 to establish two lines differing in this respect. Line A was selectively bred for a short period of laying while molting; Line B was bred for the ability to lay for a long period after the wing molt began; and both lines were carried through three generations. All birds in lines A and B came from the production-bred stock; all birds used in this experiment were pedigreed; and all females were trapnested for the first laying year.

Results are reported in two parts: I, a comparison of the molting behavior of exhibition-bred and production-bred males and females; II, the records on production-bred stock alone through seven generations.

PART I.

MOLTING BEHAVIOR IN EXHIBITION-BRED AND PRODUCTION-BRED RHODE ISLAND REDS

Males

Molting behavior was studied in five exhibition-bred Rhode Island Red males and twenty-five production-bred males hatched in 1938 and 1939. The observations began July 25 and were concluded on November 30, the usual period when laying females go through their first annual molt at the end of the first year of laying.

TABLE 1.—ANNUAL MOLT IN MALES, 1939-1940.
Time required and date of completion.

Feather Region and Stock	Number of Birds	Average Days Required	Date of Completion
Neck (Cervical)			
Exhibition	5	30.8	Aug. 20
Production	25	47.6	Sept. 8
Breast (Pectoral)			
Exhibition	5	61.6	Sept. 23
Production	25	48.7	Sept. 18
Thigh (Femoral)			
Exhibition	5	44.8	Sept. 17
Production	25	52.1	Oct. 10
Lower Leg (Tibial)			
Exhibition	5	47.6	Sept. 17
Production	25	37.0	Oct. 3
Back (Dorsal)			
Exhibition	5	22.4	Aug. 15
Production	25	49.8	Sept. 7
Wing Primaries			
Exhibition	5	78.4	Oct. 10
Production	25	97.4	Oct. 26

TIME REQUIRED FOR MOLTING

The average number of days required for the two groups of males to complete the molt in the six feather areas studied is recorded in table 1, together with the average date of completion.

The rather limited data indicate that males bred for egg production tend to molt at a slower rate than those bred for plumage color. When the wing primaries are considered, this tendency is rather pronounced. Males bred for egg production required 19 more days to shed all ten wing primaries than those bred for color. The average dates of completing the wing primary molt were October 26 and October 10, respectively.

The order of completion in different feather tracts was variable. All feathers on the neck and on the back were lost at about the same time and at a somewhat earlier date than the feathers in other tracts. The breast region followed next, with the femoral and lower leg completing almost simultaneously. The wing primary feathers were the last to be completely shed.

BODY WEIGHT DURING THE MOLTING PERIOD

The mean body weight of the thirty males, as recorded at bi-weekly intervals, is presented in chart 1.

So far as body weight is concerned, there appears to be some difference in the two groups of males. The exhibition males were somewhat smaller than the production males. During August and early September the exhibition males had an average loss of about one-third pound in weight; from the middle of September on, they showed a rather consistent increase in weight to the maximum observed at the end of November. Males bred for high fecundity were deficient in weight at the end of July when the observations began. They lost no weight as molting progressed, but rather exhibited a consistent increase up to the maximum observed at the end of November.

Although the annual molt appears to be a severe tax on the physiological functions of the male, the data do not indicate that this is accompanied by reduced body weight.

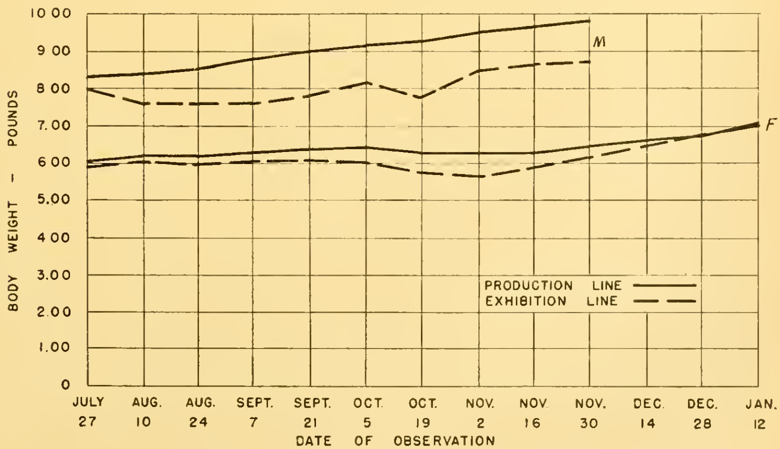


Chart 1. Mean Body Weight of Males and Females During Annual Molt. 1939-1940.

Females

Bi-weekly observations on molting behavior of females began in the summer of 1938 and were continued each year to the fall of 1944. Exhibition-bred females were studied only during 1938, 1939, and 1940, and no females of this group were used for breeding purposes. A comparison may thus be made in molting behavior of exhibition-bred females and production-bred females in three generations. Molt observations were begun near the end of July and were usually discontinued near the end of December. Females have been divided into two groups on the basis of whether or not they had completed the wing primary molt during the period of observation.

Table 2.—Annual Molt in Females, 1938-1940.
Time required and date of completion

Feather Region and Stock	Complete Wing Molt			Incomplete Wing Molt		
	Number of Birds	Average Days Required	Date of Completion	Number of Birds	Average Days Required	Date of Completion
Neck (Cervical)						
Exhibition	23	70.6	Sept. 30	10	81.2	Oct 10
Production	71	79.5	Oct. 8	60	71.2	Sept. 30
Breast (Pectoral)						
Exhibition	14*	33.0	Sept. 18	7	24.0	Oct. 12
Production	34	36.2	Sept. 26	36	46.7	Oct. 28
Thigh (Femoral)						
Exhibition	23	36.5	Oct. 2	10	37.8	Oct. 18
Production	71	36.7	Oct. 12	60	40.6	Oct. 28
Lower Leg (Tibial)						
Exhibition	23	25.0	Sept. 30	10	19.6	Oct. 22
Production	70	24.0	Oct. 13	60	23.6	Nov. 1
Back (Dorsal)						
Exhibition	23	54.2	Sept. 24	10	49.0	Sept. 30
Production	71	57.4	Sept. 28	60	67.4	Oct. 8
Wing Primaries						
Exhibition	23	98.6	Nov. 22	10	–	–
Production	71	125.4	Dec. 8	60	–	–

*Observations were not made on the breast region the first year.

TIME REQUIRED FOR MOLTING

In table 2 data are presented on the rate of molting in different feather tracts, for purposes of comparing exhibition-bred and production-bred stock.

In the group of females that completed the wing molt during the period of observation, exhibition- and production-bred birds molted in five of the feather tracts in about the same number of days. For the wing primary feathers, however, the production-bred stock required about 27 days more than the exhibition-bred.

The production-bred birds finished molting on a later date than the exhibition-bred, except in the back region, where there was no difference. The average date of completing molt of the wing primary feathers was about two weeks later in the production-bred stock. It appears, therefore, that females bred for high production have an inherited tendency to complete their molt at a later date than exhibition-bred females.

The females in the group that failed to complete their wing molt by December 31 had completed their molt in all other feather tracts studied. There was a slight tendency for the production-bred females to molt over a longer period in breast, thigh, and back. In neck molt and lower leg molt this difference failed to appear. The mean date when molt was completed was generally later for this group than for the group having complete wing molt.

Comparison with the record for males presented in table 1 shows no high consistency. Males molted more quickly than females in some feather tracts but more slowly in others. Males did require a much shorter period to shed their wing primaries, and the mean date when molting was complete was generally significantly earlier.

BODY WEIGHT DURING THE MOLTING PERIOD

Body weight records and molt records were taken on each bird at two-week intervals to discover characteristic weight changes associated with molting in females. Data are presented in chart 1 for 33 exhibition-bred females and 131 production-bred females.

Females in the exhibition group were about .14 pound lighter in weight than those in the production group at the end of July. By the end of December there was no difference in mean weights. The exhibition females increased in weight up to the middle of September and then showed a decline of about .4 by the end of October, coinciding with their most active molting period. The production-bred stock not only failed to exhibit any significant decline in body weight during the molting period, but actually showed a progressive increase of about .75 pound from late July to the end of December.

In general, the data suggest that annual molt does affect body weight in exhibition-bred females but produces no significant effect in birds bred for high fecundity.

MOLTING BEHAVIOR IN RELATION TO EGG PRODUCTION

It is a well-recognized fact that both molting and egg production are complex physiological functions. It is also known that annual molt and egg production at the end of the biological year are interdependent. Egg production normally ceases for most of the period of annual molt. There is, however, marked variability in both molting behavior and egg laying. It is, therefore, important that some of these relations be considered. For convenience both the exhibition and the production females have been divided into two groups: those completing the wing molt and those not completing the wing molt during the period of observation.

Molting of Different Feather Regions.—In table 3 data are presented on the mean number of eggs laid and the mean length of the laying period while molting in six different feather tracts.

The data show that hens may lay a considerable number of eggs while undergoing neck molt and back molt, apparently because of the early completion of molting in these regions. Molting on the breast, thigh, and lower leg is usually completed later in the fall, and the number of eggs laid while molting in these regions is small. Molting of wing primaries covers a long period during which both exhibition- and production-bred hens laid a reasonable number of eggs.

TABLE 3.—EGGS LAID AND DAYS OF LAYING DURING ANNUAL MOLT, 1938-1940.

Feather Region and Stock	Complete Wing Molt			Incomplete Wing Molt		
	Number of Birds	Average Number of Eggs Laid	Average Number of Days Laying	Number of Birds	Average Number of Eggs Laid	Average Number of Days Laying
Neck (Cervical)						
Exhibition	23	25.0	51.0	10	42.4	69.0
Production	71	31.8	59.0	60	33.3	63.0
Breast (Pectoral)						
Exhibition	14*	8.9	19.2	7	10.1	18.3
Production	34	11.9	25.6	36	17.5	36.5
Thigh (Femoral)						
Exhibition	23	8.7	18.1	10	15.6	28.1
Production	71	8.4	18.6	60	11.8	26.0
Lower Leg (Tibial)						
Exhibition	23	3.3	8.4	10	4.4	8.9
Production	70	3.7	10.1	60	5.8	12.6
Back (Dorsal)						
Exhibition	23	19.5	40.0	10	25.8	42.8
Production	71	22.9	42.8	60	29.4	56.7
Wing Primaries						
Exhibition	23	14.7	32.5	10	–	–
Production	71	30.6	72.6	60	–	–

*Observations were not made on the breast region the first year.

The production-bred group, however, averaged to lay twice as many eggs as the exhibition birds during wing molt. The fact should be remembered that molting all over the body is generally going on during this period and that many individuals may stop laying entirely.

In the population with incomplete wing molt, there was for the most part a slightly longer period of egg laying and a greater number of eggs laid than in the group with complete wing molt. This fact indicates that birds that are very late in completing their wing molt are likely to molt in other feather tracts over a somewhat longer period and are more likely to lay a greater number of eggs during molting.

Persistency in Relation to Wing Molt.—Persistency may be measured by the length of the biological laying year, which usually ends during the annual molt. Since the molting of wing primaries is more consistant than that of the other feather areas studied, it furnishes a rather satisfactory measure of molting behavior. Since persistency is the most important inherited character thus far studied in relation to annual egg production (Hays, 1944), it is obvious that the relation of molting behavior to persistency is very important. In table 4 are recorded the mean length of the biological year in days, the mean number of eggs laid, the mean number of wing primaries shed when laying stopped, the average date of completing wing molt, and the average date when the biological laying year ended.

Table 4.—Persistency and Wing Molt, 1938-1940.

	Complete Wing Molt		Incomplete Wing Molt	
	Number of Birds	Average	Number of Birds	Average
Length of biological year, days				
Exhibition	23	309.1	10	326.1
Production	71	350.8	56	369.9
Production during biological year, eggs				
Exhibition	23	177.8	10	199.0
Production	71	225.7	56	237.3
Annual production, eggs				
Exhibition	23	178.0	10	195.6
Production	71	221.5	60	231.0
Number of primaries shed when laying stopped				
Exhibition	23	2.6	10	3.0
Production	71	3.9	56	3.1
Date of completing wing molt				
Exhibition	23	Nov. 22	–	–
Production	71	Dec. 8	–	–
Date of termination of biological year				
Exhibition	23	Sept. 13	10	Oct. 16
Production	71	Sept. 25	56	Oct. 18

It is notable that birds bred for high fecundity averaged to lay about 42 and 44 days longer than those bred for color. In the group with incomplete wing molt, the mean length of the biological year was from 17 to 19 days greater than in the group that had completely shed all wing primaries by the end of December.

In the first group, egg production during the biological year was about 48 eggs greater in the high-fecundity stock than in the exhibition-bred stock; in the second group, there was a mean difference of about 38 eggs. Lengthening the biological year has therefore been an important step in increasing egg production.

Annual egg production, measured by the number of eggs laid in 365 days beginning with the first pullet egg, was significantly higher in the group of females that had not completed their wing molt by the end of December, in both production-bred and exhibition-bred stock.

It is conceivable that the number of wing primaries shed at the time laying ceases may be used as a guide in selective breeding. In the group of birds with complete wing molt, the exhibition stock stopped laying when 2.6 wing primaries had been lost, while the production stock did not stop laying until about 4 wing primaries had been shed. In the group with incomplete molt, there was no difference in the two stocks with respect to wing primaries shed. This fact suggests that very late wing molt is associated with the ability to lay after more wing primary feathers have been lost.

In the population with complete wing molt, the birds bred for high fecundity averaged to complete their wing molt about 17 days later than birds bred for color. Although this is not a wide difference, it does have a very great effect of egg production.

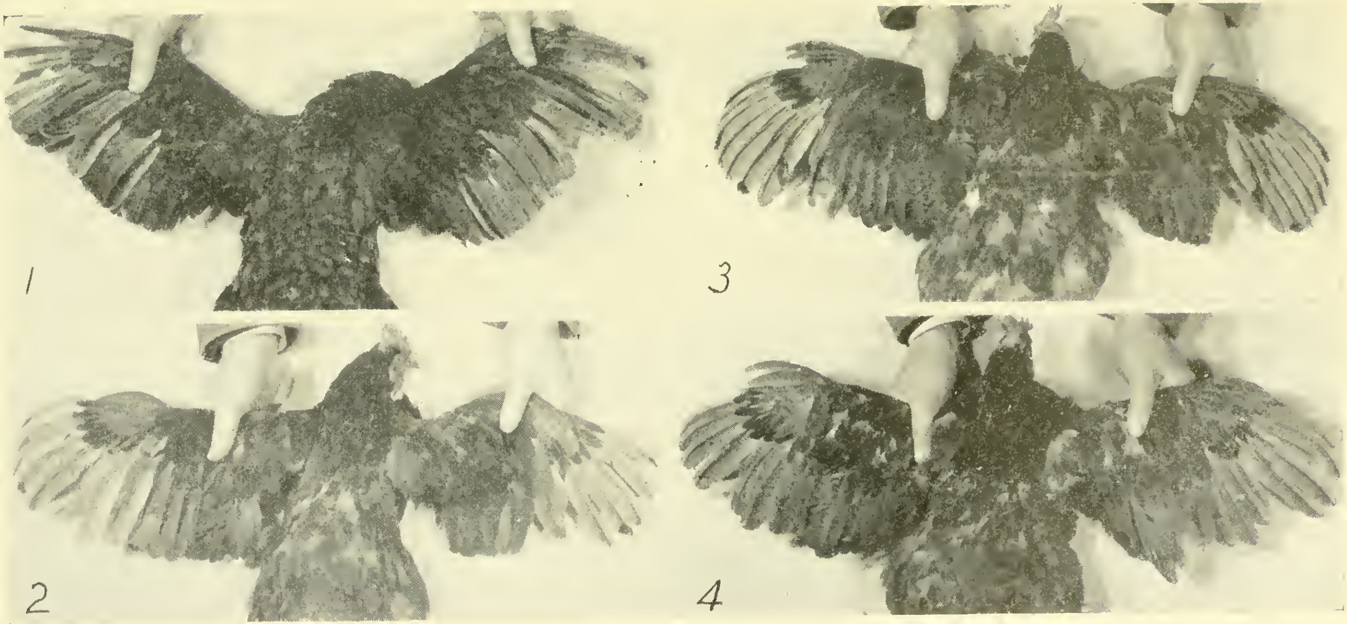
The date of termination of the biological year is extremely important, according to Lerner and Taylor (1941). In the group with complete molt (table 4), the exhibition stock stopped laying on the average about September 13; the stock bred for egg production, about September 25. In the group with incomplete wing molt, both stocks terminated their laying year about the middle of October. Late molting of primary wing feathers increased the persistency by about one month. The actual time of wing molt, therefore, appears to be very important.

Production during the Biological Year in Relation to Wing Molt.—Molting of wing primaries has proved to be the most consistent and definite measure of molting behavior in our stock. Since the rate of molting has long been considered important in relation to antecedent egg production, it seems desirable to present specific data on this point. In table 5, the birds are classified with respect to duration of wing molt, and the mean number of eggs laid by each group during the biological year is recorded.

In the limited number of exhibition-bred females observed, there is some evidence that a period of molting wing primaries shorter than 14 weeks may be associated with lower egg production. The same observation also holds for the high-fecundity stock. Aside from this, there is no evidence in either group of birds that the duration of wing molt is associated with antecedent egg production. These data certainly present no evidence that a short molt period is associated with high antecedent egg production.

Table 5.—Duration of Wing Molt and Egg Production During The Biological Year, 1938-1940.

Duration of Wing Molt Weeks	Exhibition Stock		Production Stock	
	Number of Birds	Average Production During Biological Year	Number of Birds	Average Production During Biological Year
2	0		0	
4	0		0	
6	0		0	
8	2	149.0	2	264.5
10	3	174.0	3	218.0
12	5	145.8	4	190.0
14	2	245.0	6	228.8
16	5	200.2	13	227.2
18	5	169.6	10	222.7
20	1	202.0	14	223.9
22	0		15	232.9
24	0		4	226.0

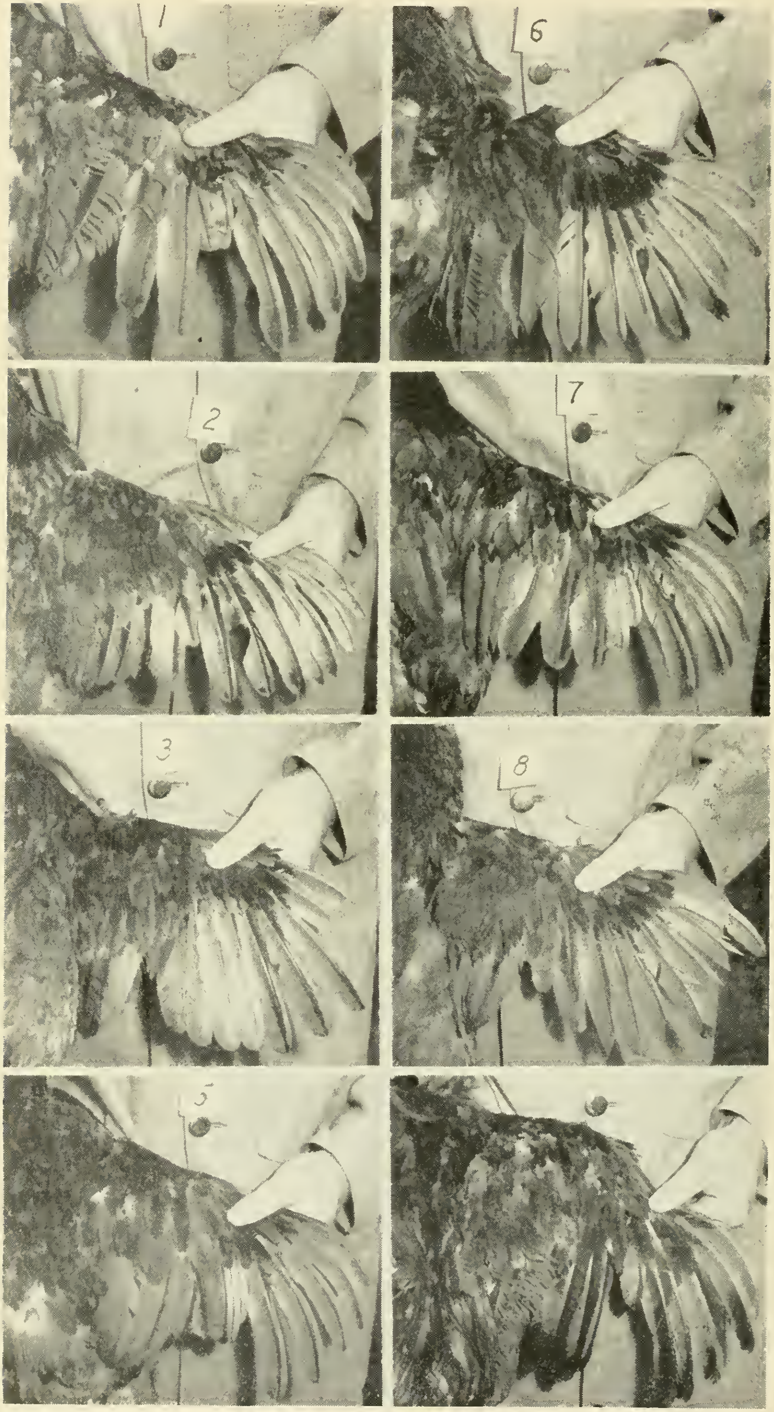


Variability in Wing Molt in the Fourth Generation of Production-bred Females December 3, 1941.

	1	2	3	4
Wing molt begun by shedding one primary...	July 29*	Oct. 7	Oct. 21	Sept. 9
Biological year ended..................	Aug. 20	Nov. 30	Dec. 19	Nov. 27
Primaries shed when laying stopped.........	1	4	3	4
Eggs laid during biological year...........	188	298	303	273
Annual egg record......................	188	246	279	262
Second laying year begun.................	Oct. 24	Jan. 23	Jan. 29	Jan. 23
Primaries shed when photograph was taken...	7	5	3	5

*Primary shed before July 29.

Representatives of Line A in the Third Generation — September 19, 1944



Representatives of Line B in the Third Generation — September 19, 1944

Four Full Sisters in Line B, Bred for the Ability to Lay Long after Wing Molt Started.

	9	10	11	12
Biological year ended.........	Oct. 25	Sept. 29	Nov. 5	Nov. 13
Eggs laid during biological year..	258	258	257	259
First primary molted...........	Oct. 3	Oct. 3	Aug. 8	Oct. 31
Primaries shed when laying stopped..	8	7	7	8
Eggs laid while molting primaries....	23	4	82	4
Wing molt on December 12...............	Complete	Complete	Incomplete	Incomplete
Primaries shed when photograph was taken...	None	None	1	None

Seven Hens in Line A, Bred for a Short Period of Laying after Wing Molt Started.

	1	2	3	5	6	7	8
Biological year ended...	Aug. 20	Oct. 26	Nov. 2	Sept. 29	Sept. 14	Aug. 14	Sept. 26
Eggs laid during biological year....	208	167	297	245	282	214	290
First primary molted by..	July 25	July 25	July 25*	Aug. 22	Sept. 5	July 25	July 25
Primaries shed when laying stopped......	2	3	7	6	7	4	9
Eggs laid while molting primaries...........	22	61	80	16	15	16	53
Wing molt completed...	Nov. 14	**	**	**	Oct. 31	**	Oct. 31
Primaries shed when photograph was taken ..	5	2	4	5	7	5	1

*Had molted 4 primaries by July 25. **Wing molt incomplete Dec. 12.

Unnumbered: A male of Line A, with 5 primaries shed. He completed wing primary molt on Nov. 14.

Early molting has long been thought to be inimical to high egg production during the first laying year. The date of onset of wing primary molt was recorded for all birds that had not molted any wing primaries by the end of July when observations began. Of the 33 exhibition females studied, only 22 began their wing molt after the first of August, and of the 277 production females, 175 began the wing molt after August 1. The date of onset of wing primary molt was therefore determined for only about two-thirds of the females.

The time of completion of wing primary molt was recorded if it occurred before January 1. If wing molt was not complete when observations stopped at the end of December, such individuals were placed in the "incomplete molt" group.

The mean number of eggs laid in the biological laying year was recorded for each group.

The data are presented in table 6.

Table 6.—Relation Between Month of Onset and Completion of Wing Primary Molt and Egg Production During Biological Year.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Complete Wing Molt						
Exhibition Stock						
Onset of wing molt						
Number of birds	8	5	3			
Average production during biological year, eggs	175.8	173.6	172.7			
Completion of wing molt						
Number of birds			4	12	4	3
Average production during biological year, eggs			149.8	180.9	191.0	185.3
Production Stock						
Onset of wing molt						
Number of birds	27	5	6			
Average production during biological year, eggs	231.4	197.6	253.3			
Completion of wing molt						
Number of birds		1	1	29	26	14
Average production during biological year, eggs		224.0	204.0	219.1	228.0	236.9
Incomplete Wing Molt						
Exhibition Stock						
Onset of wing molt						
Number of birds	1	2	3			
Average production during biological year, eggs	208.0	244.5	200.0			
Production Stock						
Onset of wing molt						
Number of birds	14	13	11	2		
Average production during biological year, eggs	226.1	235.4	268.7	249.0		

The data indicate that females that complete their wing primary molt by the end of December usually begin their wing molt earlier than those that have not completed wing molt by January 1.

In the exhibition stock there is no evidence in the limited data that time of onset of wing primary molt affects the number of eggs laid during the biological laying year. In the group of production-bred females with complete wing molt, there is no conclusive evidence that the time of onset of wing molt has any effect on first-year egg production. There is some indication, however, that high first-year egg production is associated with late onset of wing primary molt in the birds not completing their wing molt.

In both exhibition and production stocks the number of eggs laid previous to the cessation of laying associated with the first annual molt increased as the date of completing wing molt advanced. In these data the date of completion of wing primary molt appears to be far more important in relation to previous egg production than was the date of onset of wing primary molt.

Summary of Part I

In general, the comparison of exhibition and production stock reveals some rather characteristic differences with respect to annual molt. Annual molt appears to produce greater physiological effects on exhibition stock than on production stock. Both exhibition males and females showed decline in body weight during annual molt, while no important change was observed in production-bred stock.

The date of completion of wing primary molt was significantly earlier and the duration of wing molt was shorter in exhibition stock than in production stock. The number of eggs laid by production stock during wing molt was much greater than the number laid by exhibition stock. The date of onset of wing molt was more important and the mean length of the biological laying year was characteristically greater in the stock bred for high fecundity.

PART II.

MOLTING BEHAVIOR IN PRODUCTION-BRED RHODE ISLAND REDS

Data on Rhode Island Reds bred for high fecundity over a seven-year period are presented for both males and females. During the first three years preliminary records were collected. In the spring of 1941 specific matings were begun in an attempt to establish two lines, using only birds bred for high fecundity. Line A was started with females laying for a very short period after wing molt began, mated to a male that completed his wing molt early. Line B was begun with females showing the ability to lay for a long time after wing molt started, mated to a male that completed his wing molt late. Three generations were produced in the two lines.

Attention will be given first to all production-bred stock, using the same measures as were applied in Part I.

Males

TIME REQUIRED FOR MOLTING

Observations extended over a six-year period and include a total of 44 males bred for high fecundity. Consideration is given to the time interval between the start and completion of molt in six feather regions. The average date of completion is also recorded.

The number of days required to complete the molt did not differ greatly in most of the feather tracts. In the lower leg area, the time required was very short. Wing primaries were molted slowly, requiring on the average about 101 days. Males finished the molt in the neck and back regions first; the breast was completed soon after; the thigh and lower leg were molted somewhat later; and all males had shed all wing primary feathers by October 30.

TABLE 7.—ANNUAL MOLT IN MALES, PRODUCTION STOCK ONLY, 1939-1944. Time required and date of completion.

Feather Region	Number of Birds	Average Days Required	Average Date of Completion
Neck (Cervical)	44	45.8	Sept. 9
Breast (Pectoral)	44	47.1	Sept. 20
Thigh (Femoral)	44	51.9	Oct. 15
Lower Leg (Tibial)	44	36.0	Oct. 7
Back (Dorsal)	44	53.8	Sept. 11
Wing Primaries	44	101.2	Oct. 30

BODY WEIGHT DURING THE MOLTING PERIOD

Body weight records were obtained at the time of the molt observations on 44 males representing six generations of production-bred birds. The results are depicted in chart 2.

This chart confirms the observations made on two generations of production-bred males shown in chart 1, to the effect that such males do not decline in weight while undergoing annual molt. Body weight records taken at two-week intervals from July 27 to November 30 indicate a very consistent increase throughout the period.

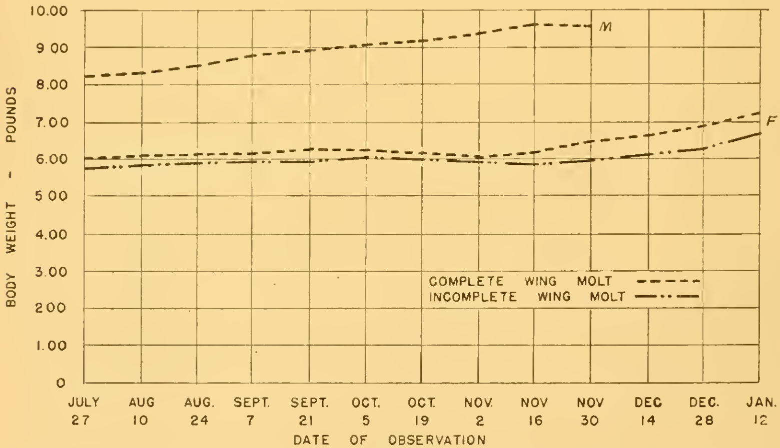


Chart 2. Mean Body Weight of Males and Females During Annual Molt. Production Line, 1938-1944.

Females

TIME REQUIRED FOR MOLTING

In the seven-year period records were secured on 135 females that had completed wing molt by the end of December and 142 that had not molted all wing primaries by that date. The data available should be sufficient to furnish reasonably accurate information.

TABLE 8.—ANNUAL MOLT IN FEMALES, PRODUCTION STOCK ONLY, 1938-1944. Time required and date of completion.

Feather Region	Complete Wing Molt			Incomplete Wing Molt		
	Number of Birds	Average Days Required	Date of Completion	Number of Birds	Average Days Required	Date of Completion
Neck (Cervical)	135	65.4	Sept. 22	142	57.3	Sept. 16
Breast (Pectoral)	98	32.3	Oct. 1	114	38.6	Oct. 31
Thigh (Femoral	135	39.9	Oct. 12	138	41.9	Nov. 4
Lower Leg (Tibial)	134	26.4	Oct. 12	141	28.1	Nov. 8
Back (Dorsal)	135	54.3	Sept. 28	139	61.2	Oct. 15
Wing Primaries	135	122.3	Dec. 6	142	–	–

A comparison of tables 7 and 8 indicates differences in molting behavior between males and females. Females molt more slowly in the neck region and more rapidly on breast, thigh, and lower leg. Both sexes shed their back feathers in about the same length of time. Females in the complete molt group were about three weeks later than males in shedding all wing primaries, but less than half of the females had completed wing molt by the end of December.

For the most part, males generally completed the shedding of feathers earlier than females. This observation does not hold for thigh and lower leg regions. Males had completely molted their wing primaries by the end of October, while females did not complete their molt until December or later.

BODY WEIGHT DURING THE MOLTING PERIOD

Production-bred females were again divided into two groups: those with complete wing molt by the end of December and those with incomplete wing molt. The graph for body weight of the two groups is presented in chart 2.

The females in the earlier molting group declined on the average about .19 pound during October to a mean weight of 6.03 pounds. They began to recover weight in November and by the end of the month were considerably heavier than before the molt. After November 15 they increased rapidly in weight and reached a final weight of more than 7 pounds by January 10.

Females in the late molting group averaged slightly less in weight (about .20 pound) than the earlier group. There was an average falling off in weight of about .14 pound in this group during October and the first half of November. After November 15 there was a consistent and rapid increase amounting to about .82 pound by January 10.

In a general way these data indicate a slight falling off in body weight of females at the time of most active molt.

MOLTING BEHAVIOR IN RELATION TO EGG PRODUCTION

Molting in Different Feather Regions.—Production-bred females have again been divided into two groups with respect to completion of wing molt.

Table 9 shows no significant difference between the two groups of females in number of days of laying and number of eggs laid while molting in the various feather regions. The earlier molting group averaged to lay for about 72 days while molting wing primaries, with a mean of about 30 eggs. Since the molting of wing primaries is one of the last phases of annual molt, it is apparent that production-bred birds have the ability to lay when the molt is well advanced.

Table 9.—Eggs Laid and Days of Laying During Annual Molt, Production Stock Only, 1938-1944.

Feather Region	Complete Wing Molt			Incomplete Wing Molt		
	Number of Birds	Average Number of Eggs Laid	Average Number of Days Laying	Number of Birds	Average Number of Eggs Laid	Average Number of Days Laying
Neck (Cervical)	135	28.8	53.6	142	29.2	52.4
Breast (Pectoral)	98	9.4	20.8	114	12.9	27.0
Thigh (Femoral)	135	10.0	22.9	138	12.4	26.2
Lower Leg (Tibial)	134	5.2	12.9	141	7.2	14.5
Back (Dorsal)	135	21.8	41.8	139	25.9	49.2
Wing Primaries	135	29.9	71.9	142	–	–

Persistency in Relation to Wing Molt.—The seven generations of females bred for high fecundity have been combined into two groups: those in which molt was complete by the end of December and those that had not completed the molt on that date. The two groups are compared in table 10.

Table 10.—Persistency and Wing Molt, Production Stock Only, 1938-1944.

	Complete Wing Molt		Incomplete Wing Molt	
	Number of Birds	Average	Number of Birds	Average
Length of biological year, days	135	360.2	138	378.9
Production during biological year, eggs	135	228.0	138	241.0
Annual production, eggs	135	222.1	142	229.4
Number of primaries shed when laying stopped	135	3.8	138	3.3
Date of completing wing molt	135	Dec. 6	138	–
Date of termination of biological year	135	Sept. 27	138	Oct. 20

Birds with incomplete wing molt by the end of December had a biological laying year about 19 days longer than birds that had completed the wing molt by that date. These later molting birds had a mean laying period of about 379 days from their first pullet egg to the cessation of production associated with annual molt.

Egg production during the biological year differed significantly in the two groups. The birds completing wing molt by the end of December averaged to lay 23 fewer eggs than those completing wing molt after December.

The number of eggs laid in a 365-day laying year was also slightly higher in the late-molting group. It should be noted, however, that even the birds completing wing molt in December can scarcely be considered as molting early.

The earlier molting group averaged slightly higher than the later molting group in number of primary wing feathers molted when laying stopped, but the difference is of doubtful significance. The data as a whole indicate that these birds bred for high persistency do possess the ability to lay when the annual molt is well advanced.

December 6 was the average date when wing molt was completed in the earlier molting group. For the later group, the date of completion was well into January.

The biological laying year terminated about September 27 in the earlier group, compared with October 20 for the later group. An average persistency three weeks longer in the later molting group had a very significant effect on the number of eggs laid.

Production during the Biological Year in Relation to Wing Molt.—It is desirable to know whether the number of weeks spent in shedding the primary wing feathers is associated with the number of eggs laid during the biological year. In other words, is rapid molting advantageous from the standpoint of egg production? Table 11 presents the data on 135 production-bred females.

TABLE 11.—DURATION OF WING MOLT AND EGG PRODUCTION DURING THE BIOLOGICAL YEAR, PRODUCTION STOCK ONLY, 1939-1944.

Duration of Wing Molt Weeks	Number of Birds	Average Production During Biological Year
2	0	
4	0	
6	1	207.0
8	2	264.5
10	9	238.6
12	12	230.2
14	11	234.9
16	24	230.2
18	23	234.0
20	16	223.8
22	29	228.3
24	8	180.4

There was a wide range in the number of weeks required to shed the ten primary wing feathers. The shortest period observed was six weeks, and the longest 24 weeks. The most common period was 16 to 18 weeks. No association was observed between the duration of wing molt and antecedent egg production.

All females in seven generations of the production-bred stock have been tabulated to study date of onset and date of completion of wing primary molt in relation to the number of eggs laid during the first biological year. Since a considerable number of these birds began their wing molt before August 1, no record was secured on when they began. Records for date of onset are available on 175 out of a total of 277. These 175 birds are divided into complete and incomplete molt groups in table 12.

The onset of wing molt occurred slightly earlier on the average in the group of birds that finished this molt by the end of December than in the group finishing later. There is considerable evidence that late onset of molt is likely to be preceded by high egg production.

Late completion of wing primary molt again appears to be a good criterion of high antecedent egg production. In the population with complete wing molt by the end of December, the majority of the birds terminated their molt in November and December; but only about 49 percent of the 277 females studied had completed the wing primary molt by January 1.

TABLE 12.—RELATION OF MONTH OF ONSET AND COMPLETION OF WING PRIMARY MOLT TO EGG PRODUCTION DURING BIOLOGICAL YEAR, PRODUCTION STOCK ONLY

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Complete Wing Molt						
Onset of wing molt*						
Number of birds	39	18	15			
Average production during biological year, eggs	232.8	233.8	248.8			
Completion of wing molt						
Number of birds	....	1	5	51	64	14
Average production during biological year, eggs		224.0	235.8	224.2	228.5	236.9
Incomplele Wing Molt						
Onset of wing molt*						
Number of birds	28	31	36	8		
Average production during biological year, eggs	229.1	239.5	265.7	240.6		

*Data on the time of onset of wing molt are incomplete because a considerable proportion of the birds began molting before August.

Inheritance Studies—Results from Breeding Two Lines

Matings were made over a three-year period beginning in 1941, to study the mode of inheritance of time required for molting and date of completion of molt. Line A was selectively bred from females that stopped laying soon after the onset of molt in wing primaries, mated to males that completed their wing molt early in the fall. Line B was selectively bred from females that continued to lay for a considerable period after the onset of molt in wing primaries, mated to males that completed their wing molt late in the fall. The molting behavior of the sons is considered first.

MOLTING BEHAVIOR OF FATHERS AND SONS

The time required for molting in the different feather regions and the date of completion are recorded in table 13 by generations.

In the first generation there is opportunity for a comparison of a father with his two sons in line A. Although the time required for the molting process was highly variable, the sons molted at a more rapid rate than their sire in all regions except thigh, lower leg, and wing primaries. The date on which molting was complete was extremely close in father and sons, except in wing primaries. In wing primaries the sons completed their molt one month later than their sire.

Line A in the second generation showed little variability between father and sons either in the date that molt was completed in the different feather regions or in the average number of days required for the molt.

In line B in the second generation, the sire was a slow molting individual. In general, his sons molted more rapidly than their sire, but in wing molt they were slow. The four sons also completed their molt in the different regions at an earlier date than their sire. A comparison of the sons in lines A and B indicates that the males in line B molted their wing primaries more slowly and completed their wing molt at a considerably later date than those of line A.

Data are very meager for the third generation. In line A molt was completed rather early in most feather regions except the wing primaries, with the average date November 3.

For the three generations in line A the mean time required to shed all wing primaries was 98, 101.5, and 109.2 days, respectively. The corresponding dates of completion were Oct. 20, Oct. 23, and Nov. 3. The mean time interval for wing molt in the single generation of sons studied in line B was 115.5 days and the date of completion was Nov. 13. These limited data suggest that there may be a significant difference in molting of wing primaries between lines A and B.

TABLE 13.—MOLTING BEHAVIOR IN MALES IN THREE GENERATIONS. Time required and date of completion of annual molt in fathers and sons of Lines A and B.

Feather Region	Line A				Line B			
	Father		Sons		Father		Sons	
	Days	Date of Completion	Days	Date of Completion	Days	Date of Completion	Days	Date of Completion
First Generation, 1941								
Neck (Cervical)	70	Sept. 19	28.0	Sept. 29	42	Sept. 19		
Breast (Pectoral)	84	Oct. 3	49.0	Oct. 6	42	Oct. 3		
Thigh (Femoral)	42	Oct. 3	49.0	Oct. 13	98	Nov. 14		
Lower Leg (Tibial)	28	Sept. 19	35.0	Oct. 6	70	Oct. 31		
Back (Dorsal)	70	Sept. 19	42.0	Sept. 8	42	Sept. 19		
Wing Primaries	70	Sept. 19	98.0	Oct. 20	Incomplete			
Second Generation, 1942								
Neck (Cervical)	56	Sept. 9	49.0	Sept. 10	70	Sept. 23	35.0	Aug. 28
Breast (Pectoral)	56	Sept. 9	59.5	Sept. 28	14	Oct. 7	38.5	Sept 10
Thigh (Femoral)	70	Nov. 4	59.5	Oct. 26	56	Nov. 4	52.5	Oct. 23
Lower Leg (Tibial)	28	Oct. 7	35.0	Oct. 5	14	Nov. 4	35.0	Oct. 16
Back (Dorsal)	56	Sept. 9	59.5	Sept. 14	126	Nov. 18	56.0	Sept. 14
Wing Primaries	98	Oct. 21	101.5	Oct. 23	126	Dec. 2	115.5	Nov. 13
Third Generation, 1943								
Neck (Cervical)	28	Oct. 6	42.0	Aug. 30	28	Sept. 9		
Breast (Pectoral)	42	Oct. 6	33.6	Sept. 13	56	Oct. 7		
Thigh (Femoral)	42	Oct. 6	42.0	Oct. 9	56	Oct. 21		
Lower Leg (Tibial)	28	Oct. 6	44.8	Oct. 17	14	Sept. 23		
Back (Dorsal)	56	Sept. 8	56.0	Sept. 13	56	Sept. 9		
Wing Primaries	98	Oct. 20	109.2	Nov. 3	56	Nov. 4		

NOTE:

	Line A	Line B
First Generation	2 sons	No sons available
Second Generation	4 sons	4 sons
Third Generation	5 sons	No sons available

ABILITY TO LAY AFTER THE ONSET OF WING MOLT

As previously pointed out, molting behavior in wing primaries was more consistent and regular than in any of the other feather regions observed. An attempt was made to breed for the ability to lay for a considerable period after molting of wing primaries began. The rather limited data are presented in table 14.

In the first two generations, line A exhibited a considerably shorter period of wing molt than line B. In the third generation, line A showed a marked increase in the time required for wing primary molting and line B a marked decline.

In line A the date of completion of wing molt remained constant in the first two generations but came two weeks earlier in the third generation. In line B the date of completion was December 29 in the first generation, December 1 in the second generation, and December 12 in the third generation.

In the first generation, the mean number of eggs laid after molting of wing primaries began was greater in line A than in line B. In the second generation, the birds in line A averaged 11.1 fewer eggs after wing molt started than the birds in line B. In the third generation, the line A birds again showed heavier production after the molt started than did line B. Apparently no success was attained in this attempt to breed for increased production during wing molt.

In the first two generations, the number of eggs laid during the biological year and the number of eggs laid in 365 days were both significantly greater in line A than in line B. In the third generation, production was essentially the same in both lines.

There is no evidence in table 14 that selective breeding will increase the number of eggs laid while in wing molt.

TABLE 14.—BREEDING FOR THE ABILITY TO LAY AFTER THE ONSET OF WING MOLT.

	Line A		Line B	
	Number of Birds	Average	Number of Birds	Average
1941 Generation of Daughters				
Duration of wing molt, days	10	130.2	2	168.0
Date of completing wing molt	10	Dec. 7	2	Dec. 29
Number of eggs laid during wing molt	10	25.2	2	16.5
Production during biological year, eggs	10	190.5	2	136.5
Annual production, eggs	10	187.2	2	136.5
1942 Generation of Daughters				
Duration of wing molt, days	4	98.0	11	113.3
Date of completing wing molt	4	Dec. 11	11	Dec. 1
Number of eggs laid during wing molt	4	19.5	11	30.6
Production during biological year, eggs	4	290.0	11	246.7
Annual production, eggs	4	276.3	11	237.0
1943 Generation of Daughters				
Duration of wing molt, days	18	122.9	3	93.3
Date of completing wing molt	18	Nov. 25	3	Dec. 12
Number of eggs laid during wing molt	18	33.8	3	14.7
Production during biological year, eggs	18	235.4	3	237.7
Annual production, eggs	18	228.1	3	229.7

Relation of Wing Molt to Subsequent Hatchability

There is a rather widespread belief that very late molting may be inimical to subsequent hatchability. Hays (1943) found no correlation between the length of the biological laying year and subsequent hatchability. In table 15 some data are presented concerning the duration of wing molt, the time of completion of wing molt, and subsequent hatchability.

The rather fragmentary evidence suggests that if molting of wing primary feathers extends over a greater period than 14 weeks, it may be accompanied by reduced hatchability. There is also some evidence that the completion of molt after November may be associated with lower subsequent hatchability.

Table 15.—Relation of Duration and Month of Completion of Wing Molt to Subsequent Hatchability.

Duration of Wing Molt			Time of Completion of Wing Molt		
Number or Weeks	Number of Birds	Mean Hatchability	Month	Number of Birds	Mean Hatchability
8	1	94.0	September	–	–
10	2	88.0	October	–	–
12	1	100.0	November	13	88.8
14	2	93.5	December	15	77.1
16	6	83.0	January	6	81.3
18	4	80.0			
20	6	74.8			
22	10	80.4			
24	2	85.0			

Summary of Part II

Data secured on seven generations of stock bred for high fecundity furnish some important information.

Production males completed their molt earlier than females. The average date for males was October 30, and they required about 101 days to molt their wing primaries. The date of completion for most females was far in December, and they required 122 days or more to shed their wing primary feathers. Very insignificant changes in body weight during molt were observed in both males and females.

In those females with complete molt, the average number of days of laying while molting wing primaries was 72, with a mean of about 30 eggs. Late completion of wing primary molt was associated with higher persistency and a significantly greater number of eggs in the first year. Females in the two groups averaged to continue laying until the mean number of wing primaries shed was 3.8 and 3.3 respectively. For March and April hatched females, the biological laying year usually terminated in October.

There was no important association between the duration of wing primary molt and antecedent egg production. Month of onset of wing molt was secondary in importance to month of completion in relation to first-year egg production. Selective breeding, in an attempt to lengthen the period of laying while molting, gave inconclusive results.

GENERAL SUMMARY

Molting behavior in its relation to first-year egg production was studied in seven generations of Rhode Island Reds. A comparison was made between stocks bred for exhibition color and stocks bred for high fecundity. Both males and females were included in the study and all records were made on the first annual molt. Observations were taken at bi-weekly intervals beginning in the last week of July and extending through the month of December. An analysis of the data secured has led to the following deductions:

1. Molting behavior was more consistent in the ten wing primary feathers than in five other feather tracts studied.

2. The number of days and weeks spent in molting in different feather regions was not very important from the standpoint of first-year egg production.

3. The time of onset of wing primary molt had a significant effect on first-year egg production.

4. Date of completion of wing primary molt was probably the most important consideration from the standpoint of antecedent egg production.

5. Birds bred for high fecundity had the ability to lay for a considerable period after wing molt began, and superior layers did not usually stop laying until three or more primaries had been lost.

6. Males and females bred for high fecundity completed their annual molt later than stock bred for exhibition color. Males usually completed their molt more than a month earlier than females.

7. A decline in body weight during annual molt was characteristic of exhibition males and females. Males bred for production did not exhibit this decline, but females showed a slight decline at the height of the molt.

8. Evidence was inconclusive that selective breeding can increase the length of the laying period during wing primary molt. There is evidence, however, that the date of completion of molt is governed by inheritance.

9. Hatchability during the second laying year may be reduced by extremely long periods of molt as well as by a very late termination of molt.

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Publication of this Document Approved by Commission on Administration and Finance
4 M 1-46-17629.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 430 MARCH, 1946

Postwar Readjustments In Massachusetts Agriculture

By David Rozman

Among the various postwar readjustments leading to greater efficiency and lower costs, primary consideration should be given to the reconstruction of farm units to take full advantage of land resources.

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SUMMARY AND CONCLUSIONS

1. In the postwar period adjustments in Massachusetts agriculture will be needed both to correct previous maladjustments and to meet new developments and situations.

2. The analysis of commercial farming units in Massachusetts indicates that more than half of them fail to meet the desirable requirements of income for farm families.

3. The greatest need is for the reconstruction of substandard farming units into efficient, economic family farms capable of providing an adequate level of living under modern conditions.

4. The best opportunity for reconstruction of farms is found in the rebuilding of land resources which are at the basis of farm operations.

5. Large areas of undeveloped farm land of suitable quality are available both on farms and in adjacent rural areas.

6. Recent experience with modern power machinery, especially bulldozers, power shovels, and bog harrows, indicates that there is a good possibility for land clearing and development through removal of stones and stone walls, clearing of trees and brush, and drainage of fields. Reduction in costs will be possible by cooperative efforts, particularly through recently established soil conservation districts.

7. The classification of soil and field investigations carried out in a number of towns indicate that improvement of undeveloped areas, where justified by costs and resulting benefits, may serve to enlarge and improve land resources on existing farms, make possible the replacement of poor land now in use, and provide for new farming units.

8. In the towns of Southwick and Uxbridge where an intensive investigation has been carried on, there is a possibility of adding about 10 percent to the number of existing commercial farming units. Some of them can be utilized for the replacement of farms located in isolated areas.

9. The irregular distribution of the available land and the complicated pattern of land ownership present some difficulties in adding new tracts from undeveloped areas to existing farm units.

10. The conditions found in the town of Hubbardston indicate the necessity of careful planning in land acquisition for public purposes, to preserve a proper balance in the agricultural position of rural towns.

11. Management of farm woodlands, which represent about 37 percent of the total area of Massachusetts farms, will have to be integrated with other farming operations to secure higher returns to the producers.

12. The improvement in the condition and productivity of pasture and hay lands, the most important assets in Massachusetts agriculture, will reduce costs and improve the position of many Massachusetts farms.

13. In all important enterprises in Massachusetts agriculture, as represented by dairy, poultry, fruit, and vegetable farming, the prospects in the postwar period warrant the expectation of a high level of demand and consumption.

14. The position of Massachusetts agriculture in the postwar period will be determined by the success in reduction of costs through the adoption of the most efficient methods, whether they are in the use of land resources, the employment of labor, the use of machinery, or the marketing efforts.

POSTWAR READJUSTMENTS IN MASSACHUSETTS AGRICULTURE

By David Rozman,[1] Research Professor in Economics

INTRODUCTION AND PROCEDURE

In the postwar period the agriculture of Massachusetts, like that of other sections of the country, will be confronted with many problems of readjustment. This is not alone because of many dislocations in the normal channels of production and distribution, but also because a war of such magnitude and scope will make its imprint on practically every sector of our life. For one thing the technological changes in many fields of endeavor, which under normal circumstances proceed at a measured pace, have been accelerated and have brought about results which otherwise would have eventuated only after a long period of time.

Some of the new developments are of such a nature as to be of immense help to Massachusetts agriculture. These include all kinds of machinery better adapted for both clearing and cultivation of land; expanded facilities for the production of fertilizers at lower costs; new spraying materials to combat effectively injurious insects and plant diseases; and further improvement in the strains and varieties of plant seeds and livestock. Likewise an intensive campaign for better nutrition under wartime conditions has resulted in greater appreciation by consumers and higher demand for dairy, poultry, vegetable, and fruit products. All these are supplied by major farming enterprises of Massachusetts agriculture.

On the other hand, in the field of processing and transportation of agricultural products, new improvements and facilities have been developed which point to the possibility of greater competition for Massachusetts markets from other areas. It is not yet certain what will be the effect of speedier delivery of perishable products from longer distances or what will be the response of consumers to improved varieties of processed foods; but these are factors to be taken into consideration in appraising the future possibilities in local markets.

Whatever may be the significance of various new factors projected into the agricultural scene, one thing appears certain: to maintain their position and to keep farming in this State on a sound and solvent basis, it will be imperative for local producers to take full advantage of better methods and facilities, whether they pertain to the use of land, the introduction of improved varieties of plants and animal breeding processes, more efficient application of labor, or better marketing methods.

Sources of Information and Methods of Study

In obtaining the material for the present study both field work and analysis of the basic sources of information were extensively used. On the land utilization and production side some of the field work was carried out in a number of rural areas largely in cooperation with the United States Department of Agriculture. For a period of three years during wartime the AAA obtained records on practically all commercial farms in the State, indicating the trend in the different lines of production and also some changes in the methods of cultivation. These records were tabulated and analyzed for the present study to gain a view of the readjustments carried out during the war period. The assessors' figures and

[1]The author wishes to acknowledge the assistance of Ruth E. Sherburne in all phases of this study.

animal inspection data on the numbers and various types of livestock provided a basis for an analysis of distribution of livestock by size of enterprises in individual towns and areas. Likewise, United States Census figures and publications of the United States Department of Agriculture dealing with the trends of various phases of farm business in the State were thoroughly scrutinized for the bearing they have on the problem at hand. Previous studies on land utilization in the State by the author likewise provided a basis for developing further analysis in connection with possible readjustment in this field. For the last several years annual examination has been made of the trends and methods of production with a view to increasing State production under wartime conditions. The opinion of farm groups, agricultural leaders, and technicians during that time proved helpful in appraising the basic information and desirable adjustment relative to the various phases of agricultural production in Massachusetts.

Improvement of Agricultural Opportunities on the Existing Farms

Over a period of years the pattern of land utilization on many Massachusetts farms has become such as to render them gradually more nearly obsolete, from the standpoint of modern mechanical methods of operation. This in turn has made them inadequate to provide the necessary level of living under present conditions, and has resulted in a fundamental tendency of the agricultural set-up to be lacking in suitable opportunities in farming for deserving young men in rural areas. The plain facts indicate that the proportion of young men operating farms in Massachusetts has been declining for a number of years, while the proportion of older men has been constantly on the increase. This tendency has

TABLE 1.—AGE OF FARM OPERATORS, 1910-1940.

Age Group	1910		1920		1930		1940	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Massachusetts								
Under 25	439	1	393	1	233	1	330	1
25 – 34	3,575	10	3,072	10	1,822	7	2,369	7
35 – 44	7,904	21	6,388	20	5,137	20	5,005	16
45 – 54	9,468	26	8,580	27	6,483	25	8,229	26
55 – 64	7,740	21	7,146	22	5,964	23	7,700	24
65 or over	7,402	20	5,613	18	4,537	18	6,790	21
Not reporting	389	1	809	2	1,422	6	1,474	5
Total	36,917	100	32,001	100	25,598	100	31,897	100
United States								
Under 25	419,330	7	383,680	6	371,679	6	233,355	4
25 – 34	1,413,876	22	1,333,020	21	1,049,052	17	949,350	16
35 – 44	1,571,469	25	1,587,519	25	1,452,425	24	1,250,893	21
45 – 54	1,432,707	22	1,482,494	23	1,459,959	24	1,427,561	25
55 – 64	947,524	15	993,771	16	1,064,034	18	1,146,540	20
65 or over	554,570	9	583,679	9	676,374	11	828,251	14
Total	6,339,476	100	6,364,163	100	6,073,523	100	5,835,950	100

From U. S. Census

been in progress for the country as a whole, but the proportion of Massachusetts farmers in the older age groups is higher, even allowing for a greater amount of owner operation.

As will be seen from Table 1, farm operators in the age group of 45 and over represented 71.3 percent of the total number in Massachusetts as compared with 58.3 percent for the United States as a whole. The same comparison for the age group of 55 and over indicates 45.5 percent and 33.8 percent respectively. Recent rural surveys conducted by the College confirm this situation, as well as the fact that a number of farms drop out of use after the death of an aged operator because of insufficient numbers of young people willing to undertake farming. It must of course be admitted that in some cases tenure problems and lack of capital exert an important influence, but by and large the fundamental difficulty is that many farms have ceased to be efficient economic family units.

The extent to which a number of farms in Massachusetts fail to come up to the level required for an adequate standard of living is demonstrated in Chart 1. On the basis of the 1940 Census of Agriculture, there were 31,897 farms in Massa-

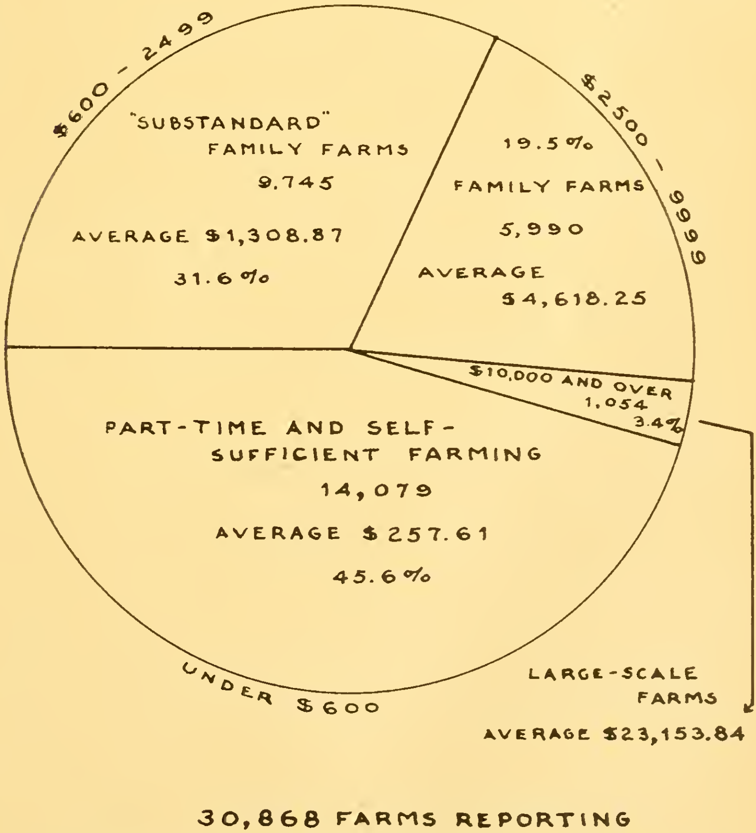


Chart 1. Massachusetts Farms Classified on the Basis of Type and Value of Output. Source: U. S. Census, 1940.

chusetts, and of these 30,868 reported as to the total value of agricultural output. For the purposes of this study these farms were classified into four groups with respect to the value of agricultural output. The classification takes into consideration also the number of producers engaged in part-time farming as reported by the Census. Because of the variety of conditions both in part-time farming and among different types of commercial farming, a certain amount of overlapping from one group to another is unavoidable. This factor, however, is of only minor significance for the purposes of the present discussion.

The largest group, 14,079 farms with under $600 of output and an average of $257.61, is represented by part-time and self-sufficient farming. Farming here is only subsidiary to other work or other income, and therefore does not carry the responsibility of full family support. However, the next largest group of 9,745 farming units, with an output between $600 and $2500 and an average of $1309 per farm, presents a real problem. It is evident that these farms, because of either inadequacy of land resources or inefficiency of operation, are not the kind to be depended upon to provide a satisfactory living by modern standards. In the ensuing years the farms in this group will require the full attention of the agricultural agencies working in the field of farm improvement. Undoubtedly many of these substandard family farms have such meager resources that the only proper thing to do is to retire them from agricultural operation entirely. On the other hand, there will be many cases where, by combination of two or three farming units or by land improvements on the individual farms, it will be possible to develop an efficient economic family unit.

ADJUSTMENTS IN AGRICULTURAL LAND USE

Major Factor — Land Use Readjustment

The field of adjustments in Massachusetts agriculture which promises the most far-reaching results, but which so far has been tackled only very perfunctorily, is the improvement of land utilization. The present maladjustments are not the results of the war or the period immediately preceding it. They have been developing over a long period of time and are intimately connected with the history of land use in this State.

The early settlers hacked their fields out of the wilderness, used their available human and animal labor to remove some of the stones, and piled up stone walls around their farms and fields, thus determining for a long time ahead the shape and size not only of their farms but also of individual fields. What was a great constructive effort and the foundation of agricultural development at the time, has become in the course of years a handicap to the adoption of more efficient methods of land utilization in the period of mechanization. The pattern of land utilization is very ill-adapted to the prevailing methods and largely for this reason considerable areas have been withdrawn from cultivation. For the State as a whole, for instance, between 1880 and 1940 the improved land declined from 63.4 percent to 40.7 percent of the total land in farming. While much of this land was undoubtedly of inferior quality and should have been withdrawn under any conditions, a considerable amount was of good quality, and an even greater amount could have been rendered suitable for cultivation by appropriate means. The latest developments in technology indicate that, as far as agricultural land is concerned, machinery will be used not only for the cultivation of the land but also for the remaking of the land to a much greater extent than has been possible heretofore. The present study of land resources in their relation to other adjustments is based largely on the above vital considerations.

On the basis of recent studies made by the Massachusetts Agricultural Experiment Station and the Soil Conservation Service, at least one and one-half million acres of land in the State are suitable for one or another sort of agricultural utilization. About one-third of this area is outside of existing farms. Of about one million acres of suitable land on farms, only one-half is used for crops, including hayland. In spite of this, there is some land in farms that should be taken out of cultivation because of inferior quality or general deterioration. On the other hand, new areas of good land, both on existing farms and in outside areas could be brought into cultivation through one or a combination of several reclamation measures. These include clearance of brush and timber, drainage of wet and swampy areas, removal of stones and stone walls, and irrigation of some limited areas.

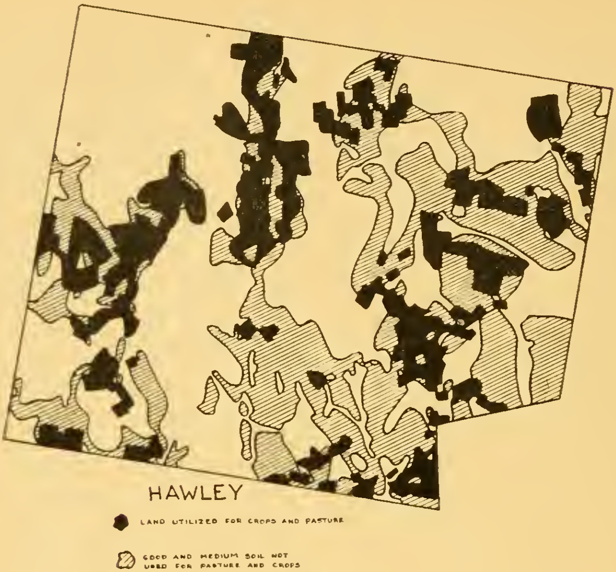
The greatest obstacles to the introduction of mechanical equipment in the cultivation of Massachusetts land are the rough terrain, the rocky and stony soils, and the considerable amount of wet land. All such areas were the first to be retired from agriculture. The most important result of these developments is not so much that the total land under cultivation has declined; of much greater significance is the fact that the land which has continued in cultivation is scattered in small patches all over the farm. This in turn has imposed a further limitation on the use of mechanical equipment and caused a considerable loss of the operator's time in moving from one small field to another. The same reduction in efficiency of farm operations is caused by the presence of stone walls on a good many farms.

Within recent years some manufacturers of farm equipment have taken definite steps to bring into the market smaller types of machinery better adapted to the scattered New England fields. This, however, meets the situation only partially and inadequately. The fundamental problem remains one of consolidating the scattered fields, and, where necessary, increasing the total amount of arable land on farms in order to obtain an efficient and economic family unit capable of using modern mechanical methods. With the needed land improvements accomplished in the field of land utilization and with desirable production and marketing methods adopted, Massachusetts producers should be in a better position to reduce the cost of production to a much narrower margin in relation to major producing regions.

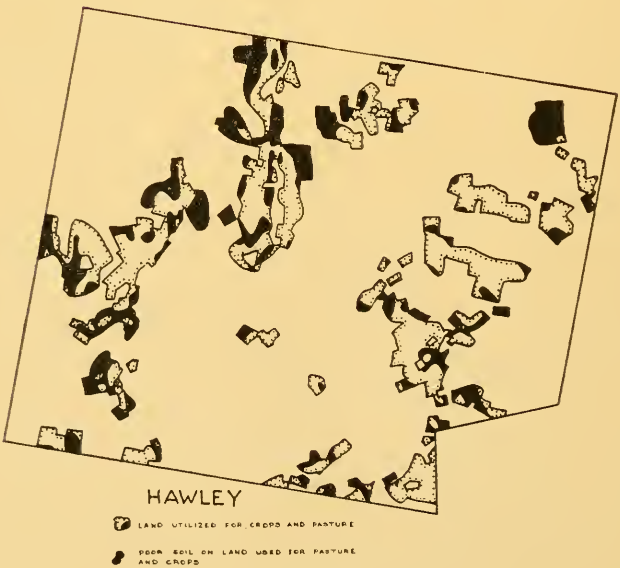
Undeveloped Land Areas of Suitable Quality

Inasmuch as undeveloped land areas of suitable quality are found both inside and outside of the boundaries of existing farms, they may become a source of needed adjustments along several important lines. In the first place, they may provide additional land for the enlargement of cultivated areas on farms where there is a need for the additional acres. On some farms where additional land for cultivation does not present a problem, undeveloped land of good quality may be brought into cultivation for the replacement of land tracts of poor quality. In some towns where undeveloped land is found in large tracts, new farm units may be developed to serve as replacements for existing farms which are likely to go out of use because of inferior soil or because of their isolated location in the town. In some towns where the isolation of individual farms presents a problem of providing good roads and other public services, a well-organized plan of relocation may be of real benefit to the entire rural economy of the area.

In an effort to determine the possibilities involved in drawing upon undeveloped land areas as a source of major land utilization adjustments in Massachusetts agriculture, thorough consideration has been given to the basic data already


HAWLEY
LAND UTILIZED FOR CROPS AND PASTURE
GOOD AND MEDIUM SOIL NOT USED FOR PASTURE AND CROPS

Map 1


HAWLEY
LAND UTILIZED FOR CROPS AND PASTURE
POOR SOIL ON LAND USED FOR PASTURE AND CROPS

Map 2

Map 3

Map 4

accumulated in this field. In a previous study[2] of land resources an analysis was made of rural communities with respect to predominant types of soil and intensity of utilization. The soil types in each town were classified into three groups of good, medium, and poor suitability and then plotted on a map drawn on the same scale as the land utilization maps made available from the land use survey of the State Planning Board. It was possible, therefore, to make an analysis of the character of the existing land utilization by superimposing the land use map on that of soil classification. The results indicated the lands of good and medium suitability not now used for crops and pasture, and likewise the presence and location of poor land that is cultivated on the existing farms. This set of conditions is illustrated on the maps for the towns of Hawley in Franklin County, Brookfield in Worcester County, and Brimfield in Hampden County.

The first pair of maps presents a town where the percentage of good and medium land to total town area is low as compared with other towns, or, stated briefly, with a low percentage of land suitability; the third pair, a town with a higher percentage of land suitability; and the second pair, a town of an intermediate type. The undeveloped lands of suitable quality indicated on these maps are located both on and outside of the farms, while the poor land under cultivation is naturally a part of some farming unit.

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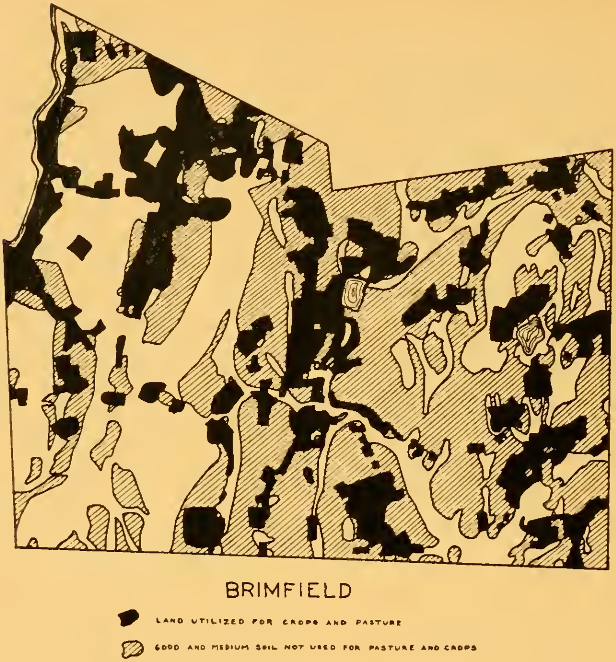
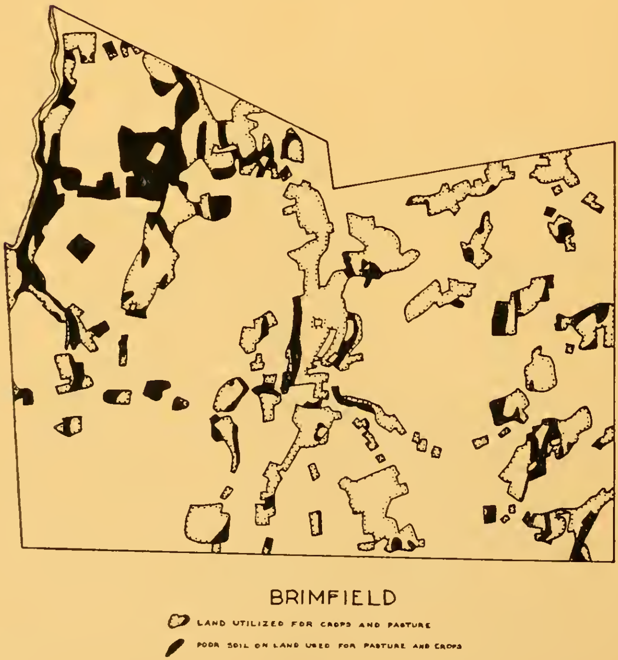
[2]Rozman, David. Interrelationship of Land Uses in Rural Massachusetts. Mass. Agr. Exp. Sta. Bul. No. 387. Dec. 1941.


BRIMFIELD
LAND UTILIZED FOR CROPS AND PASTURE
GOOD AND MEDIUM SOIL NOT USED FOR PASTURE AND CROPS

Map 5


BRIMFIELD
LAND UTILIZED FOR CROPS AND PASTURE
POOR SOIL ON LAND USED FOR PASTURE AND CROPS

Map 6

Towns Covered by Field Work and Investigation

In order to take account of the full significance of the relationship of land suitability and land utilization, field investigations and observations have been made in a number of towns. In addition, three towns with varying proportions of land suitability were mapped out and examined as to suitable land not in agricultural use. In many towns where the total proportion of good land is low, the areas of suitable land not utilized for agriculture were found to be as large as in towns with better land. However, in view of their general unfavorable environment, the towns with predominantly poor soil would be the last in line to be considered as desirable for agricultural development even though there might be a scattering of sizable areas of potentially good land. Moreover, care was taken not to include towns where agricultural land values are brought out of line by existing or potential higher land uses, as is the case in many towns in the eastern part of the State. On the basis of these criteria the towns selected for intensive study were Southwick in Hampden County and Uxbridge and Hubbardston in Worcester County.[3] These towns have a fair amount of good agricultural land and represent the most important types of farming in Massachusetts, such as dairy, poultry, fruit, and vegetable.

The Town of Southwick

GENERAL DESCRIPTION

Located in the Connecticut River Valley, the town of Southwick is in a good farming area. In addition to the major farming enterprises characteristic of the State, the town has a considerable acreage of crops typical in the Valley, like tobacco, potatoes, and onions. According to the 1940 Census there were 169 farms in Southwick. As disclosed by both the AAA records and the Census figures, less than half of these were full-time commercial farms, the rest being part-time farms or rural residences. Supplementary work is provided by the two nearest industrial centers, Springfield and Westfield. Likewise, the local agricultural products are marketed largely in these two industrial centers, although a considerable amount is also trucked into other areas.

In addition to farming, part-time farming, and rural residential areas, the town also has summer recreational developments, largely in connection with Congamond Lake.

The town of Southwick, in common with other agricultural communities in the Connecticut River Valley, has shown an increase both in population and in agricultural output. The number of dwelling houses increased even more rapidly because of considerable recreational developments. The total number of houses assessed in 1944 was 812 compared with 260 in 1910.

According to the State Census of 1875, the amount of cultivated land in Southwick was 4,523 acres as compared with 3,709 acres in 1940 registered by the Federal Census. This is a sizable decline, but not as large as occurred in most of the other sections of the State. On the basis of all the evidence obtained, it appears that the town of Southwick has a good agricultural foundation and would derive considerable benefit from improvement in the pattern of its agricultural land utilization.

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[3]In cooperation with Arthur J. Walrath of the United States Department of Agriculture.

SIZE AND DISTRIBUTION OF LAND OWNERSHIP

In order to ascertain the character and distribution of undeveloped land in the town of Southwick, the ownership of land by individual holdings was analyzed from the assessors' records. For this purpose all holdings of three acres or more were tabulated in two groups, those with buildings and those without. The latter group apparently represents the land tracts that either are not used at all or are used only incidentally in connection with adjoining farm areas. In other words, these are the areas where most of the undeveloped land outside of the existing farms is concentrated and which, depending on their quality, comprise a pool on which to draw for desirable adjustments in the land utilization pattern.

From Table 2 it will be seen that there are in the town 192 tracts of land of three acres or over without buildings, compared with 300 having buildings; the total acreage for these two groups is 4,525 and 12,615 respectively. The tracts without buildings are smaller on the average than those with buildings. There were only 25 tracts of land of 50 acres or more without buildings available in the town. The average assessed valuation of land without buildings is $20.53 per acre, compared with $30.98 for land with buildings. From all these figures it appears that there is a considerable amount of undeveloped land and that it is assessed for taxation purposes at a valuation rate somewhat lower than land in use, but sufficiently high to raise the question of the necessity of getting proper returns, where conditions are favorable.

TABLE 2.—SOUTHWICK: LAND OWNERSHIP AND ASSESSMENT OF TRACTS OF THREE ACRES OR MORE.

Size of Tract (Acres)	With Buildings			Without Buildings		
	Number	Acres	Assessment per Acre	Number	Acres	Assessment per Acre
			Residents			
3 – 9.9	63	337	$81	44	256	$33
10 – 19.9	43	579	47	56	769	21
20 – 29.9	35	811	45	38	867	17
30 – 39.9	37	1,302	32	10	342	15
40 – 49.9	22	954	31	8	341	32
50 or over	77	7,314	26	23	1,629	21
Total	277	11,297	31	179	4,204	21
			Non-Residents			
3 – 9.9	5	26	46	3	18	33
10 – 19.9	4	52	77	4	51	9
20 – 29.9	2	42	15	1	25	10
30 – 39.9	3	105	65	2	73	10
40 – 49.9	2	84	68	1	40	6
50 or over	7	1,009	21	2	115	12
Total	23	1,318	30	13	322	11
Both	300	12,615	31	192	4,526	21

From assessors' books.

LOCATION OF UNDEVELOPED LAND IN RELATION TO AGRICULTURAL USE

An examination of Map 7 reveals that the town of Southwick has considerable areas of suitable land not used for pasture or crops. In this particular map no differentiation is made as to whether these suitable areas are located on farms or outside of them. To gain a clearer picture of this situation it was necessary to map out the farm boundaries. In the town of Southwick it was possible to carry this out in a rough way because of the availability of an AAA aerial survey. As indicated on Map 8, when undeveloped land of suitable quality is plotted in relation to the farm boundaries, comparatively little of it remains outside of existing farms. This clearly shows that the major advantages to be gained from undeveloped land will be in the readjustment of the present farm land resources. The necessity and opportunities for such adjustment are brought out by Map 9 which discloses a considerable amount of poor quality land utilized for agricultural purposes on existing farms.

Under a proper reconstruction program of land utilization this poor land now in use could be retired and replacement made from better quality land areas which are available within present boundaries of the farm. Moreover, such a program should result in a better and more efficient outlay of the entire farming unit, making it more suitable for the employment of mechanized equipment. The whole plan of improvement would be carried out only to the extent that over-all benefits justified the cost.

In order to determine the significance of undeveloped lands of suitable nature outside of existing farms, these areas have been thoroughly examined in the field and their importance for agricultural use appraised from different angles. Much of this land, of course, adjoins farms already in operation and its primary importance would be to serve as a potential land supply for readjustments of the active farming units. The remaining areas of undeveloped land suitable for agriculture were examined primarily as a source for creating new farming units.

As will be seen from Map 8 one large area of undeveloped land of desirable quality is concentrated in the northeastern section of the town. This section is the least developed and, from the Roads and Waterways Map, it appears to be also least well supplied with roads and means of communication. The greatest part is covered with woods of poor second growth. It is relatively level, with part of the area broken by a small stream.

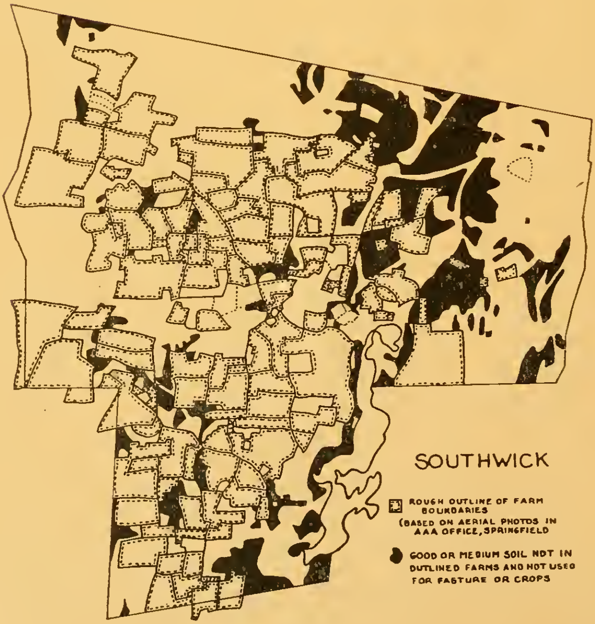
Bringing this land into cultivation would require the removal of the present forest growth and some old stumps, and a small amount of drainage. Most of the area would be suitable for truck crops, although in places it would require additional irrigation facilities. With all the necessary work carried out, the area would provide for about a dozen new farming units. In relation to the total number of commercial farms in the town of Southwick the potential increase would be not much above 10 percent. This estimate is based at this point on purely physical possibilities, without taking into consideration the costs of bringing land into cultivation.

BENEFITS AND COSTS OF LAND IMPROVEMENT

While the clearing of stones, stumps, and brush from land has been practiced on Massachusetts farms in a limited way for a good many years, these operations have recently become more extensive and are carried out by a greater use of mechanized power. It is precisely the use of heavy-duty equipment like power shovels, bulldozers, and bog harrows that focuses attention on the possibility


SOUTHWICK
GOOD OR MEDIUM SOIL NOT USED FOR PASTURE OR CROPS

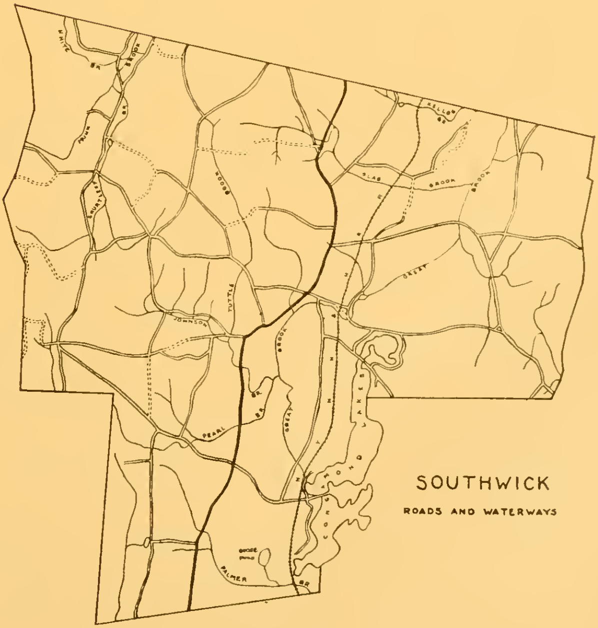
Map 7


SOUTHWICK
ROUGH OUTLINE OF FARM BOUNDARIES
(BASED ON AERIAL PHOTOS IN AAA OFFICE, SPRINGFIELD
GOOD OR MEDIUM SOIL NOT IN OUTLINED FARMS AND NOT USED FOR PASTURE OR CROPS

Map 8


SOUTHWICK
CROP LAND ON POOR SOIL

Map 9


SOUTHWICK
ROADS AND WATERWAYS

Map 10

of land-clearing operations on a greater scale. Whether such operations will become an important factor in the improvement of land utilization on farms will depend, in the final analysis, upon the benefits received in relation to the costs involved. As far as benefits are concerned they should be appraised thoroughly in each individual case. In some situations the clearing of an acre of land will result merely in the addition of an acre of crop or pasture land to the total acreage of the farm. In other cases, the clearing of one or more acres of land may lead to the consolidation of individual fields and provide opportunity for more efficient and economical operation of the entire acreage on the farm. In the latter case the benefits received are reflected in the improvement of an area much larger than that immediately cleared. The removal of stone walls or the drainage of small wet areas likewise may lead to considerable enhancement in the efficiency and value of the entire farm acreage.

The cost of clearing land with heavy-duty machinery or by any other means will depend first of all on the condition of the land to be cleared. The costs will increase with a greater amount of stoniness or larger stones. In this respect there is a variety of conditions beginning with the most favorable situations and ending with the presence of large boulders which it would not be practical to remove with the best machinery available. The removal of stumps offers the same problems with different gradations of difficulties.

A recent study[4] by the Massachusetts Agricultural Experiment Station in cooperation with the United States Department of Agriculture investigated a number of farms where land clearance operations were carried out, with the objective of determining the costs under varying conditions. The total cost of clearing for pasture, including the fertilization, seeding, and other operations for final utilization, ranged from $100 to as high as $175 per acre under less favorable conditions. The clearing alone cost about one-third less than the above figures. Most of this work is being done on contract. It is estimated that where the bulldozer and other machinery are owned the total costs of clearing would range from $75 to $100 per acre of cropland.

In actual experience, the operations so far examined in Massachusetts have been conducted on an individual basis and take into consideration the costs prevailing largely under wartime conditions. However, should the needed equipment and machinery become available on favorable terms, and operations be carried out on a cooperative basis through a continuous process on a number of farms, it should be possible to make a considerable reduction in costs.

In this connection, advantage might be taken of surplus equipment being disposed of by the Army for civilian use. The purchase and operation of this equipment cooperatively, possibly through the instrumentality of the recently adopted State provision for soil conservation districts, might be considered a promising arrangement. A considerable amount of educational work will be needed by the Extension Service and other agricultural agencies to point out to producers all the advantages as well as the difficulties involved in adopting a program of land clearance. In order to obtain adequate results it will be necessary to subject each individual case to a thorough analysis as to the character and condition of soil, the possible kind of improvement, and the resulting benefit to the entire farming unit.

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[4]Creek, C. R. and Hauck, J. F. Article in Farm Economic Facts, Massachusetts State College, March 1945.

The Town of Uxbridge

GENERAL DESCRIPTION

The town of Uxbridge in its land utilization possibilities is in many respects similar to Southwick. There are, however, some differences in the general make-up of the towns. Unlike Southwick, Uxbridge is predominantly an industrial community, with agriculture occupying an important place. As in most of the other towns of the State, the number of farms and the land in farms has declined since the end of the last century. According to the State Census of 1875, with a somewhat different definition of a farm from the present Federal Census classification, there were 224 farms. In 1940 there were only 156 farms. Of these, at least one-half were part-time farms and rural residences. Because of the industrial factor in the town, part-time farming is generally at a high point of development. The decline in the land area in farms in Uxbridge since 1875 amounted to almost 40 percent. In spite of this the volume of agricultural production has remained on about the same level, and has been even higher in some lines. On dairy farms, which are of major importance in local agriculture, the number of cows was about the same in 1940 as in 1880, the figures being 578 and 574 respectively. The total output of dairy products, however, is now considerably higher because of higher yields per cow. The number of fowls showed considerable expansion, in accordance with the general trend in the State in this line of agricultural activity. There were 6,799 hens assessed in 1940 compared with 2,365 in 1895. The cultivated land declined from 4,381 acres in 1875 to 2,895 acres in 1940.

Comparison of the present make-up of the town with old maps indicating the areas of occupancy, reveals that there has been a shift in land utilization. Over a period of time there has been a general migration from the southwestern part of the town towards the northwestern section.

The population trend in Uxbridge has been definitely upward, largely as the result of industrial activity. From 3,111 in 1880, the population increased to 6,417 in 1940. This situation has been responsible for a good demand for agricultural products, so that the major portion of the local output is marketed within the town.

SIZE AND DISTRIBUTION OF LAND OWNERSHIP

In the town of Uxbridge the tracts of three acres or more without buildings were distributed in 367 ownerships, this number being almost twice as high as in the town of Southwick. The majority of the holdings are small, however, with 163 of them less than 10 acres. There were only 16 holdings of 50 acres or more.

The multiplicity of small holdings indicates that the most favorable conditions for utilization of this land would be again in the enlargement of existing farms. To form a new farming unit out of several tracts would in most cases involve the difficulty of finding them together in one convenient location. The most important handicap, however, would be the acquisition of ownership from a number of present holders, some of whom may be reluctant to sell. In addition, the question of boundaries of individual tracts in the rural areas of the State is often confused, making the transfer of ownership difficult. The total number of tracts of 50 acres or more — the size which may be considered the lower limit for establishing the prevailing type of commercial farming — amounted to only 16 units.

Table 3.—Uxbridge: Land Ownership and Assessment of Tracts of Three or More Acres.

Size of Tract (Acres)	With Buildings			Without Buildings		
	Number	Acres	Assessment per Acre	Number	Acres	Assessment per Acre
			Residents			
3 – 9.9	99	535	$93	130	796	$27
10 – 19.9	38	538	31	76	1,086	16
20 – 29.9	20	466	27	48	1,108	13
30 – 39.9	17	581	25	18	588	11
40 – 49.9	21	936	16	10	424	11
50 or over	61	5,328	18	13	1,264	9
Total	256	8,384	24	295	5,266	14
			Non-Residents			
3 – 9.9	3	14	43	33	187	47
10 – 19.9	3	43	26	26	360	22
20 – 29.9	1	26	20	8	177	14
30 – 39.9	0	—	—	2	60	8
40 – 49.9	1	40	10	0	—	—
50 or over	2	177	10	3	240	13
Total	10	300	15	72	1,024	22
Both	266	8,684	24	367	6,290	16

From assessors' books.

The consideration of the size and distribution of undeveloped tracts confirms, in general, the conclusions gained from study in the field in regard to both the improvement of existing farm units and the formation of new farms. The possibilities in the first type of utilization are undoubtedly much greater than in the latter.

UNDEVELOPED LAND IN RELATION TO AGRICULTURAL USE

In a previous land utilization study (Mass. Agr. Expt. Sta. Bul. 387) it was estimated that in Uxbridge 35.4 percent of the total area was of good suitability and 38 percent of medium suitability, but only 16.7 percent of the total area was in any form of agricultural use.

As will be seen from Map 11, there are in general three large areas which appear to be potentially available for desirable adjustments in land utilization. As in the case of Southwick, most of this is in existing farms. Another large portion is scattered in small tracts with a considerable amount of it adjoining existing farms. These areas, both within farms and outside of them in convenient position, form a potential reservoir for the desirable adjustments of land utilization.

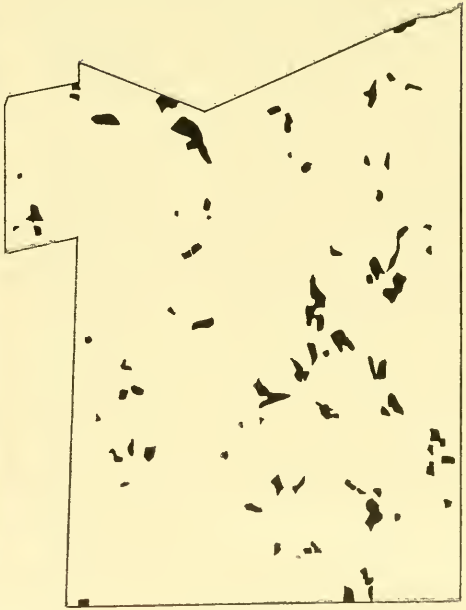
Map 12 shows areas of poor quality, now in farms, which are used for crops. These are to be in the first line of possible adjustments. On the other hand, if

UXBRIDGE

LAND UTILIZED FOR CROPS AND PASTURE

GOOD AND MEDIUM SOIL NOT USED FOR PASTURE OR CROPS

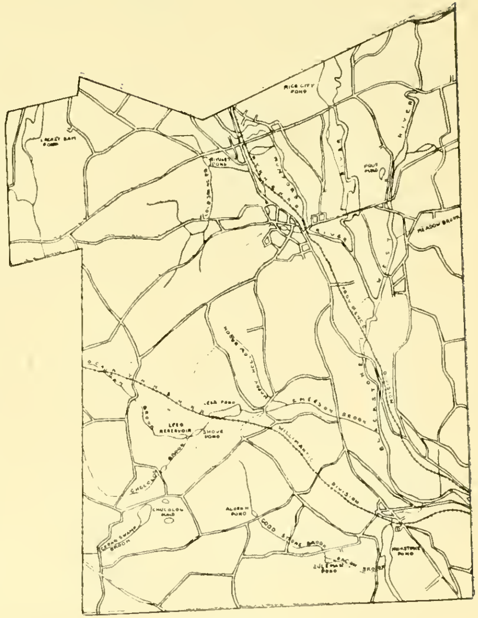
Map 11



UXBRIDGE

PASTURE AND CROP LAND ON POOR SOIL

Map 12



UXBRIDGE

ROADS AND WATERWAYS

Map 13

any farm in the vicinity of good areas of unused land needs additional tracts, these are often available, provided ownership can be settled. Many of these areas are now being utilized by farmers on the basis of some arrangement for pasture and hay. This condition is not always satisfactory as it ordinarily leaves the land as it is without allowing for any major improvement. Wherever a farmer can rehabilitate such land to his advantage and obtain the title, it will become an active factor in the improvement of land utilization.

In the northwestern part of the town there are several tracts which might offer such opportunities. One tract of approximately 80 acres is covered with a heavy mixed forest growth. If this land were cleared and otherwise improved, farmers in the adjoining areas would greatly benefit. Two farms in the immediate vicinity have only 10 acres of pasture, while others have only a slightly larger acreage of pasture. Another detached tract in the same area contains about 200 acres. With certain major improvements, and especially with the removal of some boulders, this could be used not only as a source of land for existing farms, but also for the development of one or two new farms. The factor to be taken into consideration is the strong demand for land in this vicinity for part-time farming which can compete with commercial farming in the matter of land values.

Other undeveloped tracts, ranging from 80 acres upward, are found in this area and in the west central part of the town.

In the southwestern section of the town there are also several compact sizable tracts of land with very little agricultural utilization. The present occupants are either residential or part-time farmers. Potentially there is a place for several full-sized farms, but present land utilization is determined by the character of the ownership. Some land in a sizable tract is also present in the southeastern part of the town.

On the whole, good opportunities for increased land utilization in Uxbridge will be found in the existing farms and the adjoining land. For relocation or other new developments, not more than 10 farms could be conveniently developed. Under these conditions the potential increase in new commercial farming units would be around 10 percent of the existing farms, which is very similar to the situation found in the town of Southwick.

The Town of Hubbardston

PUBLIC OWNERSHIP FACTOR

The town of Hubbardston is an example of a community which possesses considerable land areas of suitable nature for prevailing agricultural developments, but which has met reverses in its land utilization and total amount of agriculture. Traditionally, the main farming enterprise has been dairying, but the dislocation of markets and new areas of supply placed Hubbardston, in the recent past, at a disadvantage in disposing of its milk. Especially during the depression of 1930, Hubbardston had to curtail considerably its sale of milk to its important markets in Gardner, Fitchburg, and Worcester.

Tracing further back, the total land area in farms declined from 17,305 in 1875 to 9,551 acres in 1940. The main decline, however, occurred after 1925 when acreage in farms still amounted to 16,029 acres. One of the main factors has been the purchase of land by the Metropolitan Water Commission for the protection of water supplies, which, by 1944, had resulted in this agency's holding the title to 6,200 acres, a large part of which was formerly in farming. In addition, the Conservation Department holds title to 1,027 acres in State Forests.

LAND IN PUBLIC OWNERSHIP
HUBBARDSTON

HUBBARDSTON
ROADS AND WATERWAYS

Public ownership thus has more than a quarter of the total town area of 26,304 acres. Much of the land in public ownership is of a type suitable for agricultural development.

The public acquisition of large areas of land, especially if they are not all in one section of the town but are scattered, ordinarily affects the rural community in two respects. First, it reduces the total receipts of taxation. In Hubbardston so far this is not an important factor, inasmuch as the Metropolitan Water Commission continues to pay the amounts collected from former ownership, although livestock taxation receipts are not included in payments. Second, it disturbs the economic set-up of the town. If there are, for instance, several dairy farms in a particular section, the inclusion of one-half or more of them in public ownership precludes those remaining from shipping their milk to the markets efficiently. If there were formerly six farmers on the road, the truck could collect the milk of all of them at a reasonable cost. If there are only two farmers left at a great distance from the center, they can not very well command the same services at a reasonable cost. To a considerable extent that has been the situation in Hubbardston. In addition, the Metropolitan Water Commission has imposed restrictions on the use of land for livestock in the farm areas adjoining the reservations.

The presence of large areas of good land on existing farms allows for considerable readjustment of their land resources. Continued purchases of farm land and restrictions on its use by the Metropolitan Water Commission are likely to lead to a further decline in farming, at least as far as dairying is concerned.

The situation in Hubbardston is similar to that of a good many other rural towns in the State where, in spite of favorable land conditions, the agricultural area has to be contracted in order to give place to certain public and semi-public land uses which come into prominence with increased density of population. In the interest of a balanced economy for these rural towns and also of the proper utilization of the agricultural resources of the State, the facts obtained in this investigation suggest the necessity of giving greater consideration to the proper balance of local communities in extending land control for public purposes.

Relocation of the Isolated Settlement in Rural Areas

The utilization of undeveloped land areas suitable for agriculture, in addition to bringing about an improved situation in existing farming units, should serve also as a means of reducing the number of isolated farms found in various parts of the State. Most of these are located on semi-abandoned roads and at a distance from available public facilities. The provision of social services, such as schools, roads, and health and fire protection, even in a limited way, represents a real drain on the town's resources, sometimes rendering the operation of local farms unprofitable because of exceedingly high local taxes. Wherever such conditions exist, it may prove of great benefit to the whole community to make some arrangement for the relocation of isolated units on land in more favorable areas. In many cases this could be efficiently carried out by drawing upon favorably located undeveloped land areas with satisfactory soil qualifications. Such an undertaking will be fully justified if the cost of clearing, drainage, and other similar improvements is not excessive in relation to the new facilities in land utilization brought into existence. The series of town maps worked out by the Massachusetts Agricultural Experiment Station makes the identification of isolated farms in rural areas a task not too difficult to accomplish.

Part-Time Farming Needs and Opportunities

The reconstruction of existing farming units of substandard type will aim primarily at reorganization of Massachusetts agriculture on the basis of efficient economic units suitable for family operations under modern conditions. It is realized that the objective should be to eliminate as far as possible those farming units which are inadequate from the standpoint of size and available land resources to support a rural family except on a subsistence level.

An entirely different situation exists, however, in regard to part-time farming. This is a condition where the land is only a contributing factor to the family living, and the main reliance is on other sources of income, either from outside employment, pensions, annuities, or invested capital. In Massachusetts, part-time farming in this sense has been an important factor for a number of years and is now found throughout the State, especially in the vicinity of cities and rural areas where good transportation facilities are available. The conditions which are likely to exist in the postwar period indicate a very sizable increase in the number of people engaging in part-time farming.

One of the important groups will be war workers with an agricultural background who have accumulated some savings and would like to secure a place in the country not far from potential industrial or other employment. Another important group will be represented by pensioned veterans retired on account of some degree of disability caused by war. A small-scale farm may provide for them the type of activity which will not involve too much strain and still give an outlet for their desire to perform some useful work. The limited contribution of their farming operations will allow them to stretch much further the pension allowance received from the government. The same considerations and opportunities will involve settlement on the land of another larger group which will grow considerably in size in the years following the war; that is, workers retired from industry and some other occupations on account of age. With the Social Security program in full operation, a large number of these people will be receiving old-age annuities and many of them, judging by the movement already in operation, will tend to settle on the land.

The greatest problem of most of these people in trying to gain a foothold on the land will be to obtain landholdings of a suitable and convenient size. Under present conditions, most of the land available to this group is located either in the vicinity of large cities or in more remote areas on farms going out of agricultural use. In either case the situation is unsatisfactory. In the first case, land values often are inflated and the amount of land which can be purchased by an individual is usually limited to a size not allowing a desirable amount of agricultural production. In the second case the holdings are of considerably larger size than necessary and, in addition, are located less conveniently for the operator who has to commute to his place of outside employment.

The better to fill the needs for land purchase by prospective part-time farmers, there might be a place for some cooperative action to obtain suitable tracts of land and develop them in line with the needs of this group of people. The source of needed land would be largely undeveloped tracts which could be properly improved prior to actual settlement. To purchase land at a reasonable price and in tracts of adequate size, it would be necessary to draw mostly on land which needs some preliminary operations in either clearing, drainage, or stone removal or all of them combined. Such developments should be located both in the vicinity of industrial areas and in rural districts at some distance from the centers of population, depending upon the group of people they are to accommodate.

Farm Woodland

Any program of improvement in land utilization in Massachusetts will of necessity include the consideration of wooded areas. At least 60 percent of the total area of the State is under some kind of forest cover and much of this is found on the operating farms. As will be seen from Chart 2, according to the Census of 1940, woodland accounts for 37 percent of the total farm land. With the exception of some land under the control of public institutions and a few large holdings by private individuals, the major part of this woodland, both on and outside of farms, remains largely undevelopea, from the standpoint of scientific management and systematic improvement.

For the Massachusetts farmer to neglect his woodlot is to forego considerable advantages that may accrue both to his income and to farm operations from this potentially valuable part of his natural resources. In fact, under proper management, the producer will do well to integrate the operation of his woodlot with other activities on the farm. This will furnish employment to farm labor

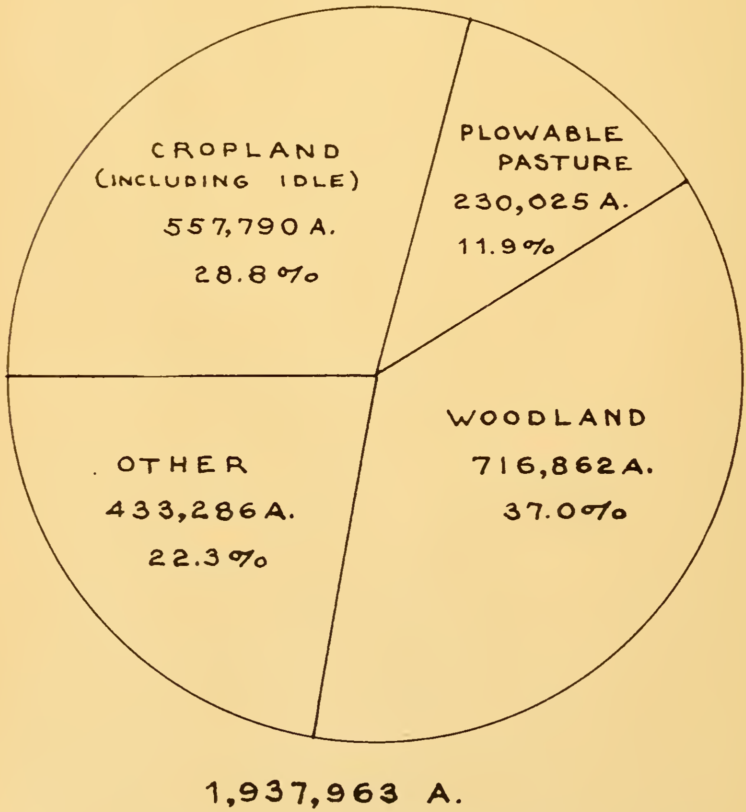


Chart 2. Utilization of Massachusetts Farm Land.
Source: U. S. Census, 1940.

in slack seasons and will increase the production of material consumed on the farm in the form of fuel, fencing, and lumber. In addition, it should bring cash revenue from periodical cuttings systematically arranged.

Within recent years the Legislature of Massachusetts has passed several acts to encourage woodland owners in scientific management and forest conservation. One of the latest laws passed with this objective in mind provides for deferred payment of taxes on timber on all woodland which is assessed for less than $25 per acre. The future success of Massachusetts farming will depend greatly on the extent to which individual producers make proper utilization of their woodland in conjunction with their other farm operations.

ADJUSTMENTS IN PRODUCTION AND DISTRIBUTION

Hay and Pasture Improvement

After the proper adjustments in the size of farms and the amount of cultivated land available, the greatest opportunities will be found in the field of hay and pasture improvement. The total acreages of hayland and plowable pasture in Massachusetts are estimated at approximately 350,000 and 230,000 acres respectively. On the basis of the last Census there are about 80,000 acres of idle cropland in Massachusetts farms. These three items amount to about 660,000 acres of land which is classified as suitable for cultivation or is already producing crops. Considering that the total in crops, exclusive of hay, amounts in Massachusetts to less than one-third of this large area, it becomes evident that the three items under consideration are of vital importance in the agricultural structure of the State. It is difficult to appraise with any degree of accuracy the suitability of these lands for more adequate utilization, because of the variety in the types of soils and other determining factors.

The lands classified as plowable pasture or hayland, as examination on individual farms shows, vary from areas with highly productive soil, an even surface, and excellent drainage to areas which are too wet, too stony, or too steep to be suitable for any adequate cultivation without extensive preliminary preparation.

Sufficient data are already available to indicate that both the carrying capacity of plowable pasture and the yield of hayland may be increased to a considerable extent by adequate application of fertilizer, by stepping up the rate of reseeding, and by more universal development of desirable forage plants, particularly ladino clover. A farm-by-farm investigation and analysis made in Worcester County on 70 representative farms disclosed that it would be feasible with the present resources to double the total acreage of improved hay and pasture on more than two-thirds of the farms.[5] This would result not only in an increased quantity of feed but actually in improved quality. The feeding value of improved pasture and hay, pound for pound, is considerably higher than for the product obtained from untreated fields. As a matter of fact, the mineral and protein content may be more than doubled in many instances.

To utilize fully the possibilities of hay and pasture land it will be necessary to carry out extensive reclamation and conservation projects. In extending improved practices on hay and pasture land, it is more feasible and desirable from the standpoint of conservation to put the emphasis on the utilization of low wet land that can be easily drained than on hilly sections that have to be cleared.

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[5]Shadegg, F. J. Farm Adjustments for Maximum Wartime Production in Worcester County, Massachusetts. U.S.D.A. in cooperation with Mass. State College and Agr. Exp. Sta. May 1944.

Dairy Production

A well-developed land use program is of prime necessity in maintaining and strengthening the competitive position of the Massachusetts dairy industry. As already pointed out, this land use program is a compound of a number of important measures. It starts with the clearing and consolidation of small fields wherever this may lead to more efficient cultivation. Likewise drainage operations will be carried out as a step to removing serious handicaps on many hay and pasture lands. This will lead to the improvement of grassland which is the cornerstone of the Massachusetts dairy program.

The number of cows on Massachusetts farms showed only slight changes during the war period, although by 1945 some evidences of decline appeared. In the last decade, as reported by the Census, this number has been maintained at a level of about 140,000 head. The production of milk per cow, however, has shown some increase, largely as a result of heavier feeding of concentrates, and during the years 1944 and 1945 the output per cow has been the highest ever reached. It can hardly be expected that this will be surpassed on the basis of the present make-up and care of dairy herds. Further improvement will come only as a result of a well-developed program carried on for a number of years.

The first point of this program will be the breeding of more efficient cows either through herd sires or through artificial insemination. This should be accompanied by better sanitation measures and general maintenance of health in the herds. Of special significance will be control and eradication of mastitis and Bang's disease on the basis of the recommendations which are available through the most recent findings in this field.

While the production of milk in Massachusetts during the wartime period did not change significantly from the prewar period, the consumption of fluid milk registered a considerable rise. It is not too much to expect that at least a part of this increase will be retained in the postwar period. Under these conditions the producers may find it advantageous to increase the number of cows by at least 10 percent, which will serve to hold their former relative position in supplying the milk requirements of the State. As will be seen from Table 4, after the first

TABLE 4.—NUMBER OF COWS ASSESSED[1] IN MASSACHUSETTS 1915-1943.

Year	Number of Cows	Year	Number of Cows	Year	Number of Cows
1915	145,049	1925	148,366	1935	131,828
1916	147,681	1926	141,006	1936	133,016
1917	149,179	1927	133,427	1937	133,819
1918	150,886	1928	131,059	1938	131,068
1919	148,687	1929	129,603	1939	135,389
1920	153,537	1930	129,654	1940	135,014
1921	158,305	1931	129,043	1941	133,317
1922	167,311	1932	131,491	1942	129,897
1923	164,135	1933	126,977	1943	128,018
1924	157,750	1934	131,459		

From Public Document 19: "Aggregates of Polls, Property and Taxes," 1915-1940; Assessors' reports. 1941-1943.

[1]The number of cows assessed is ordinarily somewhat lower than the number reported by the Census.

World War the number of cows increased by about this percentage during the first 5-year period. Conditions now are fully as favorable as in that earlier period. The technological improvements in the care of land, better and cheaper fertilizers and seeds, and the consequent development of Massachusetts grasslands to a higher degree of productivity should provide a firm basis on the side of production. As for demand, Massachusetts producers for a number of years have been supplying only about 50 percent of the total State requirements for fluid milk. Shipment for longer distances and the introduction of new products such as powdered and frozen milk, if acceptable to consumers, could undoubtedly make further inroads on the domestic market. The only way for the Massachusetts dairy industry to maintain its position is to take full advantage of efficiency of production. This will include not only the measures already indicated, but also the introduction of labor-saving devices throughout the whole process of the production and distribution of milk. Recent experiments with so-called fast milking methods indicate that this alone leads to considerable economies in the cost of labor.

To achieve lower costs in milk production, the size of herds on individual farms will have to be brought in line with available labor and other resources. The comparative distribution in the size of herds between 1935 and 1942 indicates that there is already a movement on foot to reduce the number of small units with a corresponding increase in full-sized family herds and larger units.

Table 5.—Dairy Cows in Massachusetts by Size of Herds.

Size of Herd	Herds				Cows			
	1935		1942		1935		1942	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1 – 5	16,386	69	12,163	66	29,981	21	20,802	15
6 – 9	2,469	10	1,509	8	18,218	13	11,259	8
10 – 14	2,029	9	1,658	9	23,960	17	19,793	14
15 – 19	1,128	5	1,098	6	18,904	13	18,359	13
20 – 29	977	4	1,203	7	22,984	16	28,483	20
30 – 39	309	1	432	2	10,306	7	14,529	10
40 – 49	130	1	194	1	5,650	4	8,518	6
50 or over	147	1	246	1	12,003	9	19,559	14
Total	23,575	100	18,503	100	142,006	100	141,302	100

From animal inspection books.

In the field of marketing, many savings are possible and desirable, beginning with assembly and transportation of milk to the central point. Studies in Massachusetts and other states indicate that there is considerable waste and duplication, much of which could be eliminated by more careful planning. Likewise the distribution of milk with its duplication of routes is a fertile field for possible economies. Every-other-day delivery, introduced in wartime, offers another opportunity for saving in the cost of distribution. All these factors are already well known to both producers and distributors, and the main problem is unwillingness to adopt new practices. The initiative for such action may well come from the Milk Control Board, which already has been responsible for a considerable degree of improvement in various stages of distribution. The main advantages of all the economy measures in production and distribution will be that the price of milk, while being maintained at a level providing a fair return to producers, will also be such as to encourage rather than curtail the sale of this important product to the consumer.

Taking the country as a whole, there has been a 9.5 percent increase in the number of cows during the war years. Milk production per cow, however, has increased only slightly. In the postwar period, under favorable economic conditions, it should be possible to increase the total production of milk as the result of both larger numbers of cows and higher production per cow. Massachusetts must make the most of this situation if it is to maintain at least its present relative position in the nation's dairy production. More, however, could be expected in view of the prospects for newly developed improvements in the dairy industry in the State.

Poultry Farming

The poultry industry in Massachusetts has been on the increase over a considerable period of time. As will be seen from Chart 3, the number of chickens on farms was expanding rapidly, even prior to the war. During the war, production of poultry meat and eggs was further accelerated (Chart 4). With the shortage of meat and other animal products, poultry production was the easiest way to expand and get quick results. The production of eggs for market has always been an important factor in Massachusetts agriculture, although in the prewar period only about 40 million eggs were produced, which filled less than 40 percent of local consumption requirements. During wartime the quantity of eggs produced was boosted over 45 percent which provided almost 50 percent of the wartime consumption of eggs. The production of poultry meat, largely commercial broilers, more than doubled, as compared with the prewar period.

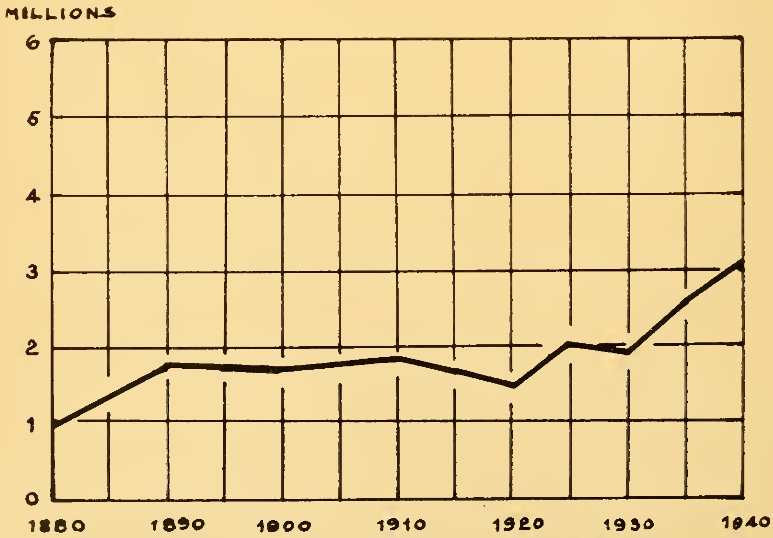

Chart 3. Chickens on Massachusetts Farms, 1880-1940.
Source: U. S. Census (The date of enumeration has varied from January 1 to June 1).

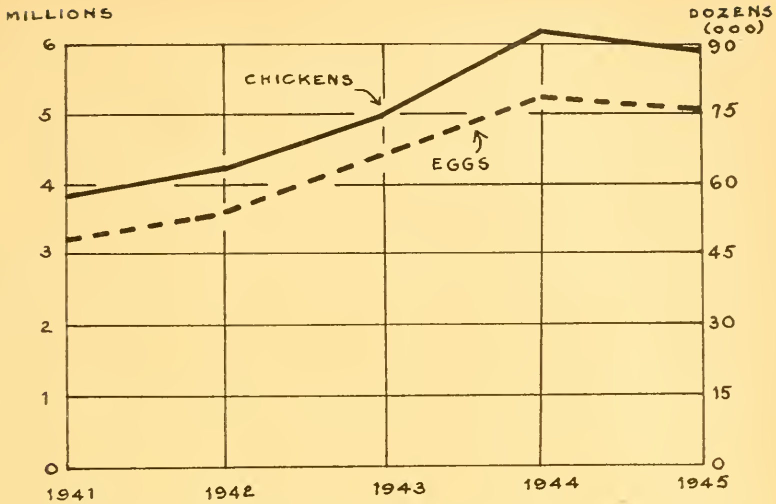

Chart 4. Wartime Trend in the Number of Chickens on Massachusetts Farms and Eggs Produced, 1941-45.
Source: BAE.

The extent to which Massachusetts producers will be able to retain these gains will depend on their continued effort to improve the production system and to adopt the best methods advanced by modern science. Undoubtedly some decline in production will come about through the removal of a number of small flocks which came into existence through wartime exigencies. The great majority of Massachusetts commercial poultry producers have maintained their competitive position in the market through better knowledge of handling their enterprises, learned by long experience, and the adoption of the most advanced methods. In the postwar period these advantages will have to be pursued to an even greater extent than in the preceding period, since competition is likely to be keener, because of the expanded poultry production throughout the country.

As it stands now producers in Massachusetts have adopted on a considerable scale sanitation and health methods which hold mortality of birds at a comparatively low level. Efforts along these lines will have to be further intensified to prevent poultry diseases prevalent in some other sections of the country from gaining a foothold in this State. Likewise, breeding and feeding methods have been constantly improved, so that productivity per bird ranks among the highest in the country. Nevertheless, these efforts should be further strengthened if the competitive position is to be maintained.

Specialization in producing chicks and hatching eggs is likely to remain most productive and there is even a possibility of some further gains. For this, continued emphasis should be placed on the strains of dual-purpose varieties.

It should be constantly kept in mind that the poultry industry in Massachusetts is maintained on purchased feed, and it is always cheaper to bring in the finished product in the form of eggs or meat rather than the grain to produce it. Massachusetts poultrymen, therefore must produce a superior product at a cost which should not be at too great a differential from other producing areas. While land resources are of less importance in poultry production, the improvement of farm lands as presented earlier in the discussion would be of benefit also to this type of farming.

Better poultry ranges and a sufficient amount of green feed crops will provide better sanitary conditions and also reduce the dependence on imported feed. The question of feed may become one of the most crucial factors in the ability to compete with the outside product. Moreover, grain prices are likely to be supported for a considerable time and this may provide some disadvantages, inasmuch as the Massachusetts producer will have to sell his product on a market very sensitive to consumer demand. High prices are likely to result in smaller volume of sales.

Reduction in cost of production and added efficiency will require careful planning in the use of labor. Generally speaking the plant will have to be so organized and labor-saving devices used to such an extent that the number of birds kept per man can be increased, thus reducing the cost per unit and increasing the total farm income.

There are numerous ways in which labor-saving devices could increase the efficiency of poultry farms. A recent film prepared for poultrymen shows such details as methods of unloading feed, feed room arrangement, feed carriers, watering devices, nests, roosts, methods of maintaining dry litter, ventilation, disposal of manure, home dressing including the picking machine, waxing, and semi-scalding, egg rooms, and egg grading. Some of these factors have a direct relation to sanitation and safeguarding the health of the bird. The reduction of mortality has always been one of the main concerns of the poultryman and gives the greatest promise of further cutting of costs. Where facilities are available and labor is not fully utilized, poultry farmers will do well to diversify their production by taking on some additional enterprises.

Of equal importance is a well-organized system of marketing. In some areas of the State cooperative marketing has proved to be of distinct advantage and might well be expanded. Sales of eggs direct to stores and other selling centers should be further extended. Where possible, direct sale to consumers either through stands or home distribution will undoubtedly prove the most profitable, as in the past. In the final analysis, it will be necessary for the Massachusetts poultryman to provide, at a reasonable price, a product equal or superior to that which can be obtained from other sources.

Vegetable Crops

Market-garden products are grown in Massachusetts in great variety and under diverse conditions. In general, there has been some shift in vegetable growing from older sections in the eastern part of the State to other sections, including the Connecticut Valley. The total acreage in market gardening in prewar years has been variously estimated, but the general agreement is about 40,000 acres, including both large-scale operations and small commercial gardens. In wartime the supply of vegetables from commercial areas has been augmented by the produce of Victory gardens which added substantially to the total volume of output in the State. With a general increase in vegetable consumption over a period of years, it may be expected that Massachusetts producers will find it profitable to extend their market garden operations, increasing their acreage by about 10 percent. A great deal will depend on possible changes in the competitive situation in the field of vegetable growing, processing, and marketing. It is not likely that yields will be further increased by means of heavier fertilization.

There is, however, considerable room for improvement in the way of using better varieties and in combating plant diseases by more adequate dusting and spraying. One of the greatest promises in the way of safeguarding vegetable crops and securing better returns to the producers is found in the recent improvements in overhead irrigation. With greater mechanization in vegetable growing and the adoption of labor-saving devices leading to lower costs, it may become profitable to use part of the crop of Massachusetts growers for processing purposes, although the sale of fresh vegetables in nearby markets will undoubtedly remain the mainstay of local producers.

Onions

For a long time onions have occupied an important place among Massachusetts farm products. In recent years a number of unfavorable factors have been handicapping the successful operation of this industry. Developed primarily in the Connecticut Valley, onion growing has depended to a large extent on hand labor. Although the amount of hand labor required has been markedly reduced by the extensive use of small two-wheeled tractors, hand labor requirements are still high. Besides the general difficulties of putting this type of agriculture on a fully mechanized basis, the prevailing system of intensive cultivation and the high cost of land in the Connecticut Valley have militated against it. It is not likely that in the near future there will be any material change in the acreage under onion cultivation. In the immediate postwar period the acreage of around 1,200 seems feasible.

Potatoes

The potato acreage in Massachusetts has increased considerably during wartime. The reported area of 25,000 acres during the peak of wartime production is over 30 percent higher than in recent normal years. It is considered feasible for producers to maintain this acreage by the greater use of machinery, such as pickers, and the general improvement in prevailing practices. The rate of fertilization is already high. There are, however, possibilities in better control of diseases and in more complete programs of spraying and dusting. One of the major problems in maintaining soil fertility and controlling erosion is the establishment of satisfactory rotations and the use of suitable cover crops. Some land in the Connecticut Valley may have to be released from continuous potato culture because of the exhausting effect of the crop on organic matter. Maintenance of the acreage will be possible by using other farm land or by opening new areas of a suitable character, as has been done recently on favorable sites in uplands.

Tobacco

Under increased wartime demand, the tobacco acreage has stopped its downward trend of recent years. Some expansion of production is possible in the next two or three years in response to continued high demand and higher prices. Later on, with the re-establishment of normal conditions and with somewhat lower prices, there will be a tendency to decrease the acreage, which is likely to be stabilized somewhere around 5,000 acres.

Fruit Production

Fruit growing has been for a long time one of the most important branches of Massachusetts agriculture. The types of soil and climate in various sections of the State are favorable for successful orcharding. For a number of years prior to the war, prevailing prices, especially in the apple market, were mostly unsatisfactory to local fruit growers. This retarded somewhat the carrying out of practices recognized as essential for the adequate maintenance of fruit trees.

Nor has there been sufficient planting of new trees to replace those passing out of profitable production.

While wartime conditions have been accompanied by more satisfactory prices, the shortage of skilled labor and the tight supply of some important materials have made it difficult for many producers to give the best care to their orchards.

In the last ten years, research work in the field of fruit growing in this State has made considerable progress in many important aspects of the industry. This is especially true in the matter of pest and disease control, and in the classification of soils most suitable for growing particular species, as well as in supplying deficient elements. The methods and technique of spraying and dusting fruit trees have been improved and are brought to the attention of growers by the agricultural extension service. Likewise to secure the development of strong and efficient orchards a campaign has been in progress for better pruning of young trees as a basis for a stronger framework.

With the establishment of normal conditions in the supply of labor and materials, Massachusetts producers are warranted in proceeding with the improvement of their orchards on a more intensive scale. The replanting program on soils suitable for fruit growing should be speeded up without further delay, and more attention paid to the removal of trees that are not profitable. Together with the development of strong and efficient apple orchards, further progress could be made in the matter of diversification, especially by raising more pears, peaches, strawberries, raspberries, blueberries, and grapes.

With the general trend toward mechanization in the whole field of agriculture, it is essential that fruit growers take advantage of the new types of machinery, such as light tractors, trucks, and electric motors. This should provide for greater efficiency in the use of labor and the possibility of taking care of larger producing units with the same amount of labor.

The most pressing problems in the local fruit industry remain probably in the field of handling and marketing. This involves a wide acceptance of more desirable systems of grading and packing, particularly as they affect such an important variety as the McIntosh apple. Also more effort should be made to sell apples in the nearby markets. As one means of disposing of low grades of apples, the possibility of using them in manufactured products, especially in apple juices, should be explored to a greater extent.

In the new developments of orchard practices should be included better practices in fertilization, spraying or dusting to control pre-harvest drop, controlled atmosphere storage, control of rodents in storage through the use of methyl bromide, and such labor-saving equipment as the brush pusher, the bulldozer for removing trees and stones and for clearing land, and the one-man power spraying outfit. As in other lines of agricultural production, the future well-being of the fruit industry in this State will depend on the readiness of producers to adopt the most modern desirable practices which lead to greater efficiency and reduction of costs.

Among the small fruits, the most important in this State are cranberries and strawberries. While strawberry cultivation has experienced some decline during the war, there has been little change in recent years in the total acreage in cranberries. The yields of both, however, have fluctuated widely, not only because of weather conditions but also because of wartime difficulties in production. The most limiting factor has been the shortage of labor, the demand for which is on a highly seasonal basis in small-fruit production. Relief in the labor situation under normal conditions would contribute greatly to the amount of the products harvested under average conditions in the growing season.

The cranberry industry in this State has been marked by the adoption of progressive methods both in the growing and in the handling of its products. Among the small growers there is a need for more extensive practice of weed and pest control, which are of vital importance for stability in this line of production.

Marketing Conditions for Agricultural Output in Massachusetts

In the wartime period the production and marketing of agricultural products have been confronted through the entire country with a set of conditions greatly different from that experienced in normal times. The prevailing factor was the necessity of providing the largest output possible with available resources, farming equipment, and manpower. The emphasis, moreover, was put on certain types of products which were most needed, and at the same time employed the least amount of the limited resources. Both production and prices have been determined largely by governmental regulations, ceiling prices, and support prices, coupled with payments and purchases by governmental agencies. All major products in Massachusetts agriculture as represented by dairy, poultry, vegetables, and fruits have been affected in one way or another by prevailing policies. As a result of high demand for all products and of limited facilities in labor and transportation, most of the previous efforts to bring the produce to the consumer in the most appealing way have been considerably relaxed. With the return of normal conditions an increased amount of re-education and further improvement in marketing methods will be needed. To be sure, in the war period some very desirable procedures in marketing and transportation have been introduced by sheer force of necessity, especially those pertaining to the collection and movement of agricultural products. In the field of milk marketing, the pooling of truck transportation by the producers and every-other-day delivery are of special significance and should be retained in the interest of both producer and consumer.

The handling of agricultural products, especially packaging and grading in which some progress had been made in the prewar period, will again have to be emphasized and further developed in the light of modern facilities and discoveries. As in the past, Massachusetts producers will do well to market their product as close to the final consumer as possible. This may take the form of roadside stands, sales to individual consumers through delivery, and other similar methods. Cooperative efforts returning a larger portion of the consumer dollar to the producer also should be exploited to the fullest extent. The farm markets need to be further organized and provided with better facilities.

It is difficult to determine with any precision what will be the general market opportunities for agricultural products in Massachusetts in the postwar period. The uncertainty is bound up with many vital factors including the trend of business and employment, changes in the comparative position of various regions producing similar products, and the degree of public acceptance of food under new processing methods, especially of frozen vegetables and of powdered milk and eggs. Transportation facilities have progressed to the point where more distant areas are brought closer to Massachusetts and will be able to offer effective competition. While nearness to the consuming market still remains an important advantage to local agriculture, everything points out that the only way to keep Massachusetts agriculture in a healthy and stable condition is to increase efficiency in both production and marketing. This will lead to the narrowing of the cost differential in production between this and other areas and place local markets in a better position.

There are several factors favorable to Massachusetts agriculture as far as postwar conditions are concerned. In the first place, during the war period there has been little or no over-extension of agricultural production in the State, except in the poultry industry and potato acreage. Therefore, no serious problem of readjustment is likely to arise, especially since some natural falling off in these lines will probably occur by the dropping out of some producers who were tempted by wartime exigencies. Of greater importance is the fact that Massachusetts agricultural production is concentrated in products like fresh milk, vegetables, fruits, and eggs, which are recognized as of primary importance in the diet and have experienced a constant increase in per capita consumption during the recent period of rising employment and wages.

APPENDIX

Table 1.—Use of Massachusetts Farm Land in 1944[1].

Use of Farm Lands	Acreage	
Corn, all (planted)	43,000	
Tobacco (harvested)	5,700	
Potatoes (planted)	24,000	
Truck crops for processing[2] (planted)	1,000	
Truck crops for fresh market[3] (harvested)	35,800	
Total cropland for intertilled crops		109,500
Oats (planted)	13,000	
Hay, all tame, except small grain hay (harvested)	335,000	
Rotation (cropland) pasture[4]	33,000	
Idle cropland	69,900	
Total cropland		560,400
Orchards, vineyards, and small fruits	48,000	
Other plowable pasture	192,300	
Open nonplowable pasture	220,000	
Woodland pasture	720,000	
Hay, wild (harvested)	10,000	
Other land in farms	188,300	
Total land in farms		1,939 000

[1]By the Bureau of Agricultural Economics.
[2]Commercial acreage of cucumbers for pickles reported by BAE.
[3]Commercial acreage of asparagus and onions reported by BAE and some market-garden acreage not reported by BAE.
[4]Exclusive of preharvest and aftermath grazing on acreages from which crops are harvested.

TABLE 2.—AVERAGE CROP YIELDS PER ACRE IN MASSACHUSETTS IN THE 1937-1941 PERIOD.

Crop	Yield per Acre
Corn, all	40.2 bushels
Tobacco	1,497.0 pounds
Potatoes	140.0 bushels
Oats for grain	32.8 bushels
Hay, all tame	1.43 ton
Hay, wild	0.98 ton

TABLE 3.—PRODUCTION OF LIVESTOCK AND LIVESTOCK PRODUCTS IN MASSACHUSETTS IN 1944[1].

	January 1
Livestock on Farms, number	
Horses, mules, and colts	18,000
Cattle and calves, all	202,000
Cows kept for milk, 2 years+	141,000
Other cows, 2 years+	1,000
Sheep and lambs, all	8,000
Ewes, 1 year+	6,000
Hens and pullets	6,144,000
	During the Year
Livestock on Farms, number	
Sows farrowed, spring[2]	16,000
Sows farrowed, fall[3]	11,000
Chickens raised[4]	10,483,000
Commercial broiler production	3,096,000
Turkeys raised	227,000
Milk cows, average during the year	132,000
Livestock Products	
Milk produced	777,000,000 pounds
Wool shorn	42,000 pounds
Eggs produced	78,700,000 dozen
Hogs, net production[5]	31,265,000 pounds

[1]By the Bureau of Agricultural Economics.
[2]December 1 (of previous year) to June 1.
[3]June 1 to December 1.
[4]Excluding commercial broilers.
[5]Twelve-month period beginning on October 1.

3500-4-3-'46

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 431 MAY 1946

Identification of Blueberry Varieties by Plant Characters

By John S. Bailey and Arthur P. French

This bulletin describes some of the vegetative characteristics which are useful in identifying plants of blueberry varieties in the nursery. Familiarity with these character'stics should aid in the prevention of variety mixtures.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

IDENTIFICATION OF BLUEBERRY VARIETIES BY PLANT CHARACTERS

By John S. Bailey, Assistant Research Professor of Pomology
and Arthur P. French, Professor of Pomology

It is of the utmost importance to the fruit grower to get varieties true to name. Varietal mixtures and substitutions are a continuing source of economic loss. Therefore, anything which can be done to reduce such losses is a distinct advantage to the fruit grower and the horticulturist alike. Shaw and his associates attacked this problem by studying the vegetative characters of nursery fruit trees. They have published a series of bulletins (8, 11, 12, 13, 14, 16, 17) describing nursery trees and pointing out differences by which varieties can be identified in the nursery. This bulletin, the eighth in this series, covers varieties of the cultivated blueberry.

The blueberry is a newcomer among cultivated fruits. The first varieties to be introduced were selections from the wild and differed markedly from each other. These selections have been hybridized and some of their progeny introduced as new varieties which show less marked differences than did their parents. It seems probable as breeding work progresses and fewer lines are used as parents that the differences between future varieties will become still smaller, while at the same time the number of varieties is increasing.

Hence, it is the purpose of this bulletin to call attention to those characteristics of blueberry plants which seem to be of value in identification work and to put on record a description of the vegetative characters of all the available varieties of cultivated blueberries, as an aid toward the prevention and elimination of variety mixtures.

Literature

Several authors have discussed blueberry varieties (1, 2, 3, 6, 7, 9, 10, 15) but few have gone farther than to say that the bush is tall or short, upright or spreading. Beckwith and Coville (2, 3) were the first to record differences in bush shape. They gave diagrams of bush shapes to call attention to these differences. Darrow and Clark (6) in discussing the three varieties Atlantic, Pemberton, and Burlington described the bushes and leaves in greater detail than had been customary. Clark (4) was the first to discuss the use of vegetative characters for identifying varieties. He constructed a simple key to separate varieties into groups similar in their characteristics. Later, Clark and Gilbert (5) investigated further the reliability of certain characters, such as leaf width, leaf length and width/length ratio, which Clark had previously used. They concluded that "leaves 4-5-6 from the tip of lateral branches 8 to 12 inches long exhibit a minimum of variability and, hence, are suggested as criterion leaves for leaf measurements to be made for the purpose of varietal identification"; also, "that tip angle, base angle, and leaf width/length ratio are valuable and relatively constant characters."

How Blueberry Varieties Differ

Variation or difference between individuals is a cardinal principle of nature. The differences between varieties are greater than those between individuals within a variety. Yet within a variety some characteristics vary more than others; for example, within a variety of the cultivated blueberry leaf size varies considerably, whereas the presence or absence of leaf serrations varies little, if any. By studying the different characteristics of the varieties and their natural limits of variation, one learns to distinguish one variety from another. Some differences are obvious and easily learned; others are less obvious and require some study. Some of these differences between varieties of cultivated blueberries are described and illustrated in the following paragraphs.

Characters Useful in Identification

The *leaf blade* is the most important part of the blueberry plant for the purpose of identification by vegetative characters. It has several characters which are very useful. However, since the leaves vary considerably, the question arises as to which leaves should be considered as typical of the variety. Clark and Gilbert (5) after making a large number of measurements decided that leaves 4-5-6 on lateral branches 8-12 inches long exhibit the least variability as regards the measurements they made and, therefore, suggest their use as criterion leaves. The use of such criterion leaves is undoubtedly advisable in a system of identification based on definite measurements such as these authors proposed. However, in a system such as Shaw and his associates have developed, such definite measurements, except for experimental purposes, are not necessary. With sufficient study certain varietal characteristics will stand out and can be found without limiting the observer to certain leaves on branches of a certain size. This over-all sort of observation is particularly important in examining a nursery where branches of a particular size might be difficult or impossible to find. Hence, the authors believe that the selection of criterion leaves must be left for the observer to determine according to the condition of the bushes under observation.

Leaf shape varies considerably among varieties and is, therefore, a very useful characteristic. Typical leaves of Wareham are narrow elliptic, those of Pioneer elliptic. Leaves of June are ovate, while those of Jersey are oval, and those of Grover are obovate (Figure 1).

Closely related to leaf shape are *length/width ratio* and apex and base angle. As pointed out by Clark (4) and Clark and Gilbert (5), the width/length ratio is very useful for identification. However, the actual measurement and calculation of this ratio in the field is too time consuming. Therefore, a simplification illustrated in Figure 2, which gives the reverse or length/width ratio, has been adopted. The tip of the leaf is bent back to the base and the leaf broken in two at the mid-point. The broken edge of the top half is then placed along the midrib of the bottom half. If the length of the half midrib is greater than the width of the leaf, the ratio is greater than 2. If they are equal, the ratio is 2. If the length of the half midrib is less than the width, the ratio is less than 2. Thus, varieties can be roughly and rapidly separated into three groups. In Figure 2 Scammell represents the group with ratio greater than 2, Pioneer 2, and Jersey less than 2.

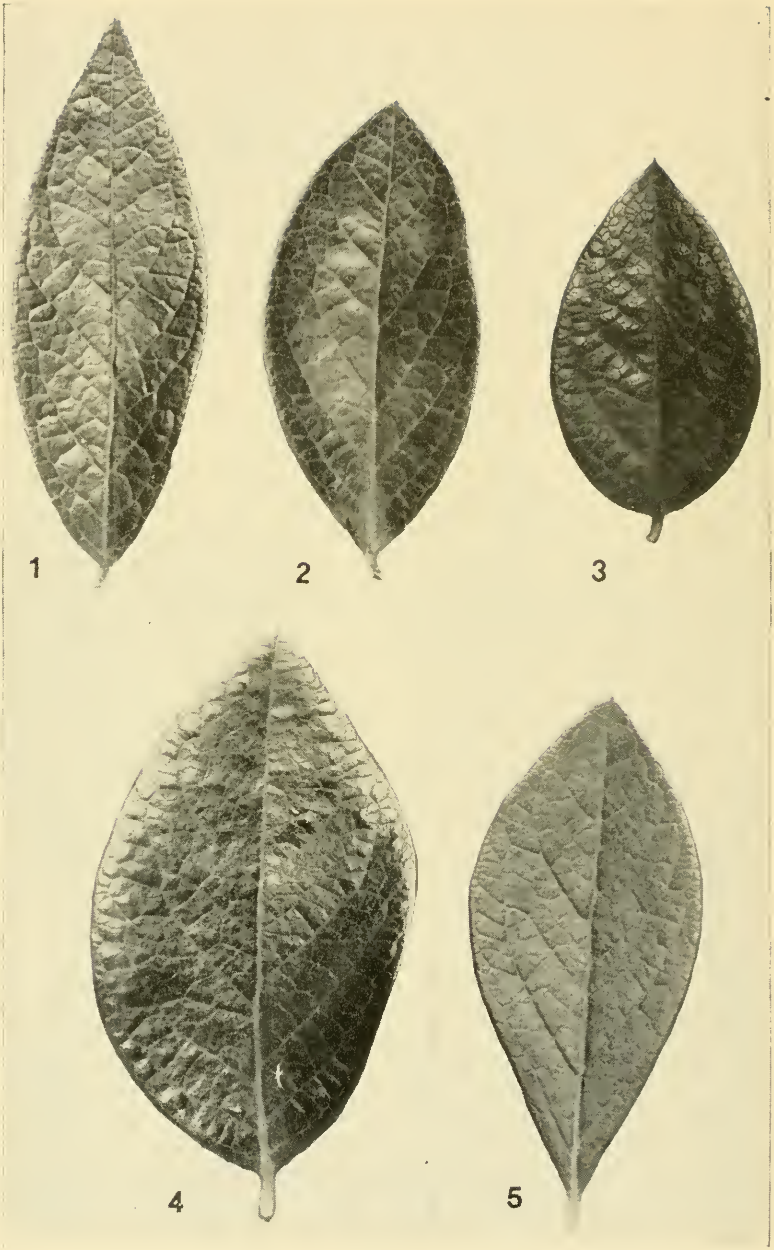

Figure 1. Leaf Shape.

1. WAREHAM — narrow elliptic
2. PIONEER — elliptic
3. JUNE — ovate
4. JERSEY — oval
5. GROVER — obovate

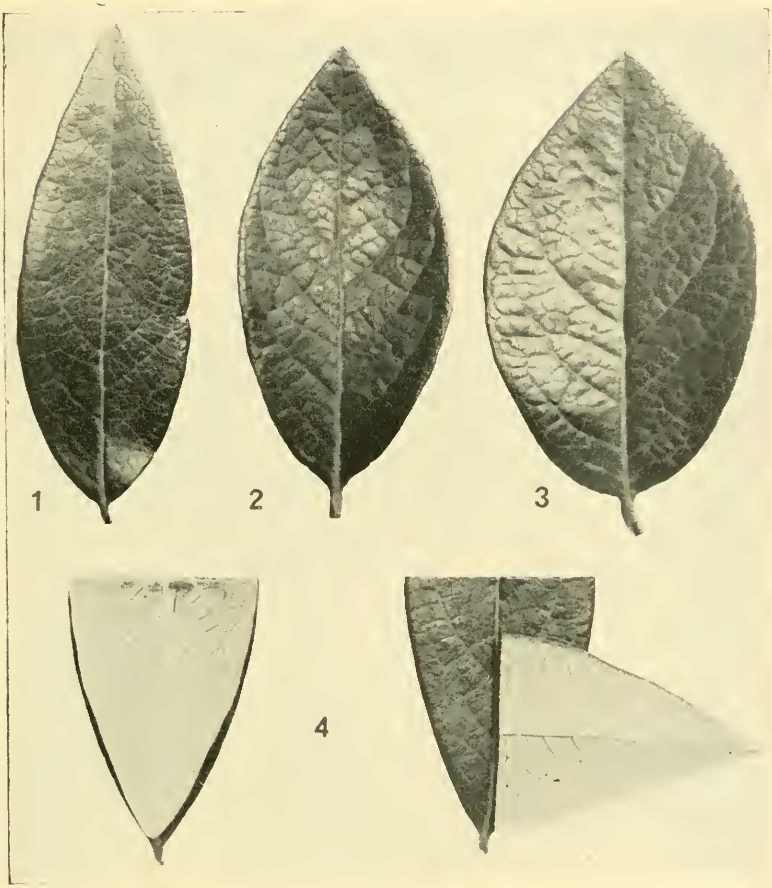

Figure 2. Length Width Ratio.

1. SCAMMELL — ratio greater than 2
2. PIONEER — ratio 2
3. JERSEY — ratio less than 2
4. How the length width ratio is obtained.

Apex angle varies enough to be another important characteristic. It may be narrow as in Cabot, medium as in Grover, or wide as in Jersey (Figure 3).

To establish classes of *base angles*, leaf bases were measured with a leaf gage furnished by Clark (4). On the basis of these measurements varieties were divided into four groups. Those having a base angle of 60°-70° are called narrow, represented in Figure 3 by the variety No. 73; 70°-80° are medium, Wareham; 80°-90° wide, Pioneer; and over 90° very wide, Jersey.

The various types of *leaf folding* are very important. In some varieties such as Sam the edges of the leaves curve back in such a way as to form a reverse

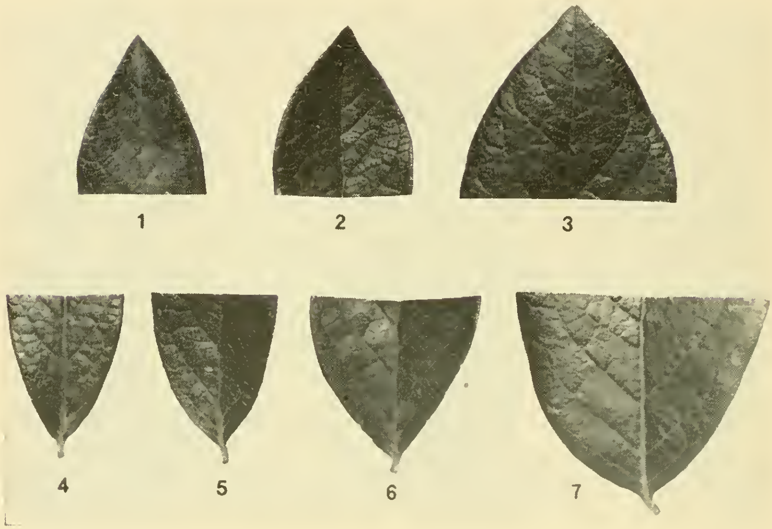

Figure 3. Leaf Apex and Base Angles

1. CABOT — narrow
2. GROVER — medium
3. JERSEY — wide
4. NO. 73 — narrow
5. WAREHAM — medium
6. PIONEER — wide
7. JERSEY — very wide

saucer (Figure 4). In others the curving is toward the top of the leaf producing saucer-folding as in Katherine. When the folding is more pronounced and nearer the midrib, a U-fold results as in Pioneer. If the folding is still more abrupt and occurs at the mid-rib, the V-fold of June results.

Waving of the leaf margin is another useful character. Some varieties have an unwaved or *even margin* like Rubel (Figure 5). Others have a distinctly *waved* margin such as Rancocas. Atlantic has a *twisted midrib* which produces an effect something like waving but distinct from it.

There are four kinds of curvature of the midrib. Some have a double curve like a broad-flat letter S; that is, a *reverse curve* as in Pioneer (Figure 6). Some

Figure 4. Leaf Folding.

1. SAM — reverse saucer-folded
2. KATHERINE — saucer-folded
3. JUNE — V-folded
4. PIONEER — U-folded

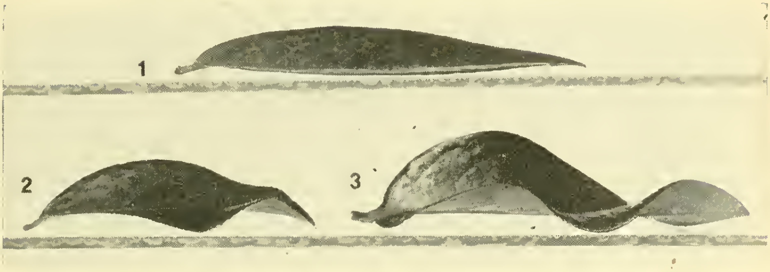

Figure 5. Leaf Waving.
1. RUBEL — even margin 2. RANCOCAS — waved
3. ATLANTIC — twisted midrib

have a slightly bent back or *reflexed tip* as Weymouth, while others have both *tip* and *base reflexed* as Scammell. Others have the whole midrib curved back, a *reflexed* midrib, as in Adams.

The appearance of the *leaf surface* is very important in distinguishing varieties. Cabot leaves have a *smooth* surface (Figure 7). Those of June have a *bullate* surface, a surface covered with little humps. In varieties such as Sam, having leaves with a *rugose* surface, the humps between the principal veins are joined together into ridges so that the surface has the appearance of a series of low rolling ridges and valleys. Wareham leaves have a *netted* surface. *Netted* and *bullate* are similar but quite distinct conditions. On a *netted* surface the veins are slightly depressed below an otherwise flat surface; on a *bullate* surface the islands between the veins are puffed up into definite humps above the general surface level. *Pockmarking* is just the reverse of bullateness; that is, there are depressions, as in Pemberton, instead of humps between the veins. Some leaves of the variety Dunfee have a special combination of bullateness with a light and dark green mottling or mosaic appearance which sets this variety off by itself. Furthermore, the leaf surface may be *dull* as in Pioneer or *glossy* as in Rancocas (Figure 8).

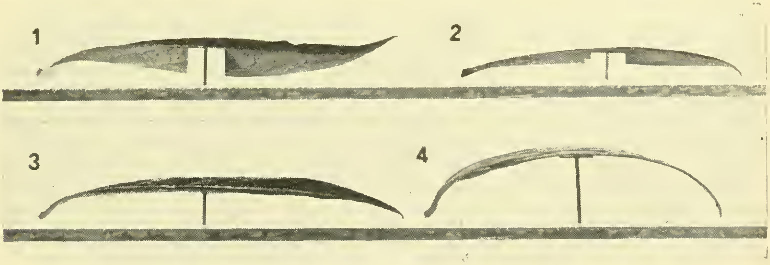

Figure 6. Curvature of Midrib.
1. PIONEER — reverse curve
2. WEYMOUTH — reflexed apex
3. SCAMMELL — apex and base reflexed
4. ADAMS — reflexed midrib

Figure 7. Leaf Surface.

1. CABOT — smooth 2. WAREHAM — netted 3. SAM — rugose

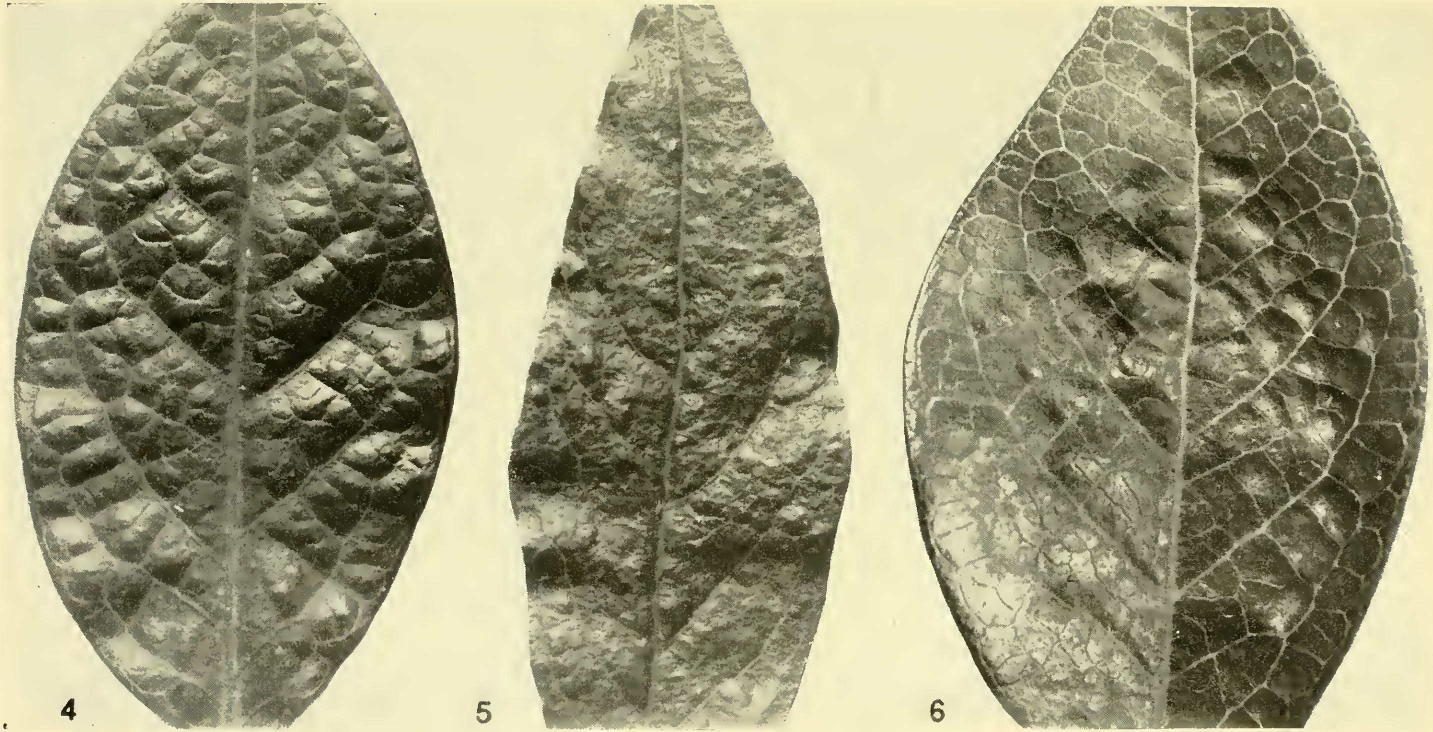

Figure 7. Leaf Surface.

4. JUNE — bullate 5. DUNFEE — bullate and mottled 6. PEMBERTON — pockmarked

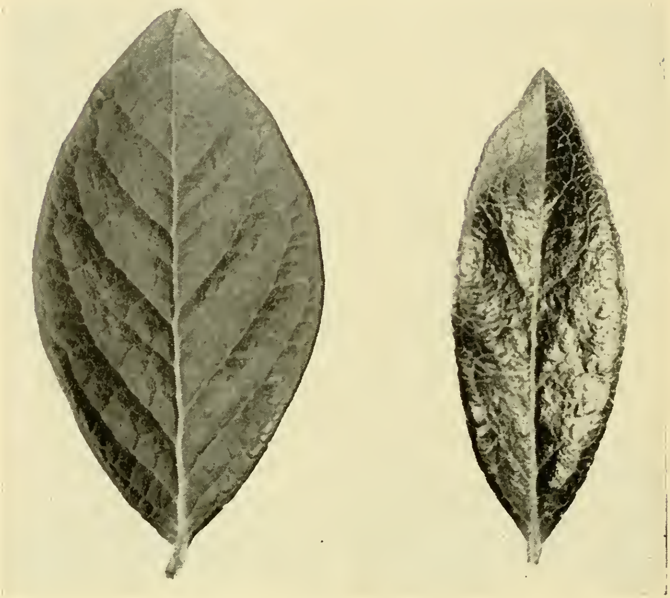

Figure 8. Leaf Surface.
Left: PIONEER — dull **Right: Rancocas — glossy**

Figure 10.
Papillose-hispid Condition of Young Leaves.

The presence or absence of *pubescence*, or fine hairs, is often very useful in distinguishing varieties. On the upper surface of the leaf, they are found along the midrib; on the lower surface of the leaf, on the midrib and sometimes also on the principal veins. Of the four varieties having pubescence on both surfaces of the leaf, Grover is outstanding (Figure 9). The varieties Dunfee and Jersey have no pubescence; that is, are *glabrous*, while a number have pubescence on the upper surface only. Sometimes the pubescence is carried down onto the petiole, or stem of the leaf, so that its presence or absence there helps in identification.

The leaves of some varieties have short, thick hairs or bristles on their top surface. This bristly, or *hispid*, condition occurs on some of the young leaves of young plants of certain varieties. The leaves which show

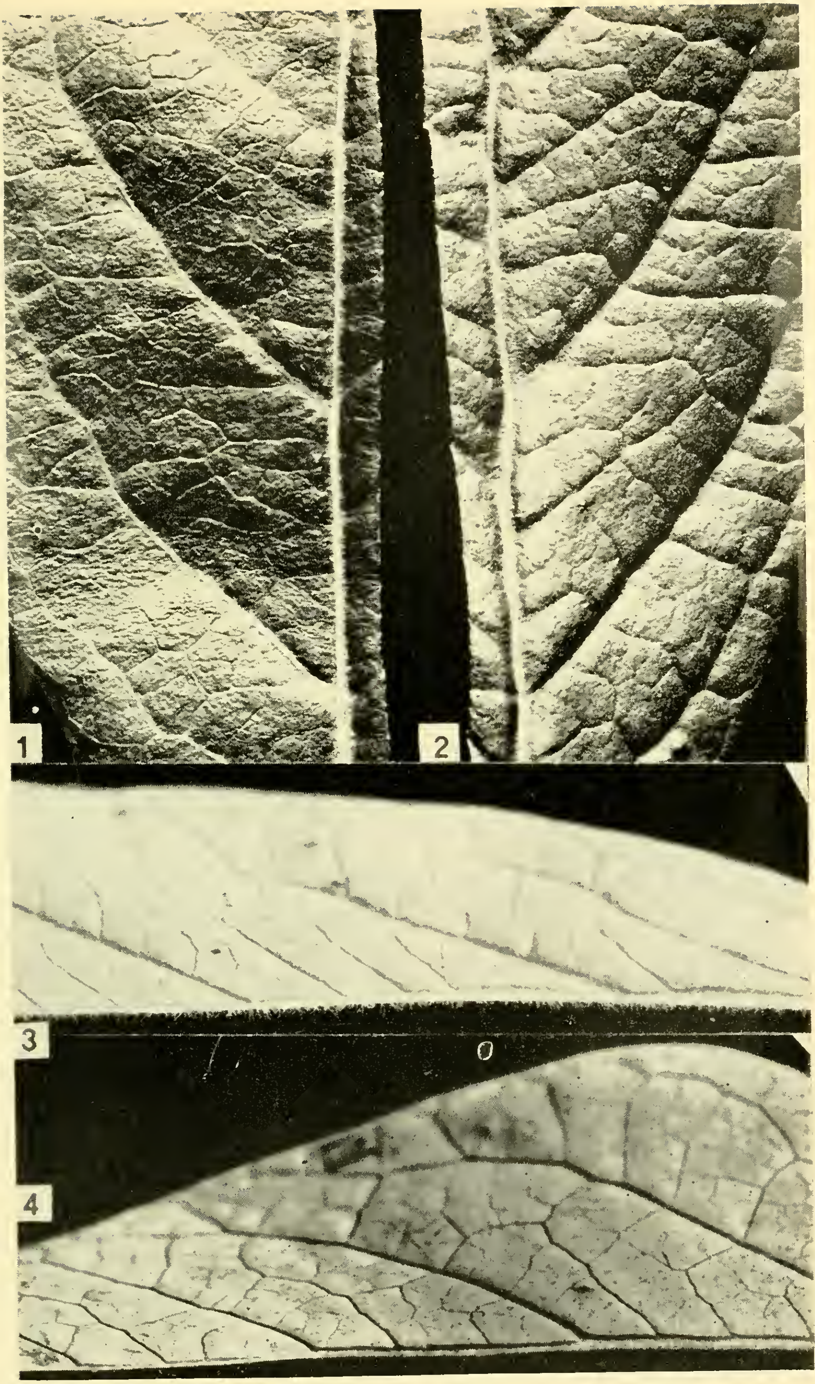

Figure 9. Leaf Pubescence.

1. JERSEY — top of midrib glabrous
2. GROVER — top of midrib pubescent
3. GROVER — bottom of midrib pubescent
4. JERSEY — bottom of midrib glabrous

this develop late in the summer, are reddish brown in color and many of the bristles arise from pimple-like swellings, or papillae, which together with the bristles is called *papillose-hispid* (Figure 10) and gives the leaf a very rough feel.

The *leaf margins* of three varieties, Rancocas, Wareham, and Harding, are *serrulate* or finely saw toothed (Figure 11); those of other varieties are *entire.* Some varieties have a *slightly reflexed* margin like Rubel, while others are strongly reflexed like Burlington (Figure 12). One variety, Concord, has the leaf margins reflexed so much that they are described as *rolled.* These characters of the leaf

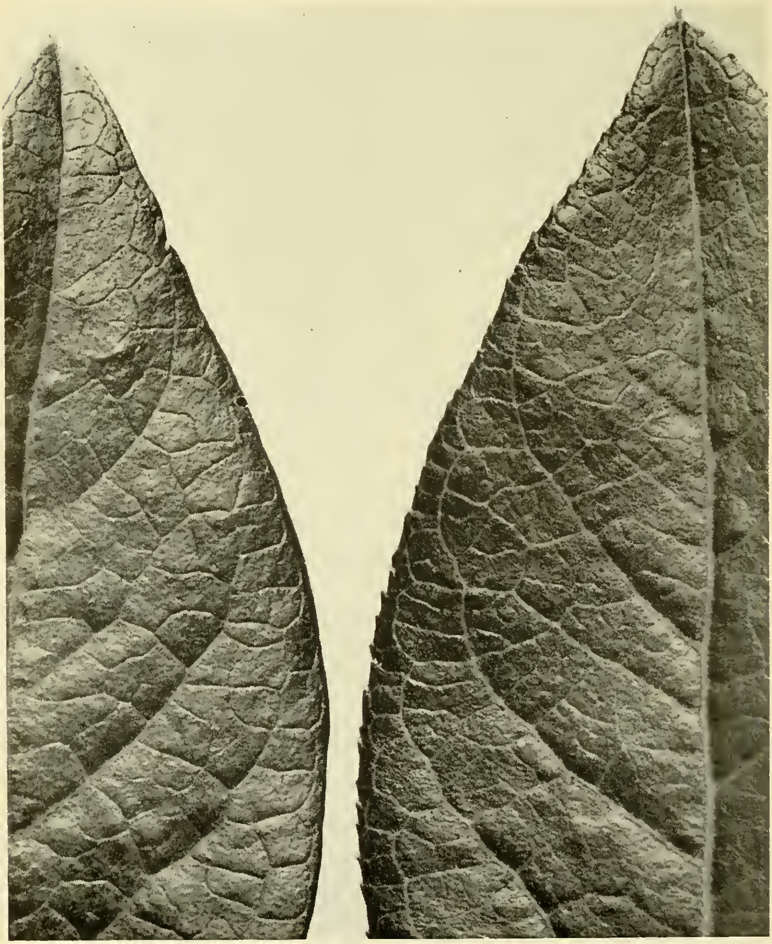

Figure 11. Leaf Serrulations.
Left: RUBEL — entire **Right: RANCOCAS — serrulate**

Figure 12. Leaf Margins.
Left: RUBEL — slightly reflexed **Right: BURLINGTON — strongly reflexed**

margin can often be more easily sensed by touch than by sight. If the forefinger is run along the edge of the leaf from the apex toward the base, the serrulations can be felt. Similarly, if a leaf is taken between the thumb and forefinger, with the upper surface of the leaf toward the thumb, and drawn from between them, a reflexed margin can be felt easily.

Leaf thickness, although not so easy to define and use as some characters, is sometimes helpful. The leaves of June are considered thick; those of Jersey medium to thick. Dunfee and Stanley have thin leaves while five varieties including Concord have leaves medium to thin. Most varieties, like Pioneer, have leaves of medium thickness.

Shoot pubescence is another useful character. Some varieties, such as Rubel, have no pubescence on the shoot; that is, are glabrous; others, such as Rancocas, have light pubescence; while still others, such as Grover, have heavy pubescence (Figure 13).

Shoot bark color is a great help in distinguishing varieties if the plants can be seen in winter. Some varieties have green bark as Adams; some have yellowish bark as Jersey; while some have bright reddish brown bark as Pioneer, and others dull reddish brown bark as Rubel.

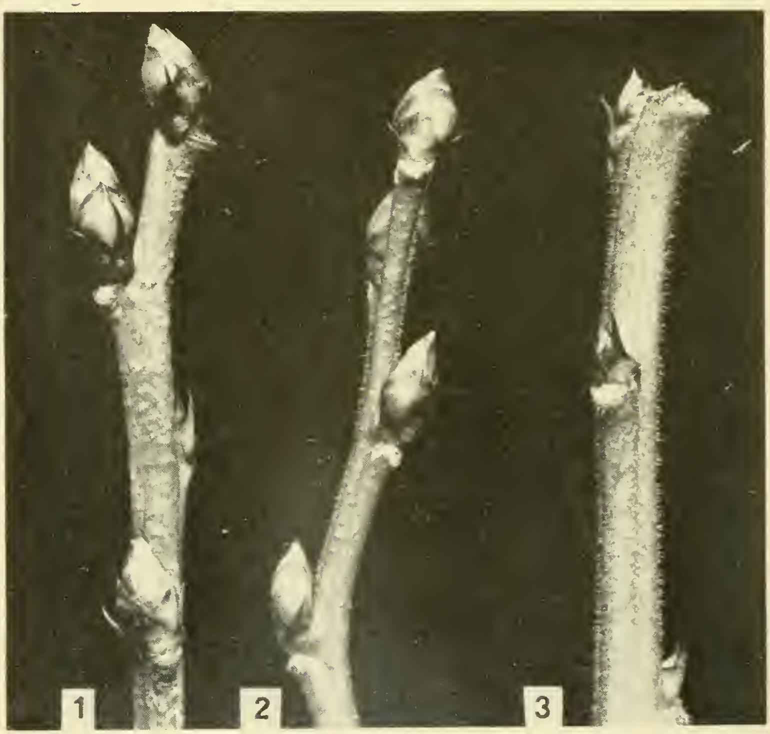

Figure 13. Shoot Pubescence.

1. RUBEL — glabrous
2. RANCOCAS — light pubescence
3 GROVER — heavy pubescence

Pairs of Similar Varieties

Certain pairs of varieties look much alike in many of their characters, especially such as are available in the nursery, and are, therefore, difficult to distinguish. In the following paragraphs, ways are given for separating these pairs.

JERSEY -- STANLEY

Although Jersey and Stanley look very much alike in the nursery, there are two characters by which they can be separated. In the spring and again in the early fall the leaves of Stanley develop a bluish green hue that is not apparent on the leaves of Jersey. While this difference is helpful, a more reliable one, which is always apparent, is the presence or absence of pubescence on the leaves. Jersey has no pubescence; Stanley has slight to moderate pubescence along the top of the midrib.

WAREHAM -- HARDING

The mature bushes of these two varieties are not difficult to distinguish. Wareham makes a vigorous, upright, slightly drooping growth; Harding a less vigorous, lower, more spreading growth. However, among young plants the differences between these two varieties are so small that this pair is one of the most difficult to separate in the nursery. Shoot pubescence is a little heavier on Harding. On the other hand, the netting of the veins is a little more prominent on Wareham leaves and they are sometimes somewhat rugose. In the fall, the veins of Wareham usually turn red earlier than those of Harding. The tip leaves of Wareham appear to be erect; those of Harding do not.

CONCORD -- RUBEL

These two varieties are not so nearly alike as the preceding pairs, but they have been found mixed in the nursery. The Concord leaf is narrow elliptic; the Rubel, elliptic. The base angle of Concord is narrow; Rubel is medium. The apex angle of Concord is medium; that of Rubel is narrow. The Concord leaf is flat and waved; the Rubel leaf flat to broadly V-folded. The leaf surface of Concord is smooth to slightly rugose; that of Rubel essentially smooth, sometimes slightly bullate or slightly netted. The leaf margin of Concord is reflexed to rolled; that of Rubel is only slightly reflexed. The tip leaves of Concord are spreading; those of Rubel erect.

ATLANTIC -- BURLINGTON

Although these varieties are not too much alike, they are new and have been mixed in the nursery. Therefore, they deserve special attention. The leaves of Atlantic are oval to ovate with a length/width ratio of less than 2. Also, there are on most plants some almost round leaves making two distinct types, which is peculiar to this variety. Burlington leaves are elliptic with a length/width ratio of 2. Atlantic leaves are flat to broadly U-folded and slightly wavy. Also, some leaves have a distinctly twisted midrib (Figure 5). Burlington leaves are saucer- to broadly V-folded. Atlantic leaves are sometimes pockmarked; Burlington leaves are not. Burlington leaves have a stiffness and sometimes a marked bluish bloom neither of which are apparent on Atlantic.

Key to Varieties

Since it is a tedious and time-consuming job to compare an unfamiliar variety with a long list of technical variety descriptions in order to make an identification, a key is usually prepared by which varieties or groups of varieties can be systematically eliminated from consideration. Such a key can be no more reliable than the characters used in making it. Since, as already pointed out, all plant characters are more or less variable, no key can be perfect. It should always be used in connection with good technical descriptions. Used with its limitations and advantages in mind a good key can be a great help. The following key was prepared with these points in mind.

- A Leaf margin serrulate
  - B Leaf midrib pubescent on top only .... *15 Rancocas
  - BB Leaf midrib pubescent on both sides
    - C Tip leaves erect .... 20 Wareham
    - CC Tip leaves not erect .... 9 Harding
- AA Leaf margin entire
  - B Leaf midrib pubescent on both sides
    - C Shoots pubescent .... 8 Grover
    - CC Shoots not pubescent .... 1 Adams
  - BB Leaf midrib not pubescent on both sides
    - C Leaf length distinctly less than twice the width
      - D Leaf midrib not pubescent .... 10 Jersey
      - DD Leaf midrib pubescent on top
        - E Leaves slightly waved and twisted .... 2 Atlantic
        - EE Leaves neither waved nor twisted
          - F Petiole pubescent
            - G Pockmarking of some leaves .... 19 Stanley
            - GG No pockmarking .... 12 Katherine
          - FF Petiole not pubescent .... 13 Pemberton
    - CC Leaf length twice the width or nearly so
      - D Petiole pubescent
        - E Some leaves reverse curved .... 14 Pioneer
        - EE Leaves not reverse curved
          - F Leaves ovate .... 6 Dixi
          - FF Leaves narrow elliptic .... 4 Cabot
      - DD Petiole not pubescent
        - E Leaves reverse saucer-folded .... 17 Sam
        - EE Leaves flat to broadly V-folded
          - F Leaves distinctly elliptic
            - G Leaf margins not distinctly reflexed .... 16 Rubel
            - GG Leaf margins strongly reflexed .... 3 Burlington
          - FF Leaves elliptic to ovate .... 11 June
    - CCC Leaf length distinctly more than twice the width
      - D Some leaves distinctly mottled and bullate .... 7 Dunfee
      - DD Leaves not mottled and bullate
        - E Petiole pubescent (on top) .... 21 Weymouth
        - EE Petiole not pubescent
          - F Leaves twisted .... 5 Concord
          - FF Leaves not twisted
            - G Leaf surface dull .... 18 Scammell
            - GG Leaf surface glossy .... 22 No. 73

*See variety descriptions, pages 17-19.

Variety Descriptions

1. ADAMS. Leaf blade small, elliptic to narrow ovate, length width ratio greater than 2, medium thickness, base angle medium, apex angle narrow, slightly saucer-folded, sometimes reflexed; surface smooth, glossy, dark green; margin entire, not reflexed; pubescence slight on top, few coarse hairs on bottom of midrib, absent on petiole and shoot; winter shoot color green.

Outstanding characters: Leaf elliptic to narrow ovate, smooth, glossy, dark green with even margin; winter shoot color green.

2. ATLANTIC. Leaf blade large, oval to ovate, length width ratio less than 2, medium thickness, base angle medium to wide, apex angle medium, flat to broadly U-folded, slightly waved, twisted; surface smooth to slightly rugose or slightly bullate, sometimes pockmarked, dull, medium green; young leaves slightly papillose-hispid; margin entire, strongly reflexed; pubescence slight on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Tip leaves waved and twisted, some leaves ovate, others round; leaf surface dull; many horizontal branches.

3. BURLINGTON. Leaf blade large, stiff, elliptic to oval, length width ratio 2, medium thickness, base and apex angles medium to wide, broadly V-folded to saucer-folded; surface smooth to somewhat bullate, dull, medium green; young leaves slightly papillose-hispid; margin entire, strongly reflexed; pubescence slight on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaf stiff; surface dull; margin strongly reflexed; leaves color early in fall.

4. CABOT. Leaf blade medium in size, narrow elliptic, length width ratio greater than 2, medium thickness, base and apex angles narrow, flat to slightly U-folded; surface smooth, dull to glossy, medium green; young leaves papillose-hispid; margin entire, slightly reflexed; pubescence moderate on top of midrib, slight on top of petiole, absent on shoots; winter shoot color yellowish brown.

Outstanding characters: Leaf narrow, smooth; growth spreading.

5. CONCORD. Leaf blade medium in size, narrow elliptic, length width ratio greater than 2, thin to medium thickness, base angle narrow, apex angle medium, flat, wavy, tips sometimes twisted; surface smooth to slightly rugose, dull, medium yellowish green; margin entire, reflexed to rolled; pubescence usually none to slight on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaves twisted and waved; margin reflexed to rolled; tip leaves spreading.

6. DIXI. Leaf blade medium in size, ovate, length width ratio little greater than 2, thin to medium, base angle medium to wide, apex angle medium, flat to broad V-folded, somewhat reflexed, sometimes waved; surface essentially smooth, sometimes slightly rugose, dull to glossy, medium to dark green; margin entire, somewhat reflexed; pubescence slight on top of midrib, none to slight on petiole, absent to slight near tip of some shoots; winter shoot color yellowish green.

Outstanding characters: Leaf smooth, thin, ovate; tip leaves waved and spreading; growth spreading.

7. DUNFEE. Leaf blade medium in size, narrow elliptic, length width ratio greater than 2, thin, base angle narrow to medium, apex angle very narrow, U- to V-folded, essentially broad; surface characteristically mottled and finely bullate, glossy, medium to dark green; margin entire; pubescence absent on midrib, petiole, and shoot; winter shoot color dull reddish brown.

Outstanding characters: Some leaves mottled and bullate, apex narrow.

8. GROVER. Leaf blade medium in size, elliptic to obovate, length/width ratio 2, thin to medium, base and apex angles medium, essentially flat to slightly reverse saucer-folded, some twisted midribs; surface slightly rugose, sometimes netted, dull, light yellowish green; margin entire, reflexed; pubescence abundant on bottom, moderate on top of midrib, abundant on both petiole and shoot; winter shoot color yellow.

Outstanding characters: Leaves, petioles, and shoots most pubescent of any variety; leaves obovate, veiny, and light colored; shoots light colored.

9. HARDING. Leaf blade medium in size, narrow elliptic, length width ratio greater than 2, medium thickness, base and apex angles narrow, broadly V-folded; surface netted, dull to glossy, dark green; margin serrulate, slightly reflexed; pubescence slight to moderate on top and bottom of midrib, moderate on top and bottom of petiole, moderate on shoot; winter shoot color yellowish brown.

Outstanding characters: Leaf margin serrulate; shoots pubescent.

10. JERSEY. Leaf blade large, oval, length width ratio less than 2, medium to thick, base angle medium to wide, apex angle wide, mostly flat with a tendency to reversed curve on tip leaves; surface smooth to slightly rugose, sometimes pockmarked, dull to semi-glossy, medium yellowish green; margin entire, reflexed; pubescence absent on midrib, petiole, and shoot; winter shoot color yellow.

Outstanding characters: Leaf large, oval, glabrous; tip leaves sometimes reverse curved.

11. JUNE. Leaf blade small, elliptic to ovate, length width ratio 2, thick, base angle medium to wide, apex angle narrow, broadly V-folded; surface bullate, dull to semi-glossy, medium green; margin entire, slightly reflexed; pubescence slight to moderate on top of midrib, absent on petiole, slight on shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaf thick, bullate with tendency to be ovate and color prematurely (June Spot), growth weak.

12. KATHERINE. Leaf blade large, oval, length width ratio less than 2, medium thickness, base angle medium, apex angle wide, essentially saucer-folded; surface mostly smooth, sometimes rugose or bullate, dull to semi-glossy, medium green; young leaves papillose-hispid; margin entire, somewhat reflexed; pubescence slight to moderate on top of midrib, usually absent on petiole, absent to little on shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaves saucer-folded.

13. PEMBERTON. Leaf blade large, oval, length width ratio less than 2, medium thickness, base angle medium, apex angle medium to wide, usually flat to saucer- or broadly V-folded, sometimes slightly reverse saucer-folded; surface smooth to slightly rugose or bullate, sometimes pockmarked, dull to glossy, light yellowish green; young leaves slightly papillose-hispid; margin entire, somewhat reflexed; pubescence slight on top of midrib, absent on petiole and shoot; winter shoot color brownish yellow.

Outstanding characters. Leaf large, oval, light yellowish green, some leaves saucer folded and pockmarked.

14. PIONEER. Leaf blade medium in size, elliptic, length width ratio 2, medium thickness, base angle wide, apex angle medium to wide, saucer- or broadly U-folded, reverse curved; surface smooth to rugose, dull, medium yellowish green; young leaves papillose-hispid; margin entire, sometimes slightly reflexed; pubescence moderate on top of midrib, little on top of petiole, absent on shoot; winter shoot color bright reddish brown.

Outstanding characters: Leaf saucer-folded and uniformly dull.

15. RANCOCAS. Leaf blade small, elliptic, length width ratio little greater than 2, thin to medium thickness, base and apex angles medium, flat, reflexed, waved; surface smooth, glossy, medium green; margin serrulate; pubescence slight to moderate on top of midrib, present on ridge of petiole, occasionally present on weaker shoots; winter shoot color bright reddish brown.

Outstanding characters: Leaf small, glossy, reflexed; margin serrulate; tip leaves spreading.

16. RUBEL. Leaf blade medium in size, elliptic, length/width ratio little greater than 2, medium thickness, base angle narrow to medium, apex angle narrow, flat to broadly V-folded; surface essentially smooth, sometimes slightly netted or slightly bullate, dull to semi-glossy, dark green; margin entire, even, slightly reflexed; pubescence none to slight on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaf apex angle narrow; margin slightly reflexed; tip leaves erect; growth upright.

17. SAM. Leaf blade small, elliptic, length width ratio little greater than 2, medium thickness, base angle narrow, apex angle medium, reverse saucer-folded, reflexed tip, sometimes twisted; surface somewhat rugose, dull, medium green; margin entire, reflexed; pubescence slight on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaf rugose and reverse saucer-folded.

18. SCAMMELL. Leaf blade small, narrow elliptic, length/width ratio greater than 2, medium thickness, base and apex angles narrow, flat, reflexed base and tip; surface smooth to slightly netted, dull, dark green; margin entire, reflexed; pubescence slight to moderate on top of midrib, absent on petiole and shoot; winter shoot color dull reddish brown.

Outstanding characters: Leaf small, narrow, erect, base and tip reflexed; internode short.

19. STANLEY. Leaf blade large, oval, length/width ratio less than 2, thin, base and apex angles medium to wide, flat to saucer-folded; surface essentially smooth, some leaves pockmarked, dull, medium green; young leaves papillose-hispid; margin entire, strongly reflexed; pubescence slight to moderate on top of midrib, moderate on top of petiole, absent on shoot; winter shoot color yellow.

Outstanding characters: Leaf oval, pockmarked; surface dull; margin strongly reflexed; young leaves papillose-hispid; growth upright.

20. WAREHAM. Leaf blade medium in size, narrow elliptic, length/width ratio greater than 2, medium thickness, base and apex angles narrow to medium, broadly V-folded; surface distinctly netted to somewhat rugose, dull to glossy, dark green; margin serrulate, reflexed; pubescence slight to moderate on top and bottom of midrib, heavy on top and bottom of petiole, usually slight to moderate but sometimes absent on shoots; winter shoot color olive green.

Outstanding characters: Leaf netted, dark green; margin serrulate; tip leaves sometimes erect.

21. WEYMOUTH. Leaf blade small, narrow elliptic, length/width ratio greater than 2, thin to medium, base angle narrow to medium, apex angle narrow to medium usually narrow broadly V-folded, tip reflexed; surface netted, dull to glossy, medium to dark green; margin entire, strongly reflexed; pubescence slight to moderate on top of midrib, medium on top of petiole, fine on some shoots; winter shoot color bright reddish brown.

Outstanding characters: Leaf small, narrow, tends to color prematurely; surface netted; margin strongly reflexed.

22. NO. 73. Leaf blade small, stiff, narrow elliptic, length/width ratio greater than 2, medium thickness, base and apex angles narrow, flat to broadly V-folded, slightly reflexed, sometimes slightly waved; surface somewhat rugose and netted, glossy, dark green; margin entire, reflexed; pubescence slight on top of midrib, absent on petiole and shoot; winter shoot color yellowish brown.

Outstanding characters: Leaf small, narrow, stiff, dark green; surface netted.

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Publication of this Document Approved by Commission on Administration and Finance
4M (a) 5-46-18696.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 432 MAY 1946

Black Root Rot Resistant Strains of Havana Seed Tobacco for the Connecticut Valley

By C. V. Kightlinger

This bulletin reports attempts to develop a strain of Havana Seed tobacco satisfactorily resistant to black root rot, yet capable of producing high yields of good quality.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BLACK ROOT-ROT RESISTANT STRAINS OF HAVANA SEED TOBACCO FOR THE CONNECTICUT VALLEY

By C. V. Kightlinger, Research Professor of Agronomy

Havana Seed is one of the three principal types of tobacco grown commercially in the Connecticut Valley, and the principal type grown in Massachusetts. It is more or less susceptible to all of the diseases of tobacco in the Connecticut Valley, of which black root rot is one of the most important. These facts warrant persistent, earnest effort to find a satisfactory means of controlling the disease.

The nature of black root rot and the general adaptability of the causal organism to environmental conditions make immunization the only control that can be fully effective. There are promising prospects that strains of Havana Seed tobacco can be produced by breeding which will be highly resistant to black root rot and capable of producing good yields of tobacco of good type and quality on land that is badly infested with the causal organism of the disease, as well as being superior to regular Havana Seed tobacco on land that is relatively free of the causal organism of black root rot and otherwise favorable to the production of tobacco. Much progress has been made already to this end.

The Importance of Havana Seed Tobacco in the Connecticut Valley

The importance of Havana Seed tobacco in the Connecticut Valley and in Massachusetts is shown in the following table:

Table 1.—Havana Seed Tobacco and Its Relation to All Tobacco in the Connecticut Valley.*

	Acres		Yield		Value	
	Number (Havana Seed)	Percent of all Tobacco	Pounds (Havana Seed)	Percent of all Tobacco	Dollars (Havana Seed)	Percent of all Tobacco
Connecticut Valley						
1943	6,500	34	10,960,000	39	4,129,000	20
5-year average, 1939-43	7,500	35	12,960,000	41	3,400,000	24
Massachusetts						
1943	4,300	83	7,267,000	88	2,761,000	63
5-year average, 1939-43	4,700	82	8,302,000	88	2,147,000	66

*Figures are based on estimates of Crop Reporting Service

Kinds of Havana Seed Tobacco and Their Susceptibility to Black Root Rot

Havana Seed as a type of tobacco consists of many strains sufficiently alike to be distinguishable collectively from other types, but differing sufficiently to make it possible to distinguish readily between many if not all of them.

One important difference among the strains is their degree of susceptibility to black root rot, ranging from moderate to severe susceptibility on the part of much the greater number of strains to high resistance on the part of a relatively small number. The former are known generally as common or regular Havana Seed; the latter, as black root rot resistant Havana Seed, or sometimes by the shorter name resistant Havana Seed. The strains of regular Havana Seed probably resulted from farmers first selecting from existing strains seed plants that seemed to meet their needs under the conditions prevailing on their farms, and continuing the process year after year according to the same standards. Havana Seed tobacco manifests differences in many of its minor characteristics readily under different environmental conditions. Continued selection of seed plants year after year according to the ideals of different farmers, therefore, could produce strains of tobacco which differ genetically in the minor characteristics such as differentiate the strains of regular Havana Seed, but would not be likely to produce changes in major properties of the strains. Since there is good reason to believe that the original stock from which the present strains have developed was inherently susceptible to black root rot in moderate to severe degree, it is improbable that high resistance could have accumulated in any of these strains by the method by which they probably were produced.

The strains of black root rot resistant Havana Seed have been produced by artificial methods designed to create strains possessing high resistance to the disease. For the greater part they have been bred from strains well suited to provide not only high resistance to black root rot but other desirable properties as well. As a result of thorough testing to determine the degree of their resistance to black root rot and their type, quality, and yielding capacity, and of selecting and propagating only those strains that seemed to fulfill these objectives, the number of strains of Havana Seed that are highly resistant to black root rot and otherwise acceptable under Connecticut Valley conditions is few.

Economic Importance of Black Root Rot in the Connecticut Valley

The economic importance of black root rot is determined largely by the extent to which it reduces yields and quality, and consequently the cash value, of tobacco crops.

The literature contains numerous statements to the effect that black root rot has been and still is one of the most highly damaging diseases of tobacco in the Connecticut Valley. Anderson (1, 2) states that black root rot was probably the most serious of all diseases of tobacco in the Connecticut Valley during the first twenty-five to thirty years of this century. Johnson (6), writing some years back about the importance of black root rot in the country as a whole, states that it undoubtedly has caused more loss to tobacco growers than any other disease with which they have had to contend.

The occurrence of black root rot and the amount of damage caused before its identity was determined in 1906 (3) cannot be ascertained with certainty. However, the nature of the disease and the farming and cultural practices known to have been used in growing tobacco warrant the presumption that black root rot was prevalent and caused heavy damage in the Connecticut Valley long before its identity was known. Numerous investigators hold to this belief.

Observation and survey of tobacco diseases each year since 1930, and experience with black root rot in investigational work, have convinced the writer that it has been one of the most damaging diseases of Havana Seed tobacco in the Connecticut Valley during the last fifteen years. It is certain that it causes much more damage and entails heavier economic losses than most growers and other people who work with tobacco realize.

Cause and Symptoms of Black Root Rot

Black root rot of tobacco is caused by a soil-borne fungus, *Thielaviopsis basicola* (3,9), which occurs in most if not all tobacco land in the Connecticut Valley. It is capable of living in decaying vegetable matter in soils for several years in the absence of tobacco or other suscepts; and, therefore, inoculum is almost always present in tobacco soils in sufficient amounts to initiate attacks of black root rot whenever other factors are favorable for the development of the disease.

Black root rot may occur both in seedbeds and in fields. However, because effective control measures for seedbeds are known and rather generally used, the disease is principally important as a field disease of tobacco in the Connecticut Valley at the present time.

As the name implies, it is a disease of the roots of tobacco plants. The causal organism first attacks the cortical tissues of the roots, either throughout their whole length or only in segments. The first stages of the disease are characterized by a peculiar roughening of the cortex and by a peculiar rusty color of the roots, followed by rotting of the cortical tissue and usually of underlying tissues as well. The smaller fibrous roots may be entirely rotted away while the larger roots are only moderately infected, evidencing lesions underneath which the tissues may or may not be dying or entirely dead. The later stages of the disease are characterized by the usual brown color of decaying plant tissues throughout, or by this brown color intermingled with black spots. The black spots are growths of a spore form of the organism and are usually more noticeable on the larger roots, which are often encircled by the black spore masses and girdled. Diseased fibrous roots which might well bear the black spores are usually lost in digging and often are not seen. In severe cases, most of the root system may be rotted away, leaving only stubs of roots or a whisk composed of root stubs and short fibrous roots which have grown above older roots, apparently in the plant's attempt to counteract the effects of the loss of the lower roots. These later-grown fibrous roots may become diseased in turn and die and decay.

The disease disrupts the supply of water and nutrients from the roots to the tops of the plants, with a consequent stunting of the plants. The above-ground symptom usually noticed first is the greater than normal wilting of the plants. Later symptoms are either a yellowish color or, more commonly, a darker than normal green color of plants. Other later symptoms are the growth of narrow , thick, tough leaves. Badly diseased plants "top-out" or produce their inflorescense prematurely.

Black root rot seldom attacks a whole field of tobacco uniformly. Patches of diseased plants may be several acres in size, but are usually smaller. Different patches in the same field, or even different parts of the same patch, may be diseased in different degrees of intensity and accordingly manifest the distinguishing symptoms in various degrees of development.

Certain other diseases of tobacco have more or less similar above-ground symptoms, and it is not always possible, even for a person who is thoroughly familiar with black root rot, to distinguish the disease with certainty by the above-ground symptoms alone. It is by the presence of the black spore masses on the roots that the identity of the disease can be most easily determined with certainty.

Factors in the Development of Black Root Rot of Tobacco

There are four major factors that largely determine the occurrence and development of black root rot: the degree of infestation of the soil by the causal organism, soil reaction, soil moisture and temperature, and the degree of susceptibility of tobacco to black root rot.

The causal organism of the disease occurs more or less prevalently in most of the land on which tobacco is or has been grown in the Connecticut Valley. The organism has a rather wide range of suscepts, consisting of a few economic and numerous wild plants, and occurs in other than tobacco land. Because tobacco has been grown continuously for long periods on much of the tobacco land, there is usually sufficient inoculum in the soil to cause moderate to severe attacks of black root rot whenever other conditions are favorable to its development.

Relatively low soil acidity (high pH value) is favorable, and relatively high acidity (low pH value) is unfavorable to the development of black root rot. Under most weather conditions in the Connecticut Valley, the disease ordinarily causes moderate to heavy damage to tobacco at pH 6.0 and higher, but is seldom serious at soil reactions below pH 5.6, and is not likely to develop at soil reactions of pH 5.2 or lower. Because of the nature of the parent material from which they were formed, most soil types used to grow tobacco in the Connecticut Valley were originally sufficiently acid to be unfavorable for the development of black root rot. With reasonable precautions in the use of fertilizers and soil treatments, their acidity can be maintained at levels unfavorable to the disease. However, as a result of liberal treatments with alkaline fertilizers and lime, the reaction of large acreages has been increased until it is now within the range of acidity that is favorable for the development of black root rot.

The causal organism of black root rot is able to grow at soil temperatures from 10° to 40° C. (50° to 104° F.) (10), but is apparently able to infect tobacco only within the lesser range of 15° to 32° C. (59° to 89.6° F.), and severe infection is limited to the still smaller range of 18° to 23° C. (64.4° to 73.4°F.) (8). Any ability of the causal organism to infect tobacco at soil temperatures below 18° C. (64.4°F.) is of little practical importance because soil temperatures as low as this ordinarily do not occur in the Connecticut Valley after tobacco is transplanted into the field. The ability of the organism to infect tobacco lessens rapidly at soil temperatures higher than 26° C. (78.8° F.) and ceases almost entirely at 32° C. (89.6° F.) (8). This is of some practical importance because soil temperatures higher than optimum for the development of the disease occur during portions of some tobacco growing seasons, especially during the latter part. For this reason, tobacco that has become infected by black root rot early in the growing season sometimes recovers sufficiently to yield fairly good crops. Frequently, however, when soil temperatures are low, especially in heavy soils which warm up slowly, tobacco may become too severely diseased to recover much.

Soil moisture may have a dual effect on the development of black root rot. High soil moisture near the saturation point is intrinsically favorable to the development of the disease (8). A moisture content of less than saturation has little or no direct effect on the development of the disease (8); but evaporation of soil moisture lowers soil temperature; and, other things such as soil texture, structure, etc., being equal, the greater the amount of soil moisture evaporated the lower the soil temperature becomes. And, as has been explained, the lower soil temperatures are favorable to the development of black root rot.

Immunity of tobacco to black root rot would, of course, eliminate it as an important disease of the crop. However, none of the many strains of Havana Seed are immune and only a very few are highly resistant to black root rot. Strains susceptible to the disease make up the major portion of the acreage of Havana Seed grown in the Connecticut Valley each year.

Factors That Determine the Nature of an Effective Control Measure for Black Root Rot of Havana Seed Tobacco

The principal purpose of the foregoing accounts of Havana Seed tobacco and of black root rot has been to show two things. First, Havana Seed comprises so large a part of the total tobacco crop in the Connecticut Valley and especially in Massachusetts that large fluctuations in its production would cause large fluctuations in the total tobacco yield and consequently in the cash income obtained from tobacco each year. Second, black root rot causes sufficient damage to Havana Seed to reduce the production of this type of tobacco materially below its potential capacity for production. If there were an effective, easy-to-use method of controlling the disease, this loss could be prevented. Such a control measure would provide one of the greatest possible improvements in the production of Havana Seed tobacco in the Connecticut Valley.

The nature of black root rot and the adaptability of the causal organism to prevailing environmental conditions, determine the principles of disease control that may be used in devising and developing an effective control measure. Of the four fundamental principles of disease control—exclusion, protection, eradication, and immunization—all except the last are either wholly or largely inapplicable in the control of black root rot of tobacco.

The general distribution of the causal organism in Connecticut Valley tobacco soils renders the exclusionary principle of disease control inapplicable.

Black root rot, as already pointed out, is a disease of the roots of tobacco plants. Since the roots are shielded by soil, protective fungicides cannot be used directly to control the disease. However, farmers who still have tobacco land of pH 5.3 or lower can protect their crop indirectly by maintaining this soil acidity, which is unfavorable to the development of the disease. On large acreages, the soil reaction has been increased by the use of alkaline fertilizers and lime until it is favorable for the development of black root rot; and after soil has been made alkaline, there is no practical way known to reduce its alkalinity readily. As a result, the protective principle of disease control is not fully applicable in the control of black root rot of tobacco.

As has been pointed out, the causal organism of black root rot is already present in practically all tobacco land in the Connecticut Valley. Since it can live indefinitely in decaying vegetable matter in soils in the absence of tobacco, a prolonged period without tobacco would be required to eliminate the organism from the soil by starvation. Rotation of tobacco with other farm crops, to aid in the starvation of the organism, is ordinarily not advisable because the residual effects of many farm crops promote the development of brown root rot which might be as harmful to tobacco as black root rot. Neither is it practical for tobacco farmers to fallow their land for long periods of time. The regular practice in the Connecticut Valley is to grow tobacco continuously on the same land year after year, and this not only maintains but often increases the infestation of the causal organism of black root rot in tobacco soils. As a result, the eradicative principle is not applicable in the control of black root rot.

Fortunately the circumstances that prevent the use of exclusion, protection, and eradication in the control of black root rot do not affect the use of immunization for the purpose. And since immunization was found to be the only principle on which fully effective control of the disease could be based, it was undertaken to discover resistant specimens in acceptable strains of regular Havana Seed, if possible, and from them to develop new strains. If suitable specimens could not be found, it was proposed to produce, by artificial breeding procedures, new strains of Havana Seed, highly resistant to black root rot and capable of producing good yields of tobacco of good type and quality in both infested and uninfested soils.

EXPERIMENTAL PROCEDURE AND RESULTS

Materials and Methods[1]

Previous knowledge of the nature of regular Havana Seed tobacco made it seem unlikely that specimens possessing high resistance to black root rot could be found. However, in order that nothing of value might be overlooked, numerous strains were tested under severe black root rot promoting conditions on the Massachusetts Agricultural Experiment Station farm. Also, in cooperation with several leading cigar and tobacco manufacturing companies who sponsored the work, many strains were tested on an outlying farm. In addition, the progeny of unusually vigorous Havana Seed tobacco plants found in various localities and suspected of possessing more than usual resistance to black root rot were

[1] The investigational work reported in this bulletin was done in part while the writer was employed by the Bureau of Plant Industry, United States Department of Agriculture, working in cooperation with Massachusetts and Connecticut Agricultural Experiment Stations, and in part while he was employed by Massachusetts Agricultural Experiment Station. The writer is indebted to Dr. W. W. Garner, formerly of the Bureau of Plant Industry, Dr. James Johnson of the Bureau of Plant Industry, and Dr. P. J. Anderson of the Connecticut Agricultural Experiment Station for advice and materials used in the work.

also tested under severe black root rot promoting conditions on the Experiment Station farm. The first two of these tests were conducted for two and three years respectively; the other test was continued over a longer period as suitable plants were found.

If specimens that possessed satisfactory resistance to black root rot could have been found in the strains of regular Havana Seed tested, it would probably have provided a convenient solution to the problem, because regular Havana Seed is already acceptable to cigar manufacturers for type and quality. Unfortunately, although the strains tested differed somewhat in degree of resistance, none of them possessed sufficient resistance to make them suitable for growing under moderate to severe black root rot promoting conditions. It seemed doubtful whether more extensive testing of regular Havana Seed would serve any useful purpose. Therefore, controlled breeding procedures were used in an effort to produce new strains of Havana Seed which would possess high resistance to the disease in combination with acceptable type and quality, when grown under Connecticut Valley conditions.

The production of new strains by means of controlled breeding methods involved several necessary phrases of work:

1. The first phase was the choice of parental stocks that between them possessed the desired properties, and the crossing of selected parental plants.

Obviously, since the new strains had to be of true Havana Seed type, it was necessary that at least one parent be of that type. Actually, for a large part of the work, both parents were chosen from Havana Seed stock — one from a strain highly resistant to black root rot, the other from a strain highly acceptable in type and quality.

The hybridizing work consisted of making crosses and reciprocal crosses of the parental stock plants and back-crossing first generation plants from these crosses to their regular Havana Seed parent. The reason for making both crosses and reciprocal crosses was to increase the chances of recombining in single individuals the desired characters possessed by the two parents. The back-crossing was done to improve type and quality in the progeny. The technique of crossing used was similar in all essential points to that used generally to breed new strains of tobacco under controlled conditions. Garner, Allard and Clayton (5) describe in considerable detail the usual technique for hybridizing tobacco. Those interested in these details are referred to their article.

2. The second phase was small-plot testing of the progeny of the various crosses, and the selection of plants that seemed to be suitable for further use in the project. They were first tested thoroughly under severe black root rot promoting conditions, to make possible the selection of plants highly resistant to the disease and also capable of producing satisfactory yields of acceptable tobacco under these adverse conditions.

The controls were Havana 142 and acceptable strains of regular Havana Seed. Havana 142, known to be satisfactorily resistant to black root rot under Connecticut Valley conditions, was used as a standard of resistance to the disease. Highly susceptible strains of regular Havana Seed were used as indicators of the severity of black root rot attack that was capable of developing under the environmental conditions that prevailed each year of the test. By comparing the severity of infection of black root rot, and also the type, quality, and yielding capacity of the progeny of the various crosses with corresponding properties of the controls, it was possible to estimate their comparative acceptability in these respects.

The progeny of plants selected as being satisfactorily resistant to black root rot in the foregoing tests were further tested under conditions unfavorable to the development of the disease and otherwise favorable for the growth and development of tobacco, to determine their value under favorable growing conditions. The controls in these tests were strains of regular Havana Seed known to be highly acceptable in type, quality, and yielding capacity under favorable tobacco producing conditions. The most acceptable plants were selected for further use in the project.

The progeny of these latest selections were retested simultaneously under black root rot promoting conditions and under conditions favorable to the good growth and development of tobacco, to make certain of their acceptability both for resistance to black root rot and for type, quality, and yielding capacity, so far as these properties could be ascertained in small plot tests. The controls used were the same strains that had been used previously.

3. The third phase was the commercial testing of the strains to determine their acceptability to tobacco farmers and to buyers and users of Connecticut Valley Havana Seed tobacco. For these purposes the strains were placed with enough tobacco farmers and were grown in sufficient amounts to provide a fair demonstration of their productiveness and salability. Those strains which, as a result of these trials, seemed to be suitable for wider use under Connecticut Valley conditions, were distributed to farmers.

Results of the Breeding Phase of the Work

Numerous as were the strains of regular Havana Seed that were tested in search of resistant specimens, the new strains which were produced by controlled breeding procedures, partly here and partly elsewhere but all developed here, were even more numerous.

Two of the new strains seemed to be sufficiently acceptable to both farmers and buyers to warrant their continuation. These are Havana 211 and a newer strain Havana K2. Although Havana 211 has not been fully accepted on the quality basis by all of the tobacco trade, it is now being bought in large quantities by our leading tobacco dealers and cigar manufacturers. The strain has become well established in the tobacco culture of the Connecticut Valley. Although Havana K2 has not been tested long enough commercially to prove its entire suitability, it is, nevertheless, very promising. At the present time it seems to be largely acceptable to tobacco farmers and to the tobacco trade, alike.

Havana 211 (see figure 1) was produced as a result of cooperative tobacco breeding work in the Connecticut Valley and in Wisconsin. The strain was bred in Wisconsin; it was developed and distributed to tobacco farmers first in the Connecticut Valley. The original cross (5,7) from which it was developed was a cross of Page's Comstock and Havana 38. Page's Comstock was resistant to black root rot, but it was coarsely typed and largely unacceptable in quality. Havana 38 was an improved strain of regular Havana Seed, highly acceptable in type and quality.

Figure 1. Havana 211.

Figure 2. Havana K2.

Both strains were grown under conditions favorable to the good growth and development of tobacco.

Figure 3. Black Root Rot Resistant Strains of Havana Seed Tobacco.

Figure 4. Strains of Havana Seed Tobacco Grown as Controls.

All the strains shown in Figures 3 and 4 were growing under severe black root rot promoting conditions.

Havana K2 was bred and developed in Massachusetts. The original cross from which it was obtained was a cross of regular Havana Seed known locally as the Sandman strain onto Havana 211. Havana K2 (see figure 2) was developed from a selection made from the backcross of first generation plants of the original cross and the regular Havana Seed parent. Havana 211 is resistant to black root rot. The Sandman strain of regular Havana Seed was highly acceptable in type and quality.

In making comparative studies of the plant type of Havana 211 and the strains used as controls, twenty plants per strain were measured during each of two years. The plants were topped at the internode just below the lowest leafless sucker or spike and allowed to mature for harvest. The leaves were counted later. Three leaves were taken from the corresponding middle part of the plants of each strain for measurement of leaf shape. The remaining leaves were removed and measurements made of the standing stalks.

The average measurements of different characteristics of plant type of Havana 211, Havana 142, and regular Havana Seed (Brown Strain) are given in Table 2.

TABLE 2.—AVERAGE MEASUREMENTS OF CHARACTERISTICS OF PLANT TYPE OF REGULAR HAVANA SEED (BROWN STRAIN), HAVANA 211, AND HAVANA 142.

Strains	Height of Plants Inches	Number of Leaves per Plant	Length of Internodes Inches	Length of Middle Leaves Inches	Width of Middle Leaves Inches	Diameter of Stalks Butt Inches	Diameter of Stalks Top Inches
I. Average Measurements First Year							
Regular Havana Seed	35.9	17.1	2.1	27.8	12.8	1.4	0.8
Havana 142	33.9	19.1	1.8	26.0	12.3	1.3	0.8
Havana 211	38.9	16.9	2.3	28.5	15.0	1.4	0.8
II. Average Measurements Second Year							
Regular Havana Seed	36.7	17.8	2.1	26.7	13.1	1.4	0.8
Havana 142	38.9	20.0	1.9	25.3	13.4	1.3	0.7
Havana 211	42.6	17.5	2.4	27.8	14.9	1.4	0.6

The measurements for comparing average leaf shapes of the different strains were made by using a measuring board constructed specially for the purpose. The plan of the board consisted of a horizontal axis from whose center radii were drawn at angles of 5, 10, 15, 20, 25, 30, 45, 65, 90, 115, 135, 150, 155, 160, 165, 170 and 175 degrees. In using this board, the midrib of the leaf was held on the horizontal axis of the board with the center of the midrib at the center of the axis, and measurements were taken from the center to the outside edge of the leaf along each of the seventeen radii. Three other measurements were made of each leaf: length along the midrib, width at the place of greatest width, and width of the butt.

The diagrams of the comparative leaf shapes of Havana 211 and a strain of regular Havana Seed (Brown Strain) were plotted from proportionate reductions of average measurements of leaf characteristics. (See Diagrams 1 and 2.)

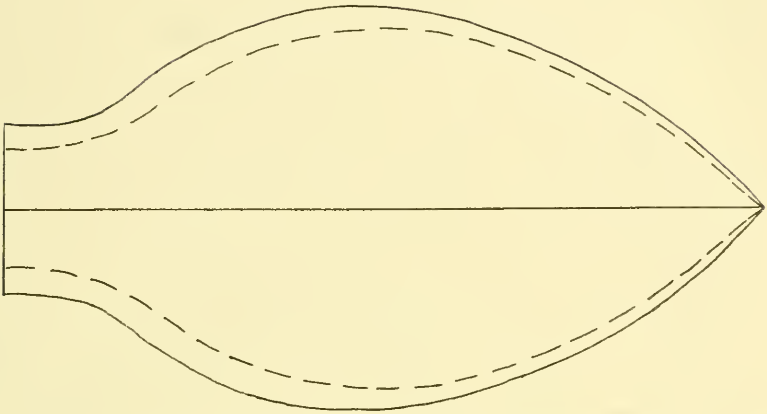

Diagram 1. Comparative Leaf Shape, First Year of Experiment.

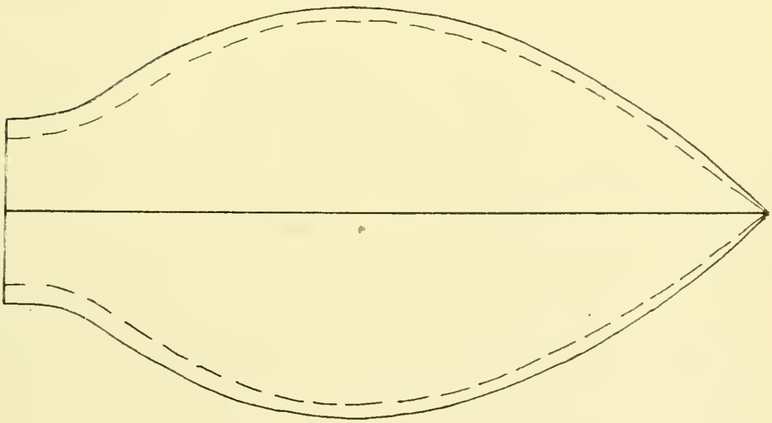

Diagram 2. Comparative Leaf Shape, Second Year of Experiment.

———————— Havana 211 — — — — — — Regular Havana Seed

Results of small-plot tests to determine the comparative productiveness of Havana 211 and the controls both under black root rot promoting conditions and under favorable producing conditions in which the disease was not an important factor, are given in Table 3. The results as given are averages obtained over a five-year period in the earlier part of the project before Havana K2 had been developed.

Results of similar tests with both Havana 211 and Havana K2 and the controls are given in Table 4, and are averages obtained over the five-year period from 1940-1944 inclusive.

Table 3.—Average Productiveness of Havana 211 and Controls.

Strain	Grown on Black Root Rot Free Land			Grown on Black Root Rot Land		
	Average Yield per Acre (Pounds)	Average Grade Index	Average Crop Index	Average Yield per Acre (Pounds)	Average Grade Index	Average Crop Index
Regular Havana Seed	2,050	417	855	1,323	.309	420
Havana 142	2,200	.451	992	1,872	.362	678
Havana 211	2,212	.476	1053	1,944	.407	791

Table 4.—Average Productiveness of Havana 211, Havana K2, and Controls.

Strain	Grown on Black Root Rot Free Land			Grown on Black Root Rot Land		
	Average Yield per Acre (Pounds)	Average Grade Index	Average Crop Index	Average Yield per Acre (Pounds)	Average Grade Index	Average Crop Index
Regular Havana Seed	1,803	.452	815	1,486	.382	568
Havana 142				1,968	.421	829
Havana 211	2,188	.481	1052	2,060	.444	920
Havana K2	2,111	.470	992	1,984	.425	843

Grade Index, as used here, is a number expressing the grading quality of tobacco sorted according to the usual standards for Havana Seed. It is based on the percentage yield of each grade of tobacco in a crop and the relative ratings of these grades, which are percentages based on the light wrapper grade as a standard of highest quality in Havana Seed tobacco. The relative ratings of grades are given below:

Light Wrapper	1.00
Medium Wrapper	.70
Long No. 1 Seconds (18″ and longer)	.70
Short No. 1 Seconds (16″ and shorter)	.30
Long No. 2 Seconds (18″ and longer)	.30
Short No. 2 Seconds (16″ and shorter)	.10
Long No. 1 Darks (20″ and longer)	.40
Short No. 1 Darks (18″ and shorter)	.30
Long No. 2 Darks (29″ and longer)	.20
Short No. 2 Darks (18″ and shorter)	.10
Fillers	.10

Grade Index is derived by multiplying the percentage yield of each grade by its relative rating and adding the products. Crop Index is derived by multiplying the yield of tobacco in pounds per acre by the grade index of the tobacco.

Neither the adopted relative values of the different grades, nor the grade index, nor the crop index represents commercial prices of tobacco.

Discussion of Results

The suitability of any strain of tobacco for general commercial growing depends principally upon the ability of the strain to produce sufficient readily salable tobacco to be profitable to the producer. To be readily salable, tobacco must be of a quality that is acceptable to buyers.

So far as gross yields are concerned, it is natural for farmers to want to produce as much readily salable tobacco as they can. There is a limit, however, to the size of tobacco that can be handled and cured successfully with the equipment available. Rather than attempt to formulate an arbitrary standard for profitable gross yields, it seemed advisable to use the actual gross yielding capacity of Havana 142 under black root rot promoting conditions and of regular Havana Seed under favorable producing conditions as standards. So far as gross yields are concerned, Havana 142 has long been acceptable under root rot promoting conditions, and regular Havana Seed is largely acceptable under favorable conditions when black root rot is not an important factor.

The following analysis of data in Tables 3 and 4 shows how Havana 211 and Havana K2 compare with the controls in productiveness under different conditions.

Strain	Percent Increase over Regular Havana Seed			Percent Increase over Havana 142		
	Yield	Grade Index	Crop Index	Yield	Grade Index	Crop Index
I. Under Black Root Rot Promoting Conditions						
Havana 211						
(Table 3)	47	32	88	4	12	17
(Table 4)	39	16	63	4.5	5.5	10
Havana K2						
(Table 4)	33.5	11	48	0.8	0.9	1.7
II. Under Favorable Producing Conditions						
Havana 211						
(Table 3)	8	14	23	.05	5.5	6
(Table 4)	21	6.5	29	–	–	–
Havana K2						
(Table 4)	17	4	22	–	–	–

Since Havana 211 and Havana K2 equaled or exceeded Havana 142 slightly in gross yielding capacity under black root rot promoting conditions, and exceeded regular Havana Seed considerably under favorable tobacco producing conditions, it would seem that there can be little if any doubt about their acceptability in productiveness under most, if not all, circumstances in the Connecticut Valley. Since the productiveness of these strains under black root rot conditions depends largely upon their resistance to the disease, it would seem that there can be little doubt about their being satisfactorily resistant under most circumstances.

Actually, however, according to root-examination tests, Havana 211 is not so resistant to black root rot as Havana 142, and Havana K2 may not be quite so resistant as Havana 211.

Type of plant and leaf are very important in the growing, handling, and curing of Havana Seed tobacco and the production of tobacco of a quality that is readily salable. The stems or stalks should be strong enough to support the plants well during growth but not large enough to interfere with successful curing. Probably the actual size of stalks, within such range of sizes as is likely to develop in Havana Seed tobacco, is less important in the successful curing of tobacco than the average length of internodes and the size and strength of midribs of leaves. For the most successful curing, it is essential that the internodes be long enough and the midribs strong enough to hold the leaves considerably away from the stalks, to prevent their matting upon one another and around the stalks during curing. Such height of plants as will produce enough leaves to give a satisfactory yield and produce the leaves far enough apart to permit of satisfactory curing is desirable. Greater height than this is not desirable: first, on account of the likelihood that winds and storms may cause more damage to the taller plants; and second, on account of the inconvenience that the greater length of stalks may cause in harvesting. The leaves should be borne as nearly upright as possible, for this makes it easier to care for and handle the plants with little breaking of leaves, and especially of the midribs, during topping and suckering, and consequently with little dropping of leaves during harvest. The leaves should be of suitable shape and size for use in making cigars. They should be smooth and as small veined as possible and have good body.

Quality in tobacco is comprised of numerous characteristics of the cured leaf. Chief of these are color, body, burn, flavor, aroma, smoothness, veininess, elasticity, and absence of either mechanical or curing injury. Shape and size of leaf, named earlier as characteristics of plant type, are also characteristics of quality. There is general understanding of what is desirable in most of these characteristics of quality. Leaves should be free from injury to facilitate cigar making operations and to avoid waste of materials. In size and shape, they should be wide enough to permit the cutting of cigar binders of proper length and width, and oval enough to permit this to be done well toward the tip. Leaves should have enough body to withstand handling, curing, and sweating or fermenting satisfactorily. They should be smooth and small veined, and a uniform light chocolate color is preferred. Tobacco should be capable of staying lighted while a cigar is being smoked, and burn with a white, non-shattering ash. Flavor and aroma, however, can be judged only by taste and smell; and acceptability for these characteristics is largely a matter of personal perference. All things considered, it is more difficult to know what may probably comprise acceptable quality in tobacco than to know what may comprise acceptable type of leaf and plant and satisfactory yielding capacity.

Endeavor was made to incorporate into the new strains such essential characteristics of plant and leaf types and quality of cured leaf as would at least equal and, if possible, surpass the desirable characteristics of regular Havana Seed, when the latter is grown under favorable producing conditions. As for type of plant, comparative measurements showed that Havana 211 and regular Havana Seed had stems of about the same thickness. When both strains were topped at corresponding heights, the plants of Havana 211 where somewhat taller than those of regular Havana Seed but bore slightly fewer leaves, so the average length of internode was somewhat longer. The average length and width of leaves were considerably greater for Havana 211. The strain holds its leaves in a very upright position during most of its growing period, and at no time do they droop badly. They are fairly smooth and of fairly good body, with a strong midrib and medium sized lateral veins. It is, however, a matter of personal opinion with cigar manufacturers whether the quality of Havana 211 is as good usually as that of regular Havana Seed. Some of them say it is not.

Havana 211 withstands drouth better than regular Havana Seed and seldom if ever "fires" under severe drouth conditions. An unusual but desirable property of the strain is that flea beetles and thrips do not attack it so readily as they do regular Havana Seed.

On the other hand, Havana 211 has one undesirable habit of growth — it is a week to ten days later in date of maturity than regular Havana Seed. When both are planted at the same time and grown under the same cultural and environmental conditions, both develop similar symptoms of maturity at the same time. However, experience has shown that if Havana 211 is harvested at this stage of maturity, it will not cure best, and consequently will not yield the highest quality of tobacco that it is potentially capable of producing.

The characteristics of plant and leaf type of Havana K2 have not yet been measured. However, careful observation and comparison of the plants and leaves of Havana K2 and Havana 211 show that the two strains do not differ greatly in the more evident characteristics of type; such differences as there are, being largely in favor of Havana K2. The leaves have somewhat more body, and although they are slightly narrower, they are wide enough for economical use in making cigars. Havana K2 matures for harvesting several days earlier than Havana 211, and nearer the date of most strains of regular Havana Seed. In all commercial trials so far, Havana K2 has been somewhat more satisfactory than Havana 211 in curing and sweating or fermenting properties. It is largely the improvements in certain characteristics of type, earlier date of maturity, better curing, and better sweating or fermenting, that suggest the possibility that Havana K2 may be a more satisfactory strain than Havana 211 for general growing in the Connecticut Valley.

The Use of Havana 211 and Havana K2 in the Connecticut Valley

The likelihood that Havana 211 and Havana K2 would be acceptable for gross yielding capacity and for type of plant and leaf was determined rather definitely before the strains were distributed generally to growers. The standards of acceptability for quality are less definitely defined. Therefore, when the strains were distributed to farmers, there was some uncertainty as to how acceptable they might be for quality under all conditions.

Havana 211 has been grown long enough commercially to demonstrate the quality of tobacco it is capable of producing under practically all conditions in the Connecticut Valley, but this is perhaps not true of Havana K2. There seems to be no question among tobacco growers that Havana 211 is able to produce tobacco of good type and quality in large enough amounts to be profitable under most circumstances. There seems to be no question among buyers that Havana

211 grown under black root rot conditions is superior in type and quality to regular Havana Seed produced under similar conditions. There are differences of opinion, however, as to whether Havana 211 is equal to regular Havana Seed in type and quality when both are grown under favorable conditions.

Except for the deterring influence of this difference of opinion among buyers, it is reasonable to believe that Havana 211 would be grown in much larger acreage than it is at the present time, and probably would have largely supplanted regular Havana Seed in the Connecticut Valley. As it is, Havana 211 has been acceptable to enough buyers to encourage many farmers to grow the strain. It is impossible to ascertain the approximate acreage that is grown yearly at the present time, but it is known to be considerable. It is reasonable to believe that the strain has contributed materially to the increase in yield of Havana Seed tobacco which has occurred during the last few years.

Complete figures on the estimated annual yields per acre of Havana Seed tobacco in the Connecticut Valley are not readily available. The estimated annual yields in Massachusetts during the last twenty-four years are given in Table 5.

Table 5.—Estimated Acreage and Acre Yields of Havana Seed Tobacco in Massachusetts During 1921-32 and 1933-44, Inclusive.*

Year	Acres	Yield per Acre (Pounds)	Year	Acres	Yield per Acre (Pounds)
1921	6,500	1,500	1933	3,900	1,530
1922	6,800	1,125	1934	2,300	1,690
1923	7,500	1,475	1935	2,600	1,650
1924	8,100	1,440	1936	3,100	1,740
1925	8,200	1,251	1937	4,600	1,550
1926	5,700	1,530	1938	4,700	1,210**
1927	6,000	1,300	1939	4,800	1,750
1928	6,600	1,322	1940	5,100	1,770
1929	6,500	1,510	1941	4,900	1,780
1930	6,700	1,510	1942	4,600	1,760
1931	6,600	1,440	1943	4,300	1,690
1932	5,900	1,580	1944	4,600	1,820
12-year average		1,415	12-year average		1,662

*Estimates of New England Crop Reporting Service.
**Low yield due in part at least to hurricane damage.

The difference between the average yields for the two twelve-year periods is 247 pounds. The t value of this difference is 4.15, which shows that the difference in yield is very significant.

There are several factors which could cause this difference in yields, chief among them being differences in environmental conditions, differences in cultural and fertilizing practices, and differences in the inherent productiveness of the strains of Havana Seed that were grown during the periods.

Examination of weather records for Massachusetts showed years in each period when all or a large part of the tobacco growing season was unfavorable to good tobacco production. Excessively wet seasons occurred as frequently in the later as in the earlier period. The average temperature of the growing seasons of the later period was only slightly higher than in the earlier period. The average temperatures of all the tobacco growing seasons of both periods fell within the range of 18° to 23° C. (64.4° to 73.4°F.), with the temperatures of approximately half the years of each period falling within the lower half of the range. In no growing season of either period did excessive rainfall and unusually low temperatures occur simultaneously for any considerable length of time. It is improbable, therefore, that weather conditions could have caused the differences in yields of tobacco of the two periods.

So far as it is possible to learn, the cultural practices employed during the two periods did not differ much. Such differences as existed were largely in the kinds of fertilizers used rather than in the amounts of plant nutrients supplied. During the earlier period it was customary to fertilize tobacco with three to four cords of barnyard manure, supplemented with a ton or more of suitable commercial fertilizer (4). During the later period, because of the difficulty of getting barnyard manure, it became the practice to fertilize tobacco almost entirely with commercial fertilizer. Although some farmers used more, it was customary for most of them to use a ton and a half of fertilizer per acre, and this supplied little if any more plant food than did the manure and supplementary fertilizer used during the earlier period. It is improbable that any changes in cultural practices were sufficient to cause the difference in yields of tobacco of the two periods.

It has often been suggested that the increase in yields per acre of Havana Seed tobacco during the last few years was due principally to the fact that the crops of the later years were grown on a reduced acreage and probably on the choicest tobacco land. Examination of the crop records of Massachusetts for the two periods 1921-32 and 1933-44, however, shows that the decrease in acreage came largely in the earlier period and that there has been a general increase in acreage during the later period. Reduced acreage, therefore, does not fully account for the increased yields obtained in the State during the last few years.

Differences in disease resistance and other inherent properties for productiveness of the strains of Havana Seed grown could well have influenced the tobacco production of the two periods. In this connection it is of interest that Havana 211 was first distributed to farmers in a limited way in 1933. Although there are no records of the acreage grown, it is well known that it increased from year to year and was larger during the last several years. It seems that the difference in tobacco production of the two periods, 1921-32 and 1933-44, inclusive, may be reasonably attributed, for the most part, to the growing of Havana 211 during the latter period. And if this interpretation is correct, Havana 211 has been largely instrumental in increasing the cash income of many farmers who grow Havana Seed tobacco.

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Publication of this Document Approved by Commission on Administration and Finance
3M (b) 5-46-18696.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 433 JUNE 1946

Weather and Water as Factors in Cranberry Production

By Henry J. Franklin and Neil E. Stevens

This is a supplement to Bulletin 402, and together they are intended to cover our present understanding of cranberry weather and water relations.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

WEATHER AND WATER AS FACTORS IN CRANBERRY PRODUCTION

CONTENTS

WEATHER AND CRANBERRY PRODUCTION

By Henry J. Franklin[1]

Research Professor in Charge of the Cranberry Station

Weather in its known and unknown relations to cranberry production has always been a matter of much interest and speculation to growers. The unceasing references to it through the years in the reports of the meetings of the cranberry growers' associations and in other papers concerned with the industry are ample evidence of this. The problems involved have had considerable study at the Cranberry Station during fully a quarter of a century,[2] and they were finally set out for major attention in December, 1935, in a project entitled "The Relation of Weather to Cranberry Production Through Its Various Effects on Photosynthesis and Growth." The main objectives have been (1) to discover material helpful in the early and more accurate estimation of cranberry crops; and (2) to find in weather relations clues to possible improvements in bog practices. The project is now completed and the results are given here.

Temperature, precipitation, and sunshine were the only weather elements studied extensively, the available data for humidity and wind seeming to be inadequate and apparently without much significance. The three cranberry-growing regions covered by this study are those described in the previous bulletin, Weather in Cranberry Culture,[3] as follows:

> In Massachusetts all of the industry is in the eastern part of the State and most of it in Plymouth, Barnstable, and Bristol counties; in New Jersey it is nearly all in the southern half, mostly in Burlington, Ocean, and Atlantic counties; in Wisconsin it is spread widely in the central and northwestern parts of the State, Wood, Jackson, Monroe, Juneau, and Washburn being the leading counties.

All the correlations presented here, except those concerned with cranberry size and keeping quality in Massachusetts, are based on the yearly departures of the potential production from the trend lines in Figure 1. These lines mark the courses of the smoothed sliding 9-year averages of annual potential production, developed in Tables 1, 2, and 3. The determination of the potential productions was necessarily at best a rough procedure. They are based primarily on the latest revised estimates of actual cranberry production issued by the

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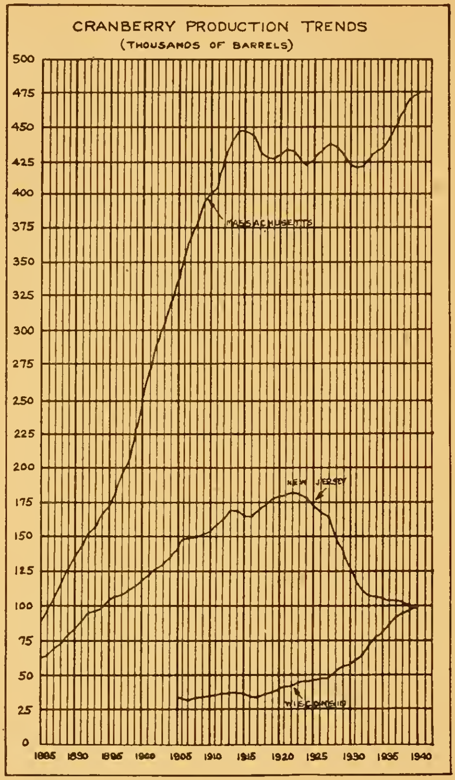
Acknowledgements:—The author acknowledges his obligations for help received to those in charge of the following offices of the United States Weather Bureau: Boston, Mass. (G. H. Noyes), Trenton, N. J. (A. E. White), New York, N. Y. (Benjamin Parry), Philadelphia, Pa. (H. P. Adams), Providence, R. I. (John Daily and Merton P. Mott), Milwaukee, Wis. (F. H. Coleman and H. J. Thompson), La Crosse, Wis. (A. D. Sanial); to C. D. Stevens, in charge of the Boston office of the Bureau of Agricultural Economics; to Dr. C. F. Brooks, Director of the Blue Hill Meteorological Observatory; to Dr. Neil E. Stevens, Professor of Botany at the University of Illinois; to the late C. S. Beckwith and C. A. Doehlert of the New Jersey Cranberry and Blueberry Laboratory at Pemberton; to H. F. Bain, formerly with the Bureau of Plant Industry and now cranberry field man in Wisconsin; to Vernon Goldsworthy, manager of the Wisconsin Cranberry Sales Company; to Dr. F. B. Chandler of the staff of the Cranberry Station; to George H. Phillips, Jr., weather observer at Middleboro; and to the office of the Plymouth County Extension Service, J. T. Brown in charge.

[1]A. F. Wolf, Economist, The Hills Brothers Company, New York, N. Y., because of his interest in weather and cranberry yield relationships, has given valuable assistance in the preparation of this bulletin.

[2]Mass. Agr. Expt. Sta. Bul. 280, 1932, pp. 209 and 210; and Bul. 293, 1933, pp. 24 and 25. (Copies in the Middleboro library.)

[3]Mass. Agr. Expt. Sta. Bul. 402, 1943, p. 26. (Copies in the Middleboro library.)

Figure 1



Bureau of Agricultural Economics, to which are added rough estimates of the more important losses by frost, winterkill, hail, fire, and storms, these being little better than mere guesses in some cases.[4] Moreover, lack of data made it impossible to allow for variations in losses due to insect injury from year to year. It can hardly be doubted that these variations have been very considerable, especially in the case of fruit worm losses, and may not have been closely related to the weather conditions studied. It was necessary also to neglect the adequacy of flower pollination except as this may have been governed by weather. Regardless of these lacks, however, it is believed that the long and reliable records of actual cranberry production in three substantial areas rather widely separated geographically and climatologically have presented a unique chance to learn something about the relations of weather to the production of fruit by a perennial.

For convenience the different weather elements were handled by months in these studies. It is, of course, not to be supposed that they are naturally confined in this way and the limits of their influence are in many cases hard to determine precisely. It is believed that the method followed is good enough for practical purposes.

[4]The sources of information about these losses are the same as those given on page 25 of Bul. 402 mentioned above.

The correlations found worthy of notice in this study, together with conclusions drawn from them, follow. The differences in the weather relations of the cranberry crops of the different areas studied are surprisingly great.

Sunlight

It must be said that no fully satisfying sunshine records that cover long terms of years and may properly be used in cranberry-production correlations exist anywhere. It has been necessary to use records made at centers outside the cranberry-growing districts, and these are of value only as they may show the general sky conditions that prevailed over the cranberry areas themselves. It is only fair to note that no important correlations were found between the cranberry crop and the sunshine records made at the Blue Hill Observatory and at Providence.

No evidence was found that variation in the amount of sunlight is considerably related to cranberry production in New Jersey. Reduced sunlight evidently is seldom a limiting factor in that State, probably because of the more direct rays of the sun there. Correlations in Tables 4, 5, 6, and 18 and Figure 2 show the sunlight relations found in Massachusetts data.[5] The Boston records seem to show that the amount of sunlight in the year before that of the crop has an important effect on the size of the crop and on the size and keeping quality of the berries. This probably comes about through the build-up of the vines in starch and sugars. It appears to be one of the major influences that determine the amount and character of Massachusetts cranberry crops. This may be due partly to limiting effects of the frequent and persistent fogs that occur along the Massachusetts coast.

Table 4 shows also the relation found between sunshine in the year before the year of the crop and cranberry production in Wisconsin. The correlation coefficient suggests that this relation, as compared with that in Massachusetts, is a modest one; but it is probably more important than it seems, for it appears in the face of temperature influences so powerful that they dwarf the effects of all other elements except winterkill and frost. Adequate data on the size of the berries and the keeping quality of Wisconsin cranberry crops, whereby possible effects of sunshine might be determined, are not available anywhere.

It was hard to determine the proper limits of the sunshine period that should be used in the above studies. The sunshine at Boston from April to September, inclusive, of the year before that of the crop shows exactly the same degree of correlation as that of the whole year, and the latter seems quite satisfactory for practical purposes, especially when it is summed and published in tabular form in comparison with that of other years as it has been heretofore in the Annual Meteorological Summary for Boston published by the Weather Bureau.

No relation was found between the amount of sunshine in any part of the crop year and the size or quality of the crop in either Massachusetts or Wisconsin.

Temperature

The studies disclosed no important variation in New Jersey cranberry crops due to temperatures.

Table 7 and Figures 3, 4, and 5 show the temperatures found to affect cranberry production in Massachusetts, the higher temperatures being somewhat destructive in all cases. Material in Table 6 suggests that the harmful effect of high temperatures in March may be partly pathological. It may be related also to unrecognized frost injury in April. It should be noted that the March

[5]See also Mass. Agr. Expt. Sta. Bul. 402, 1943, pp. 85-88.

reduction occurs in spite of the favorable effect on cranberry size of high temperatures in that month.[6] The harmful effect of high temperatures in July is probably due to the burning of flowers and small berries which occurs rather commonly on the bogs in hot weather. Storage losses seem to account mainly for the reduction caused by warm weather in September and October.

The effects of spring temperatures on the cranberry crops of Wisconsin, shown in Table 8 and Figures 6 and 7, are very great. It is impossible, with our present knowledge of these matters, to say just why high temperatures in March[7] of the year of the crop are so destructive there. Probably the relation is somehow indirect. The very favorable effect of a warm spring in the year before the crop year suggests that in years with cold springs the growing season in Wisconsin is not long enough for best results. Because of the relatively great variation in the mean temperatures of the spring months in that State, in conjunction with the very steep seasonal rise in temperature in the spring (compare the material at the ends of Tables 11, 13, and 16), warm springs in effect extend the growing season. The temperature means at La Crosse, Wisconsin, show practically the same degree of correlation as those at Meadow Valley.

Precipitation

The relations between variations in amounts of precipitation and cranberry production in the three states are shown as follows: Massachusetts, Table 9 and Figures 8 to 16, inclusive; New Jersey, Figures 17 to 20, inclusive; Wisconsin, Figures 8 to 12, inclusive. They are summarized briefly here. On the whole, and all three of the cranberry-growing districts considered, it appears that, with the possible exception of frost, excessive rain in the growing season has been the outstanding weather factor limiting production.

Massachusetts. — The precipitation in the crop year seems to be a major influence in cranberry production. Abundant precipitation in March and April (Table 9) is probably moderately beneficial because it builds up water supplies for use in flooding in the spring frost season. Monthly rainfall of two to four inches throughout the growing season (May, June, July, and August) is evidently conducive to large production (Figures 13, 14, and 15). Definite drouth in any month of the growing season is harmful (Figure 13) but appears to be less so than excessive rainfall (Figure 15). Drouth seems to be most harmful in August and an excess of rain in July (compare Figures 10 and 11). It should be remembered, however, that plentiful rain in July and August helps the size of the berries (Table 9A) and that the related crop reduction shown in Figures 10 and 11 occurs in spite of this. The indication that excessive precipitation in May and June reduces the crop, without any evidence that it impairs the keeping quality of the berries, strongly suggests that its adverse effect is largely physiological. The material in Table 6 indicates pathological effects of too much rain in July and August. Figure 12 seems to indicate some reduction of the crop from heavy rainfall in September and this may be pathological. The physiological and pathological effects of drouth and rainfall, in addition to those of other indicated weather influences, seem sufficient to account for the variations in the crop without giving important consideration to the possibilities in flower fertilization. The latter, however, should be investigated much more carefully and extensively than it ever has been.

[6]Mass. Agr. Expt. Sta. Bul. 402, 1943, pp. 85-88.

[7]The period of this influence seems to include a part of April also.

The great importance of a fair, but not excessive, supply of moisture, shown by these studies, suggests that too great attention can hardly be given to the regulation of the water table in the cranberry bogs of Massachusetts throughout the growing season. Beckwith[8] found that in New Jersey the optimum for the water table on unsanded bogs is about eleven inches below the bog surface. His opinion that the water should be kept lower in the soil of sanded areas than in that of unsanded ones seems hardly tenable in view of the relatively great capillarity of peat. *It seems probable, therefore, that Massachusetts cranberry growers will do well, at least until more exact information is available, to keep the water table during the growing season very constantly ten to twelve inches below the surface, except after heavy rains when it probably will be best to drain out the ditches completely for a few days and then refill them to the ten-twelve inch level. This will require very constant attention and, because of the fact that most bogs are not level, a much more extensive use of ditch stop-waters. It appears that a lot of moisture applied from below does not do the same harm to cranberry crops as excessive precipitation.*[9]

Those using sprinkling systems should note carefully the moisture requirements of cranberry bogs indicated by the effects of different amounts of monthly rainfall.

New Jersey. — Moisture relations are evidently the great controlling influence in cranberry production in New Jersey. Excessive rainfall in the growing season (May, June, July, and August) of the year before that of the crop (Figures 17 and 18) seems to be extremely harmful and only moderately less harmful in the season of the crop (Figures 19 and 20). It is impossible from the meager data available concerning the character of the fruit of the New Jersey crops to reach any idea as to whether the harmful effect of heavy rains is mainly physiological or more largely pathological. At any rate, *the findings suggest that more attention to drainage might considerably improve the production of the New Jersey bogs.* Drouth in August (Figure 19) seems even more harmful in New Jersey than in Massachusetts and its effects in other months may be largely masked by their opposition to some of the effects of too much rain.

Cranberry moisture relations seem on the whole to be decidedly more unsatisfactory in New Jersey than in any of the other states in which this fruit is largely grown.

Wisconsin. — Meager precipitation in May and to a less extent in June (Figures 8 and 9) is evidently an important crop liability in Wisconsin. The opinion of trained observers and the experience of cranberry growers indicate that this is not due to the development of drouth conditions in these months. It may be largely an indirect effect in which the sufficiency of water supplies for frost flooding is concerned, the time of greatest frost danger following so closely the long yearly period of light precipitation from late fall to mid-spring (see means at end of Table 17). It also must accentuate the effect of drouth later in the growing season in summers of generally light rainfall. The optimum amount of rain appears to be four to five inches in May and in June and two to four inches in July and in August (Figures 8 to 11). Excessive rainfall in July and August seems to be nearly as harmful as it is in Massachusetts, and excessive rainfall in May also has a definite effect.

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[8]Proceedings of the 70th Annual Meeting, American Cranberry Growers' Association, January, 1940, pp. 11-13.

[9]Mass. Agr. Expt. Sta. Bul. 271, 1931, p. 250.

Summer Rainfall and Size of Massachusetts Cranberries

It was shown in Bulletin 402 (pages 85-88) that there is a relation between the amount of rainfall in August and the size of Massachusetts cranberries. Further study with more data indicates that July rainfall is also involved. The correlations between rainfall and cranberry size, as derived from Table 9A, are as follows: For July, $+0.361 \pm 0.128$; for August, $+0.432 \pm 0.12$; for July and August, $+0.554 \pm 0.102$. Evidently the berries require a lot of moisture throughout the period in which they are growing.

Distribution of the Berries Among the Vines

Massachusetts cranberry crops vary greatly from year to year in this respect, some being largely in the tops of the vines while others are well distributed among them. As the following table shows, the distribution varies largely according to the amount of rainfall in August, drouth in that month evidently being mainly responsible for the "top-berry" condition by its more harmful effect on the development of the under berries. The crop of 1936 may seem to be an exception; but the rainfall was only 1.87 inches in July and .90 of an inch in the first half of August that year. As the distribution of rainfall in July and August in 1937 was much like that in 1936, it may be thought that the effect on the berry distribution should have been the same; but the 1937 crop was ten days later than that of 1936 and evidently benefited from the rain later in August.

Year	Percentage of Growers with Crops Mainly "Top" Berries[1]	August Rainfall (Inches)[2]	Year	Percentage of Growers with Crops Mainly "Top" Berries[1]	August Rainfall (Inches)[2]
1928	42	1.40	1937	19	4.31
1929	34	4.62	1938	73	1.41
1930	39	2.40	1939	35	3.36
1931	18	4.44	1940	66	0.87
1932	No record	4.55	1941	28	3.55
1933	12	3.73	1942	38	6.55
1934	63	2.17	1943	39	3.83
1935	57	1.55	1944	70	1.17
1936	63	5.79	1945	29	2.92

[1] From October Growers' reports, provided by C. D. Stevens.
[2] From Table 12.

It follows from the above that cranberry crops after dry Augusts are liable to a higher percentage of injury from fall frosts than those following plenty of rain in August.[10]

Snowfall and Cranberry Yields

No evidence was found that the amount of snowfall at any time materially affects the cranberry crop in any of the three States. This is not surprising, for the duration and character of the snow cover should be as important as the amount,[11] and adequate information about this is lacking.

[10] Mass. Agr. Expt. Sta. Bul. 402, 1943, p. 36.
[11] Ibid., p. 11.

Frost Flooding and Cranberry Production

The records provide some evidence that frequent flooding for frost protection in the spring tends to reduce the crop of the year in which it occurs. Very little such flooding preceded the great crops of 1937 and 1942 in Massachusetts. Frost flooding, however, does not seem to be as important a factor as one might expect from opinions held by cranberry growers and from the effect of excessive precipitation in May and June (Figures 8 and 9). The low temperatures in frost periods probably reduce the harmful effect of the water considerably. This is evidenced by the relatively high yields now obtained in frosty Wisconsin. It probably explains partly the greater harm that is generally believed to be done when frost floods are held over on bogs from day to day.

Late-Holding of the Winter Flood and Cranberry Yields

It is widely believed that late-holding of the winter water tends to reduce cranberry crops, and this is borne out by the fact that extreme late-holding eliminates the crop altogether. A peculiar situation in New Jersey is interesting in this connection. Following recommendations made in 1916 and 1917,[12] most of the growers in that State have held the winter flood almost yearly till May 10 or even later to control insects and for frost protection. Wilcox[13] has shown that abnormally warm weather in April and early May while this water is being held materially reduces the crop. Presumably this temperature relation is true of all late-holding of the winter water or of long spring reflows on cranberry bogs everywhere. It may be due to some restriction of respiration of the vines and their roots from slow or occasional oxygen starvation under high temperatures with reduced sunlight.

Biennial Cropping

It is very generally believed by cranberry men that the amount of the crop in one year has an important influence on that of the following year. There seems to be nothing in the general production records of any of the three cranberry-growing areas under consideration to support this opinion. Successive cranberry crops behave as though they were placed largely in separate compartments of the plant economy. Effects of the weather — temperature, sunshine, and rainfall — in the year before that of the crop carry powerfully past the intervening crop, thus suggesting that the products of plant synthesis affected by weather must largely pass through a period or process of incubation before becoming available for the production of fruit. Their more immediate use may be in the growth and conditioning of the vines. On the whole, cranberry weather relations in any year seem to be mostly constructive for the crop of the following year, but more largely destructive for the crop more immediately in hand.

Weather and Cranberry Keeping

This subject has been very ably treated by Stevens,[14] but important information has been obtained since his findings were published and an attempt is made in Tables 6 and 18 to present the main features of our present understanding

[12]Proceedings of the 47th Annual Convention, American Cranberry Growers' Association, 1916, pp. 8-11; and U. S. Dept. Agr. Farmers' Bul. 860, 1917, pp. 8, 11, and 12.

[13]Proceedings of the 70th Annual Meeting, American Cranberry Growers' Association, 1940, pp. 18-21.

[14]Mass. Agr. Expt. Sta. Bul. 402, 1943, pp. 68-83.

of this relationship. *It is believed that material like this can be used effectively to predict the general keeping quality of cranberry crops and as a guide in conducting bog operations for the control of rots and in arranging programs for the sale of the fruit. It will be seen in the table that the keeping quality of the general crop was appraised as poor in all nine of the years in which both the amount of sunshine in the previous year and the mean temperature of May were above normal and the temperature of March was above 34 degrees. On the other hand, the general keeping quality was at least fair in all but one of the sixteen years in which the sunshine of the year before was less than normal and in all but one of the sixteen years in which the temperature of May was below normal, regardless of all other influences.* This connection between sunshine and cranberry keeping quality is probably a sugar relation. The effect of high temperature in May on keeping quality seems to call for a corresponding reduction in the size of the crop. The records, however, show no such effect but rather, if anything, a slight increase. It appears, therefore, that high May temperature tends to increase the size of the crop while it impairs its keeping quality and that the two effects nearly balance each other in the amount of fruit produced and finally marketed.

The following three of the four weather elements [15]that seem to influence the size of cranberries in Massachusetts are found to affect keeping quality also:

1. *Amount of sunshine the year before the crop year* (Tables 5 and 6)—the more sun, the larger the cranberries and the poorer their keeping quality.

2. *Sunshine and mean temperature of March of the crop year* (Table 18)—the more sunshine and the lower the mean temperature, the smaller and sounder the cranberries.

3. *Amount of precipitation in July and August of the crop year* (Tables 6 and 9A)—the more rain, the larger the berries and the poorer their keeping quality.

This clarifies the strong normal relation heretofore found between the general size of the berries of a cranberry crop and their keeping quality.[16] As the amount of sunshine the year before the crop year (Table 4) is also outstandingly related to cranberry production, it is clear that the size of the crop may serve as something of an indication of keeping quality,[17] but it has proved less reliable than berry size.

Temperature in September and October (Table 7 and Figure 5) seems to lead among the minor factors affecting cranberry keeping. The rate of berry respiration and the rate of development of putrefactive fungi in their relation to storage losses are concerned here. (U.S. Dept. Agr. Tech. Bul. 258, 1931, pp. 25–38; Mass. Agr. Expt. Sta. Buls. 180, 1917, p. 217, and 192, 1919, pp. 114, 115.)

The considerable relations between spring temperatures and cranberry keeping brought out here seem to do much to explain the connection between the late ripening and good keeping of cranberry crops.[18]

General Remarks on Cranberry Production

In this paper weather elements in Massachusetts are found to affect the size of cranberry crops, the size of the berries, and the keeping quality of the berries. It is believed that the relations of those elements that seem to affect all three are most likely to be well established, these being the sunshine in the year before the

[15]The fourth is the amount of sunshine in December and January (Bulletin 402, pp. 85-88.) In this relation, the sunshine at Boston alone for the years 1925 to 1942, inclusive, shows a correlation coefficient of $+0.63 \pm .096$.

[16]Mass. Agr. Expt. Sta. Bul. 402, 1943. p. 88.

[17]Ibid, p. 75.

[18]Ibid., p. 91.

crop year and the sunshine and temperature of March and the rainfall of July and August of the crop year.

Four horsemen of a bumper cranberry crop in Massachusetts are:

1. Plenty of sunshine the year before.
2. Little or no winterkilling and little trouble with spring frosts.
3. Two to four inches of rain each month in the growing season (pp 6, 14, and 15.).
4. Light damage by insects.

Very temporary weather occurrences, aside from those already considered, seem generally to have less effect on cranberry production than is supposed by many. Nothing has appeared anywhere to lend any substance to the belief that low temperatures short of freezing harm cranberry buds or flowers or in any way materially affect the set of the fruit. No study has been made of a possible effect of heavy and persistent fogs on bee activity during the cranberry blossoming period, but it may be fairly doubted whether this is important, for cranberries are grown successfully and in fair abundance on Nantucket, the foggiest place in the eastern United States. Heavy rain for a day or two in the blooming period may perhaps greatly dilute the nectar of the flowers and so upset the work of bees for a few days, but it is doubtful whether it affects the set of fruit much if it is not continued or repeated. Much interference from continual rain or frequent early frosts retards harvesting and so finally causes the berries to be larger and the crop therefore more abundant (e.g., crop of 1922, Massachusetts berries larger than in any other year in which records of size have been made[19]).

It is interesting to note, in connection with Figure 1, that the cranberry acreage in Massachusetts and New Jersey has not changed much since 1905,[20] while that in Wisconsin has increased considerably. The greater production in Massachusetts in that time must, therefore, be due to increased acre yields. These have been obtained in spite of the development here of three new major enemies of the cranberry industry: the false-blossom disease, the gypsy moth, and the root grub. The drop in New Jersey production since 1925 must have been a per acre decrease and has been generally regarded as an effect of the false-blossom disease. The Wisconsin cranberry industry, meanwhile, has had to contend with the false-blossom disease but is not known to have encountered any other unusual adverse development; it has profited largely since 1933 from the use of water from the Wisconsin River in the Cranmoor district.

[19]Ibid., pp. 86, 87, and 91.

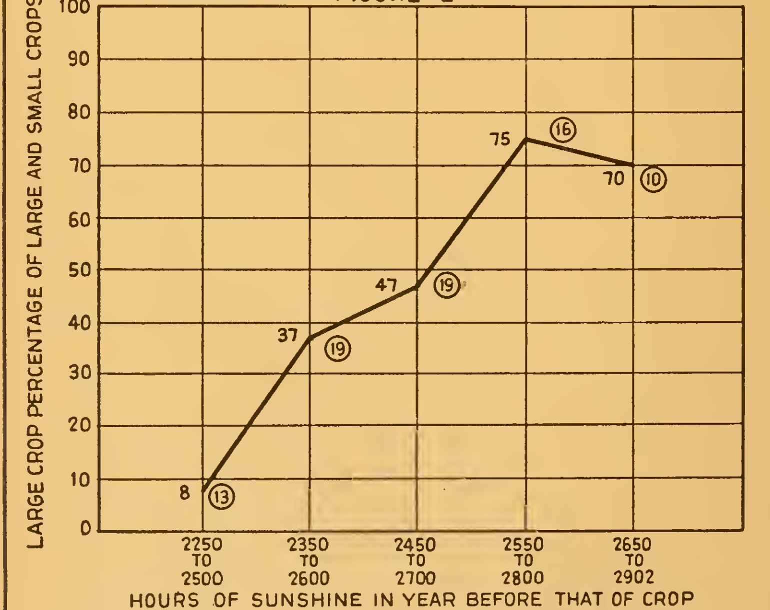
[20]Mass. Agr. Expt. Sta. Bul. 332, 1936, pp. 4 and 20.

Graphs and Tables

The weather elements in Figures 2 to 12 and 17 to 20 are arranged in lapping groups, and the percentages in Figures 2 to 20 are based on the relationship of the large crops to the sum of the large and the small crops. It is arbitrarily considered that all crops (potential production) more than 7 percent larger or smaller than the smoothed sliding nine-year average for their year (Tables 1, 2, 3) are large or small as the case may be. Figures in circles at the intersections of the graph lines with the vertical lines in Figures 2 to 16 show the number of occurrences involving departures of more than 7 percent, both plus and minus, from the smoothed sliding average; those without circles show the large-crop percentages to the nearest integer. The corresponding data for Figures 17 to 20 are given in tables which accompany the charts, the numbers in parenthesis showing the occurrences and the others the large-crop percentages.

Nineteen tables are included here. The coefficients of correlation are given at the end of those tables showing correlations. Tables 10–17, inclusive are included to "complete the picture" and for the use of any who may wish to pursue these studies further.

FIGURE 2



SUNSHINE AT BOSTON AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1894-1940 INCL.

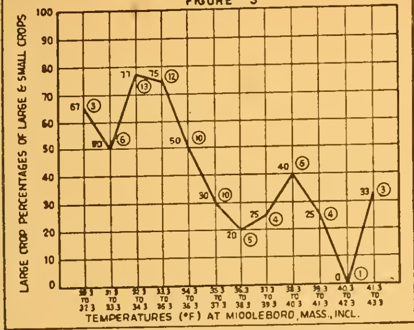


FIGURE 3

MARCH MEAN TEMPERATURES AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1888 - 1940, INCL.

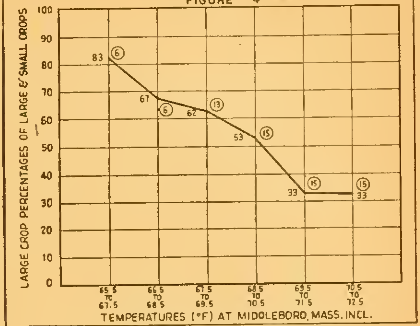


FIGURE 4

JULY MEAN TEMPERATURES AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1888 - 1940, INCL.

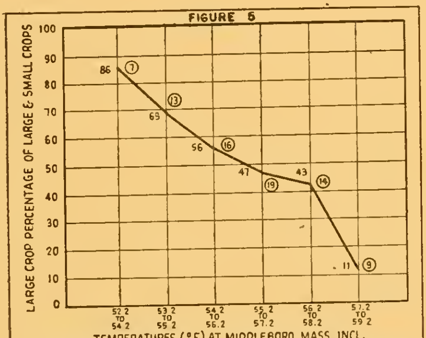


FIGURE 5

SEPTEMBER & OCTOBER MEAN TEMPERATURE AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1888 - 1940, INCL.

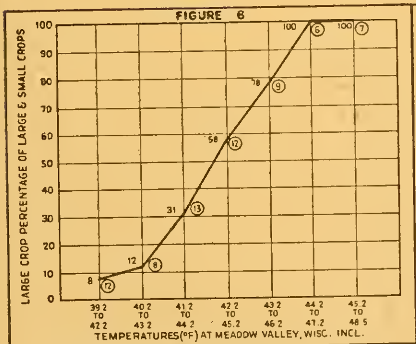


FIGURE 6

MEAN TEMPERATURE OF MARCH TO MAY INCL. OF YEAR BEFORE YEAR OF CROP AND CRANBERRY PRODUCTION IN WISCONSIN 1905 - 1940 INCL.

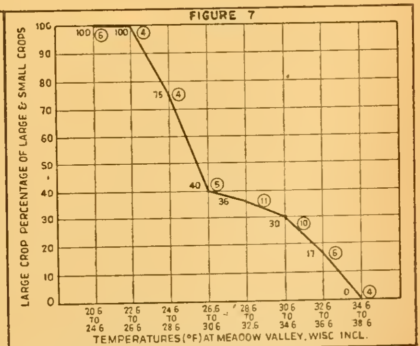
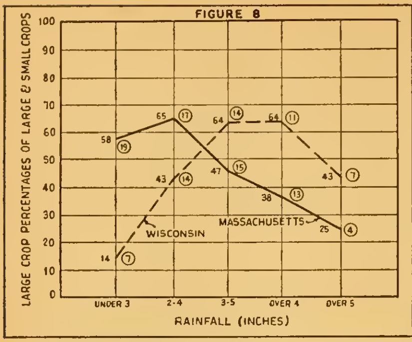
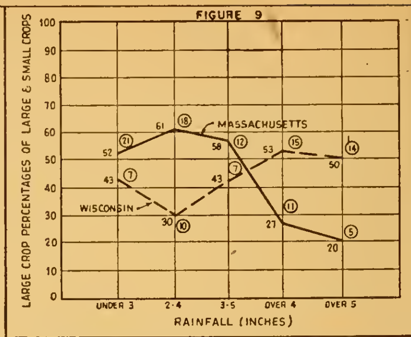


FIGURE 7

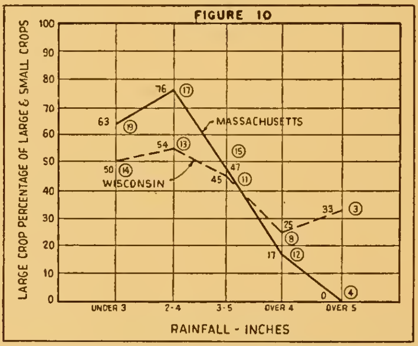
MEAN TEMPERATURE OF MARCH OF YEAR OF CROP AND CRANBERRY PRODUCTION IN WISCONSIN 1905 - 1940 INCL.



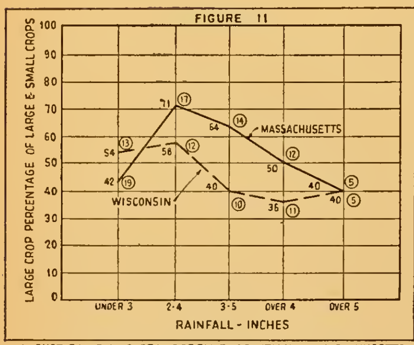
MAY RAINFALL AND CRANBERRY PRODUCTION IN MASSACHUSETTS, (1889-1940, INCL.), AND WISCONSIN, (1905-1940, INCL.)



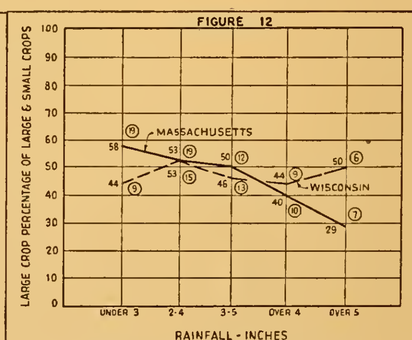
JUNE RAINFALL AND CRANBERRY PRODUCTION IN MASSACHUSETTS, (1889-1940, INCL.), AND WISCONSIN, (1905-1940, INCL.)



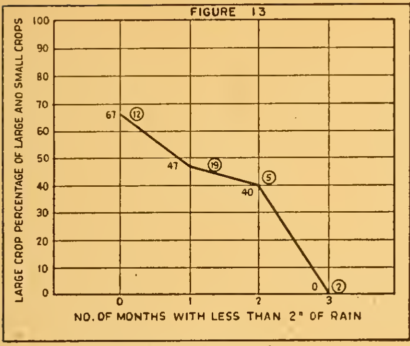
JULY RAINFALL AND CRANBERRY PRODUCTION IN MASSACHUSETTS (1889 - 1940, INCL.) AND WISCONSIN (1905 - 1940, INCL.)



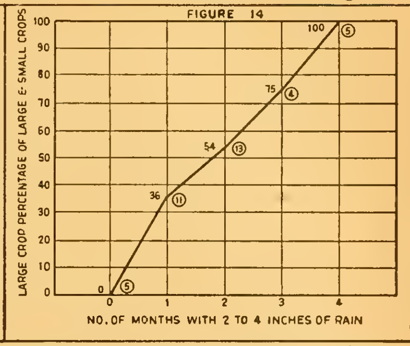
AUGUST RAINFALL & CRANBERRY PRODUCTION IN MASSACHUSETTS (1889 - 1940, INCL.) & WISCONSIN (1905 - 1940, INCL.)



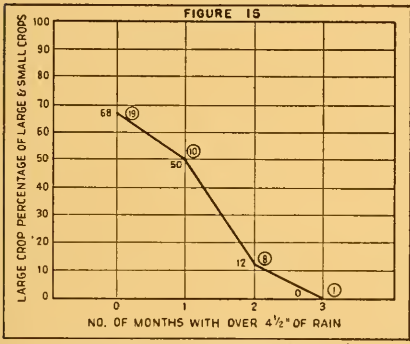
SEPTEMBER RAINFALL & CRANBERRY PRODUCTION IN MASSACHUSETTS (1889-1940, INCL.) & WISCONSIN (1905-1940, INCL.)



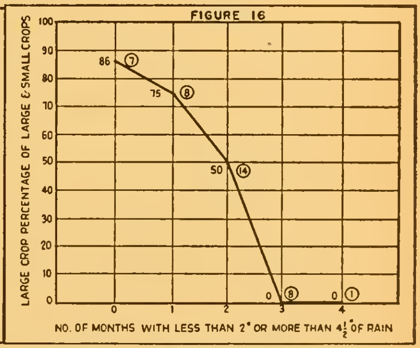
RAINFALL DURING GROWING SEASON (MAY, JUNE, JULY & AUGUST) OF YEAR OF CROP AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1889 - 1940 INCL.



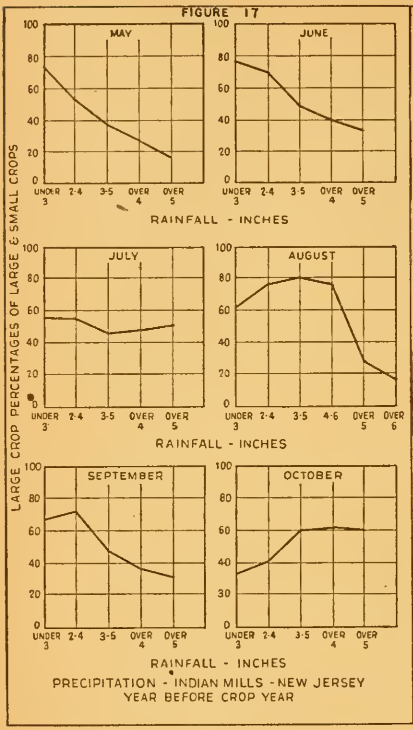
RAINFALL DURING THE CRANBERRY GROWING SEASON (MAY, JUNE, JULY & AUGUST) AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1889 - 1940 INCL.



RAINFALL DURING THE CRANBERRY GROWING SEASON (MAY, JUNE, JULY & AUGUST) AND CRANBERRY PRODUCTION IN MASSACHUSETTS, 1889 - 1940 INCL.



RAINFALL DURING THE CRANBERRY GROWING SEASON (MAY, JUNE, JULY & AUGUST) AND CRANBERRY PRODUCTION IN MASSACHUSETTS (1889 - 1940 INCL.)



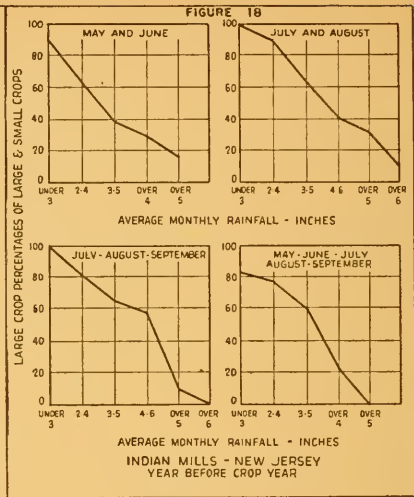
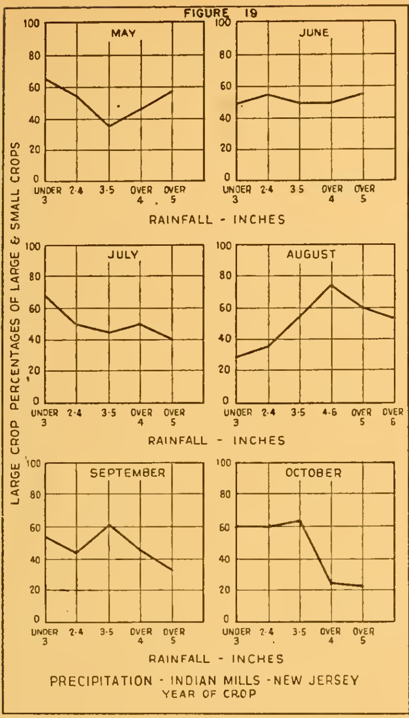


Figure 17.

Rainfall (Inches)	May	June	July	August	September	October
Under 3	(15) 73	(9) 78	(11) 55	(8) 62	(12) 67	(14) 36
2-4	(15) 53	(10) 70	(13) 54	(12) 75	(7) 71	(12) 42
3-5	(13) 38	(15) 47	(11) 45	(10) 80	(13) 46	(10) 60
Over 4	(11) 27	(20) 40	(19) 47	(8) 75	(17) 35	(13) 61
Over 5	(6) 17	(9) 33	(12) 50	(15) 26	(9) 33	(10) 60
Over 6				(12) 17		

Figure 18.

Average Monthly Rainfall	May and June	July and August	July, August and September	May, June, July, August and September
Under 3	(10) 90	(2) 100	(4) 100	(6) 83
2-4	(19) 63	(10) 90	(11) 82	(17) 76
3-5	(18) 39	(16) 62	(20) 65	(22) 59
Over 4	(14) 29	(17) 41	(14) 57	(17) 23
Over 5	(6) 17	(16) 31	(11) 9	(7) 0
Over 6		(7) 14	(9) 0	



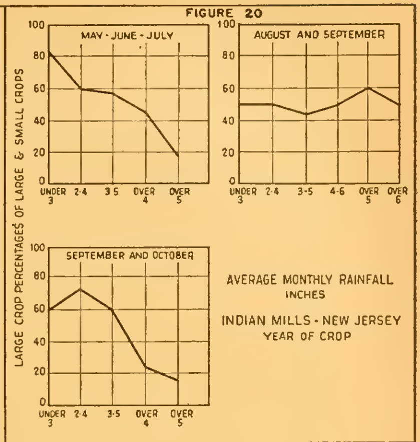


Figure 19.

Rainfall (Inches)	May	June	July	August	September	October
Under 3	(14) 64	(10) 50	(12) 67	(7) 29	(13) 54	(15) 60
2-4	(13) 54	(11) 55	(14) 50	(12) 33	(9) 44	(15) 60
3-5	(14) 36	(16) 50	(11) 45	(9) 56	(13) 61	(11) 64
Over 4	(13) 46	(20) 50	(18) 50	(8) 75	(15) 47	(12) 25
Over 5	(7) 57	(9) 56	(12) 42	(18) 61	(9) 33	(9) 22
Over 6				(15) 53		

Figure 20.

Average Monthly Rainfall (Inches)	May, June and July	August and September	September and October
Under 3	(6) 83	(4) 50	(13) 61
2-4	(15) 60	(10) 50	(18) 72
3-5	(13) 56	(18) 44	(15) 60
Over 4	(20) 45	(14) 50	(13) 23
Over 5	(6) 17	(13) 61	(7) 14
Over 6		(10) 50	

Table 1.—Cranberry Production in Massachusetts, 1880-1944, Inclusive
(In Barrels)

Year	Actual Production	Estimated Losses by — Winterkill	Frost	Storm, Flood and Hail	Potential Production — Annual	Sliding 9-year Average	Smoothed Sliding 9-year Average	Departure from Smoothed 9-year Average (Percent)
1880	82,500				82,500			
1881	51,942	10,000			61,942			
1882	63,888				63,888			
1883	47,321				47,321			
1884	43,528		44,000		87,528	84,055		
1885	93,626				93,626	85,240		
1886	91,600		10,000		101,600	92,246	94,995	+ 7.0
1887	102,521				102,521	103,481	104,657	− 2.0
1888	86,667		28,900		115,567	116,723	115,284	+ 0.2
1889	67,167		3,000	23,000*	93,167	128,294	125,355	−25.7
1890	125,000				125,000	131,595	134,279	− 6.9
1891	160,000		5,000		165,000	143,195	142,791	+15.6
1892	125,000		41,500		166,500	154,026	150,445	+10.7
1893	191,667				191,667	156,000	157,235	+21.9
1894	61,666		61,666		123,332	161,944	163,891	−24.7
1895	140,000	41,000	25,000		206,000	171,981	172,401	+19.5
1896	200,000				200,000	179,203	182,395	+ 9.7
1897	133,333				133,333	197,370	195,150	−31.7
1898	141,666		5,000		146,666	203,296	210,765	−30.4
1899	208,333		7,000		215,333	227,259	229,928	− 6.3
1900	200,000		30,000		230,000	258,537	250,716	− 8.3
1901	264,000	66,000			330,000	266,537	270,375	+22.1
1902	238,000		7,000		245,000	289,944	288,397	−15.0
1903	226,000		113,000		339,000	309,537	304,739	+11.2
1904	281,000	50,000	94,000	62,500*	487,500	315,056	320,867	+51.9
1905	165,000	82,500	20,000	4,500*	272,000	337,500	337,702	−19.5
1906	264,000		80,000		344,000	358,611	354,525	− 3.0
1907	310,000		13,000		323,000	369,944	367,950	−12.2
1908	257,000		8,000		265,000	384,944	378,901	−30.1
1909	402,000		30,000		432,000	377,111	387,955	+11.4
1910	312,000		208,000		520,000	402,555	400,029	+30.0
1911	298,000	34,000	15,000		347,000	415,322	412,746	−15.9
1912	354,000		120,000		474,000	422,789	427,079	+11.0
1913	367,000		50,000		417,000	440,955	439,200	− 5.1
1914	471,000		30,000		501,000	460,233	447,616	+11.9
1915	257,000		201,900		458,900	448,567	447,128	+ 2.6
1916	364,000		1,200	25,000	390,200	446,011	441,369	−11.6
1917	137,000	86,000	205,500		428,500	425,011	432,925	− 1.0
1918	218,000	121,000	266,500		605,500	426,900	428,563	+41.3
1919	395,000		20,000		415,000	426,900	428,179	− 3.1
1920	309,000			15,000	324,000	426,533	431,754	−25.0
1921	208,000		52,000	25,000	285,000	441,033	434,413	−34.4
1922	337,000		97,000		434,000	443,422	432,317	+ 0.4
1923	451,000		50,000		501,000	419,811	426,487	+17.5
1924	339,000	91,100	25,500		455,600	412,367	423,638	+ 7.5
1925	447,000		48,700	25,000*	520,700	426,339	427,356	+21.8
1926	438,000		12,000		450,000	439,917	433,953	+ 3.7
1927	385,000		8,000		393,000	442,806	438,449	−10.4
1928	348,000				348,000	435,172	436,837	−20.3
1929	421,000		28,750		449,750	441,106	431,933	+ 4.1
1930	395,000		12,200		407,200	418,272	424,101	− 4.0
1931	460,000				460,000	414,383	421,414	+ 9.2
1932	415,000		17,300		432,300	415,939	422,821	+ 2.2
1933	506,000			3,000	509,000	440,050	429,720	+18.4
1934	290,000		25,200		315,200	430,439	433,768	−27.3
1935	332,000	83,000			415,000	440,189	438,180	− 5.3
1936	346,000		61,000		407,000	436,178	442,644	− 8.1
1937	565,000				565,000	449,767	452,864	+24.8
1938	325,000		28,250	10,000**	363,250	464,911	463,710	−21.7
1939	490,000		4,950		494,950	484,889	471,942	+ 4.9
1940	322,000	86,800	15,100		423,900	474,722	474,722	−10.7
1941	500,000	37,600	17,000		554,600			
1942	572,000	63,300	10,000		645,300			
1943	492,000		2,500	500*	495,000			
1944	153,000	100,000	70,000	500*	323,500			

*Hail. **5,000 of this was hail damage.

TABLE 2.—CRANBERRY PRODUCTION IN NEW JERSEY, 1879-1944, INCLUSIVE.
(In Barrels)

Year	Actual Production	Estimated Loss by — Winter-kill	Frost	Storm Flood and Hail	Fire	Potential Production — Annual	Sliding 9-year Average	Smoothed Sliding 9-year Average	Departure from Smoothed 9-year Average (Percent)
1879	30,000					30,000			
1880	42,900				2,000	44,900			
1881	52,338		26,150		2,000	80,488			
1882	26,169			5,000		31,169			
1883	39,508					39,508	58,482		
1884	41,549		14,000		1,000	56,549	63,482		
1885	66,042				18,000	84,042	65,715	64,566	+30.2
1886	78,085		12,000		10,000	100,085	64,179	66,620	+50.2
1887	54,596			5,000		59,596	70,142	69,841	−14.7
1888	75,000					75,000	71,845	73,800	+ 1.6
1889	45,000			20,000		65,000	80,376	79,090	−17.8
1890	66,666					66,666	83,446	83,979	−20.6
1891	83,333				1,500	84,833	89,955	88,550	− 4.2
1892	53,333				1,500	54,833	92,963	91,978	−40.4
1893	108,333				25,000	133,333	93,889	95,262	+40.0
1894	66,667		10,000		35,000	111,667	97,778	98,819	+13.0
1895	66,667		67,000		25,000	158,667	104,252	103,511	+53.3
1896	66,666		10,000		10,000	86,666	106,792	107,426	−19.3
1897	83,333					83,333	115,811	110,885	−24.8
1898	100,000					100,000	108,552	112,342	−11.0
1899	83,333		41,600			124,933	115,589	114,865	+ 8.8
1900	100,000			7,000*	700	107,700	115,831	117,725	− 8.5
1901	110,000	26,000				136,000	122,446	122,128	+11.4
1902	33,000		35,000			68,000	127,409	125,194	−45.7
1903	175,000					175,000	129,743	127,466	+37.3
1904	83,000	40,200	27,650	10,000*		160,850	124,306	129,748	+24.0
1905	88,000	29,200	29,000			146,200	132,083	135,367	+ 8.0
1906	103,000			25,000		128,000	143,750	142,485	−10.2
1907	121,000					121,000	156,194	148,215	−18.4
1908	75,000			1,000*		76,000	150,250	149,975	−49.3
1909	169,000		8,700			177,700	145,267	150,643	+18.0
1910	241,000					241,000	152,356	153,213	+57.3
1911	145,000			35,000		180,000	158,578	158,679	+13.4
1912	113,000		7,000	1,500*		121,500	163,911	164,693	−26.2
1913	101,000		15,000			116,000	174,578	168,539	−31.2
1914	160,000		50,000			210,000	171,833	168,430	+24.7
1915	184,000					184,000	163,056	166,423	+10.6
1916	169,000					169,000	161,194	166,159	+ 1.7
1917	129,000		43.000			172,000	168,006	169,133	+ 1.7
1918	127,000	25,000	1,000			153,000	177,894	174,094	−12,1
1919	155,000			7,000		162,000	176,950	177,453	− 8.7
1920	130,000		33,250			163,250	182,061	179,745	− 9.2
1921	165,000		17,800			182,800	178,317	180,552	+ 1.2
1922	205,000					205,000	183,094	181,510	+12.9
1923	200,000			1,500*		201,500	182,761	180,548	+11.6
1924	215,000		15,000			230,000	180,094	177,853	+29.3
1925	115,000		20,300			135,300	171,956	172,701	—21.7
1926	215,000					215,000	167,867	165,931	+29.6
1927	75,000		75,000			150,000	159,756	157,402	− 4.7
1928	138,000					138,000	146,256	147,839	− 6.7
1929	90,000					90,000	137,144	137,794	−34.7
1930	146,000					146,000	130,111	128,102	+14.0
1931	132,000					132,000	116,222	119,883	+10.1
1932	80,000					80,000	109,600	114,705	−30.3
1933	142,000			6,000		148,000	113,711	112,313	+31.8
1934	72,000					72,000	113,567	110,924	−35.1
1935	85,000			5,000		90,000	107,122	109,151	−17.5
1936	75,000		15,400			90,400	106,344	107,079	−15.6
1937	175,000					175,000	107,456	105,227	+66.3
1938	62,000		20,700	6,000		88,700	101,956	103,110	−14.0
1939	88,000					88,000	100,956	101,012	−12.9
1940	90,000	25,000	10,000			125,000	98,956	98,956	+26 3
1941	80,000			10,000		90,000			
1942	95,000		3,500			98,500			
1943	62,000		1,000			63,000			
1944	59,000	8,600	4,400			72,000			

*Hail

TABLE 3.—CRANBERRY PRODUCTION IN WISCONSIN, 1899-1944, INCLUSIVE.
(In Barrels)

Year	Actual Production	Estimated Losses by — Winter-kill	Frost	Hail	Potential Production Annual	Sliding 9-year Average	Smoothed Sliding 9-year Average	Departure from Smoothed Average (Percent)
1899	36,666				36,666			
1900	18,000	2,000	17,000		37,000			
1901	40,000	8,000			48,000			
1902	46,000		3,000		49,000			
1903	18,000		8,000		26,000	36,852		
1904	21,000	1,000	14,000		36,000	34,444		
1905	18,000		6,000		24,000	36,444	34,810	−31.1
1906	45,000		4,000	2,000	51,000	32,889	33,938	+50.3
1907	21,000			3,000	24,000	32,444	33,716	−28.8
1908	12,000	1,500	1,500		15,000	34,556	34,086	−56.0
1909	30,000		25,000		55,000	34,778	34,605	+58.9
1910	16,000				16,000	35,778	35,000	−54.3
1911	30,000	15,000			45,000	34,000	35,148	+28.0
1912	45,000				45,000	35,556	35,371	+27.2
1913	30,000		8,000		38,000	36,889	35,642	+ 6.6
1914	33,000				33,000	34,111	35,630	− 7.4
1915	35,000				35,000	36,778	35,525	− 1.5
1916	38,000				38,000	35,444	35,117	+ 8.2
1917	27,000				27,000	33,389	34,957	−22.8
1918	30,000				30,000	35,278	35,278	−15.0
1919	40,000				40,000	36,222	35,796	+11.7
1920	33,000				33,000	37,000	36,870	−10.5
1921	24,000		2,500		26,500	35,556	38,037	−30.3
1922	55,000				55,000	42,000	39,914	+37.8
1923	35,000	5,000		1,500	41,500	41,444	41,482	0.0
1924	42,000				42,000	42,222	43,124	− 2.6
1925	25,000				25,000	45,000	44,568	−43.9
1926	85,000				85,000	46,556	46,327	+83.5
1927	25,000				25,000	47,111	48,463	−48.4
1928	45,000			2,000	47,000	50,833	51,605	− 8.9
1929	42,000		15,000	1,000	58,000	55,056	55,210	+ 5.1
1930	36,000		4,500		40,500	61,056	58,969	−31.3
1931	48,000	12,000			60,000	60,833	62,451	− 3.9
1932	75,000				75,000	64,944	66,191	+13.3
1933	42,000	38,000			80,000	72,500	70,580	+13.3
1934	59,000	20,000			79,000	73,167	75,358	+ 4.8
1935	77,000	3,000		3,000	83,000	80,667	80,648	+ 2.9
1936	62,000				62,000	87,444	85,574	−27.5
1937	115,000				115,000	90,111	89,753	+28.1
1938	64,000				64,000	93,111	93,062	−31.2
1939	108,000				108,000	95,667	96,062	+12.4
1940	121,000				121,000	99,222	99,222	+21.9
1941	99,000				99,000			
1942	107,000				107,000			
1943	102,000				102,000			
1944	115,000				115,000			

TABLE 4.—SUNSHINE IN YEAR BEFORE YEAR OF CROP, AND CRANBERRY PRODUCTION IN MASSACHUSETTS AND WISCONSIN.

Crop Year	Hours of Sunshine, Year Before Year of Crop[1] Boston, Mass. Jan.-Dec., inclusive	LaCrosse, Wis. Apr.-Sept., inclusive	Departure from Average (Hours) Boston	LaCrosse	Potential Production Departure from Average[2] (Percent) Massachusetts	Wisconsin
1894	2,472		−97		−24.7	
1895	2,556		−13		+19.5	
1896	2,557		−12		+9.7	
1897	2,412		−157		−31.7	
1898	2,370		−199		−30.4	
1899	2,316		−253		−6.3	
1900	2,652		+83		−8.3	
1901	2,527		−42		+22.1	
1902	2,349		−220		−15.0	
1903	2,479		−90		+11.2	
1904	2,714		+146		+51.9	
1905	2,452	1,675	−117	−2	−19.5	−31.1
1906	2,700	1,795	+131	+118	−3.0	+50.3
1907	2,649	1,711	+80	+34	−12.2	−28.8
1908	2,363	1,634	−206	−43	−30.1	−56.0
1909	2,760	1,635	+191	−42	+11.4	+58.9
1910	2,763	1,441	+194	−236	+30.0	−54.3
1911	2,547	1,787	−22	+110	−15.9	+28.0
1912	2,764	1,678	+195	+1	+11.0	+27.2
1913	2,902	1,588	+333	−89	−5.1	+6.6
1914	2,623	1,631	+54	−46	+11.9	−7.4
1915	2,419	1,706	−150	+29	+2.6	−1.5
1916	2,705	1,290	+136	−387	−11.6	+8.2
1917	2,678	1,596	+109	−81	−1.0	−22.8
1918	2,558	1,599	−11	−78	+41.3	−15.0
1919	2,608	1,529	+39	−148	−3.1	+11.7
1920	2,451	1,573	−118	−104	−25.0	−10.5
1921	2,484	1,885	−85	+208	−34.4	−30.3
1922	2,659	1,806	+90	+129	+0.4	+37.8
1923	2,514	1,583	−55	−94	+17.5	−0.0
1924	2,512	1,694	−57	+17	+7.5	−2.6
1925	2,723	1,499	+154	−178	+21.8	−43.9
1926	2,596	1,736	+27	+59	+3.7	+83.5
1927	2,401	1,615	−168	−62	−10.4	−48.4
1928	2,651	1,443	+82	−234	−20.3	−8.9
1929	2,669	1,654	+100	−23	+4.1	+5.1
1930	2,712	1,746	+143	+69	−4.0	−31.3
1931	2,724	1,712	+155	+35	+9.2	−3.9
1932	2,621	1,809	+52	+132	+2.2	+13.3
1933	2,781	1,716	+212	+39	+18.4	+13.3
1934	2,537	1,835	−32	+158	−27.3	+4.8
1935	2,518	1,765	−51	+88	−5.3	+2.9
1936	2,265	1,629	−304	−48	−8.1	−27.5
1937	2,644	1,820	+75	+143	+24.8	+28.1
1938	2,492	1,955	−77	+278	−21.7	−31.2
1939	2,470	1,708	−99	+31	+4.9	+12.4
1940	2,428	1,908	−141	+231	−10.7	+21.9
Average	2,569	1,677				

[1]From Tables 10 and 15.
[2]From Tables 1 and 3.
The coefficients of correlation from the above table are:
Massachusetts......... +0.463 ± 0.077
Wisconsin............. +0.257 ± 0.105

TABLE 5.—SUNSHINE IN YEAR BEFORE YEAR OF CROP, AND SIZE OF MASSACHUSETTS CRANBERRIES.

Crop Year	Sunshine at Boston, Year Before Year of Crop: Total Hours[1]	Sunshine at Boston, Year Before Year of Crop: Departure of Total from Average	Size of Berries (All Varieties), (C. D. Stevens' Data): Percentages from Growers' Reports for October: Large	Medium	Small	Index (Large less Small)	Departure of Index from Average
1925	2,723	+162	48*	50*	2*	+46	+34
1926	2,596	+35	10	59	31	−21	−33
1927	2,401	−160	40	47	13	+27	+15
1928	2,651	+90	33	61	6	+27	+15
1929	2,669	+108	33	62	5	+28	+16
1930	2,712	+151	11	69	20	−9	−21
1931	2,724	+163	47	53	0	+47	+35
1932	2,621	+60	15*	71*	14*	+1	−11
1933	2,781	+220	49	47	4	+45	+33
1934	2,537	−24	17	70	13	+4	−8
1935	2,518	−43	27	63	10	+17	+5
1936	2,265	−296	28	64	8	+20	+8
1937	2,644	+83	26	52	22	+4	−8
1938	2,492	−69	23	66	11	+12	0
1939	2,470	−91	9	80	11	−2	−14
1940	2,428	−133	10	53	37	−27	−39
1941	2,460	−101	16	74	10	+6	−6
1942	2,666	+105	45	48	7	+38	+26
1943	2,346	−215	26	65	9	+17	+5
1944	2,473	−88	7	33	60	−53	−65
1945	2,597	+36	38	53	9	+29	+17
Average	2,561					+12	

[1]From Table 10.
*August growers' reports (no October reports).
The coefficient of correlation from the above table is $+0.373 \pm 0.127$.

TABLE 6.—WEATHER CHIEFLY AFFECTING THE KEEPING OF MASSACHUSETTS CRANBERRIES.
(For use with Table 18 in making crop appraisals.)

Crop Year	Sunshine Year Before Year of Crop[1] (Total Hours)	Year of Crop: Mean Temperature[2] (Degrees F.)		Year of Crop: Precipitation[3] (Inches) July and Aug.	Keeping Quality[4]	
		March	May		Early Black	Howes
1889	No record	36.3	58.0	12.49	Very poor	Very poor
1912	2,764	34.3	56.8	6.91	Poor	Poor
1913	2,902	40.9	53.4	5.49	Good	Good
1914	2,623	34.2	57.5	8.20	Very poor	Very poor
1915	2,419	32.8	53.6	8.62	Fair[5]	Poor[5]
1916	2,705	27.2	54.4	9.06	Good	Good
1917	2,678	33.6	48.1	5.26	Good	Good
1918	2,558	33.9	59.4	5.84	Good	Good
1919	2,608	38.1	56.3	13.24	Poor	Poor
1920	2,451	36.1	51.6	5.30	Very good	Very good
1921	2,484	42.7	54.5	11.49	Fair	Fair
1922	2,659	37.0	58.0	13.91	Very poor	Very poor
1923	2,514	33.8	56.1	4.93	Good	Good
1924	2,512	34.1	53.3	8.35	Good	Good
1925	2,723	39.4	53.4	5.38	Good	Good
1926	2,596	31.6	53.7	6.13	Good	Poor
1927	2,401	38.6	52.9	13.95	Good	Fair
1928	2,651	35.3	53.4	5.60	Very good	Good
1929	2,669	39.5	56.8	6.97	Poor	Poor
1930	2,712	34.8	57.3	4.72	Poor	Poor
1931	2,724	36.3	57.6	8.43	Very poor	Very poor
1932	2,621	33.2	56.6	6.49	Good	Good
1933	2,781	34.5	58.6	7.40	Very poor	Very poor
1934	2,537	33.9	58.5	3.43	Good	Good
1935	2,518	38.3	54.0	6.38	Good	Good
1936	2,265	43.2	57.8	7.66	Good*	Good*
1937	2,644	32.6	57.9	5.33	Good*	Good*
1938	2,492	38.2	54.3	6.22	Fair*	Fair*
1939	2,470	33.1	55.6	4.78	Good*	Good*
1940	2,428	31.6	54.9	4.93	Good*	Good*
1941	2,460	32.3	56.6	8.15	Good*	Good*
1942	2,666	39.1	59.4	9.68	Very poor	Very poor
1943	2,346	34.5	56.4	8.29	Good*	Good*
1944	2,473	34.1	61.9	2.00	Fair*	Fair*
1945	2,597	44.3	54.6	5.23	Good*	Good*
Average	2,578	35.8	55.7	7.17		

[1]At Boston (from Table 10)
[2]At Middleboro (from Table 11).
[3]Averages of precipitation at Middleboro, Plymouth, and Hyannis (from Table 12).
[4]Most of these appraisals are from page 73 of Bulletin 402, mentioned above. Those marked * are made from data of November growers' reports, provided by C. D. Stevens.
[5]Probably unsound appraisals.

March temperature is included in Table 6 for handy use and as perhaps the most significant element in the weather complex elaborated in Table 18. The evident remarkable correlations of this complex with both the size and keeping quality of cranberries may be related to oxygen deficiency in the bog waters in March, but this possibility has not yet been explored. The influence of precipitation may be through an effect on the ionization of these waters.

TABLE 7.—TEMPERATURE AND CRANBERRY PRODUCTION IN MASSACHUSETTS.

Crop Year	Potential Production, Departure from Average[1] (Percent)	Mean Temperatures,[2] Year of Crop (Degrees F.) March	July	Sept. and Oct.	Departure from Average Degrees F. March	July	Sept. and Oct.
1888	+0.2	31.1	65.5	51.9	−4.3	−3.9	−4.1
1889	−25.7	36.3	68.5	55.2	+0.9	−0.9	−0.8
1890	−6.9	34.0	68.0	54.7	−1.4	−1.4	−1.3
1891	+15.6	33.6	65.7	56.8	−1.8	−3.7	+0.8
1892	+10.7	31.5	69.3	53.8	−3.9	−0.1	−2.2
1893	+21.9	32.8	68.6	54.3	−2.6	−0.8	−1.7
1894	−24.7	39.6	71.5	57.6	+4.2	+2.1	+1.6
1895	+19.5	33.6	66.6	54.5	−1.8	−2.8	−1.5
1896	+9.7	30.4	70.6	54.0	−5.0	+1.2	−2.0
1897	−31.7	35.5	70.8	55.3	+0.1	+1.4	−0.7
1898	−30.4	40.0	70.1	58.0	+4.6	+0.7	+2.0
1899	−6.3	34.0	69.4	55.7	−1.4	0.0	−0.3
1900	−8.3	32.4	70.7	58.8	−3.0	+1.3	+2.8
1901	+22.1	35.3	71.7	56.7	−0.1	+2.3	+0.7
1902	−15.0	41.1	66.4	56.5	+5.7	−3.0	+0.5
1903	+11.2	42.5	69.2	55.4	+7.1	−0.2	−0.6
1904	+51.9	34.0	69.1	54.0	−1.4	−0.3	−2.0
1905	−19.5	35.5	70.6	55.2	+0.1	+1.2	−0.8
1906	−3.0	31.0	69.3	56.5	−4.4	−0.1	+0.5
1907	−12.2	36.4	69.9	55.3	+1.0	+0.5	−0.7
1908	−30.1	37.3	72.1	57.5	+1.9	+2.7	+1.5
1909	+11.4	35.5	67.1	53.8	+0.1	−2.3	−2.2
1910	+30.0	39.0	70.6	56.0	+3.6	+1.2	0.0
1911	−15.9	33.3	72.4	54.8	−2.1	+3.0	−1.2
1912	+11.0	34.3	70.0	56.2	−1.1	+0.6	+0.2
1913	− 5.1	40.9	70.2	57.4	+5.5	+0.8	+1.4
1914	+11.9	34.2	66.2	56.2	−1.2	−3.2	+0.2
1915	+2.6	32.8	67.8	57.9	−2.6	−1.6	+1.9
1916	−11.6	27.2	68.9	56.0	−8.2	−0.5	0.0
1917	−1.0	33.6	70.5	52.2	−1.8	+1.1	−3.8
1918	+41.3	33.9	68.7	55.0	−1.5	−0.7	−1.0
1919	−3.1	38.1	70.3	56.8	+2.7	+0.9	+0.8
1920	−25.0	36.1	68.2	59.1	+0.7	−1.2	+3.1
1921	−34.4	42.7	71.9	58.5	+7.3	+2.5	+2.5
1922	+0.4	37.0	70.1*	58.4	+1.6	+0.7	+2.4
1923	+17.5	33.8*	66.2	56.5	−1.6	−3.2	+0.5
1924	+7.5	34.1	69.2	54.2	−1.3	−0.2	−1.8
1925	+21.8	39.4	68.5	53.6	+4.0	−0.9	−2.4
1926	+3.7	31.6	67.5	54.4	−3.8	−1.9	−1.6
1927	−10.4	38.6	69.3	58.0	+3.2	−0.1	+2.0
1928	−20.3	35.3	71.0	56.0	−0.1	+1.6	0.0
1929	+4.1	39.5	68.8	56.0	+4.1	−0.6	0.0
1930	−4.0	34.8	69.4	56.5	−0.6	0.0	+0.5
1931	+9.2	36.3	71.4	59.1	+0.9	+2.0	+3.1
1932	+2.2	33.2	68.1	57.3	−2.2	−1.3	+1.3
1933	+18.4	34.5	68.3	56.5	−0.9	−1.1	+0.5
1934	−27.3	33.9	71.5	56.7	−1.5	+2.0	+0.7
1935	−5.3	38.3	72.0	55.4	+2.9	+2.6	−0.6
1936	−8.1	43.2	68.8	57.0	+7.8	−0.6	+1.0
1937	+24.8	32.6	70.7	55.6	−2.8	+1.3	−0.4
1938	−21.7	38.2	71.5	57.2	+2.8	+2.1	+1.2
1939	+4.9	33.1	69.6	56.7	−2.3	+0.2	+0.7
1940	−10.7	31.6	69.9	53.9	−3.8	+0.5	−2.1
Average		35.4	69.4	56.0			

[1]From Table 1.
[2]At Middleboro (Table 11).
*Average of maximum temperatures at Brockton and minimum temperatures at Middleboro.

The above table gives the following correlation coefficients between mean temperatures and cranberry production:

March .... -0.257 ± 0.086
July .... -0.359 ± 0.08
September and October .... -0.353 ± 0.081

TABLE 8.—TEMPERATURE AND CRANBERRY PRODUCTION IN WISCONSIN.

Crop Year	Potential Production Departure from Average[1]	Mean Temperatures[2] (Degrees F.)					
		March, April, May, Year Before Year of Crop (a)	March, Year of Crop (b)	(a) − (b)	Departure from Average, Degrees F. (a)	(b)	(a) − (b)
1905	−31.1	39.9	31.9	8.0	−3.1	+2.4	−5.5
1906	+50.3	42.5	21.0	21.5	−0.5	−8.5	+8.0
1907	−28.8	41.5	33.5	8.0	−1.5	+4.0	−5.5
1908	−56.0	39.4	32.0	7.4	−3.6	+2.5	−6.1
1909	+58.9	44.8	26.2	18.6	+1.8	−3.3	+5.1
1910	−54.3	39.7	43.2	−3.5	−3.3	+13.7	−17.0
1911	+28.0	48.2	33.8	14.4	+5.2	+4.3	+0.9
1912	+27.2	46.4	22.0	24.4	+3.4	−7.5	+10.9
1913	+6.6	42.0	26.7	15.3	−1.0	−2.8	+1.8
1914	−7.4	42.8	28.8	14.0	−0.2	−0.7	+0.5
1915	−1.5	43.8	27.0	16.8	+0.8	−2.5	+3.3
1916	+8.2	43.8	26.5	17.3	+0.8	−3.0	+3.8
1917	−22.8	41.7	27.0	14.7	−1.3	−2.5	+1.2
1918	−15.0	40.0	36.3	3.7	−3.0	+6.8	−9.8
1919	+11.7	45.8	31.9	13.9	+2.8	+2.4	+0.4
1920	−10.5	43.6	31.6	12.0	+0.6	+2.1	−1.5
1921	−30.3	42.1	36.0	6.1	−0.9	+6.5	−7.4
1922	+37.8	48.5	30.8	17.7	+5.5	+1.3	+4.2
1923	0.0	45.9	21.9	24.0	+2.9	−7.6	+10.5
1924	−2.6	40.1	25.6	14.5	−2.9	−3.9	+1.0
1925	−43.9	39.2	33.1	6.1	−3.8	+3.6	−7.4
1926	+83.5	45.2	20.6	24.6	+2.2	−8.9	+11.1
1927	−48.4	39.8	35.0	4.8	−3.2	+5.5	−8.7
1928	−8.9	43.6	29.2	14.4	+0.6	−0.3	+0.9
1929	+5.1	40.5	30.9	9.6	−2.5	+1.4	−3.9
1930	−31.3	42.7	30.8	11.9	−0.3	+1.3	−1.6
1931	−3.9	44.8	30.4	14.4	+1.8	+0.9	+0.9
1932	+13.3	43.7	22.5	21.2	+0.7	−7.0	+7.7
1933	+13.3	39.8	28.6	11.2	−3.2	−0.9	−2.3
1934	+4.8	42.7	27.2	15.5	−0.3	−2.3	+2.0
1935	+2.9	44.7	31.8	12.9	+1.7	+2.3	−0.6
1936	−27.5	41.9	31.7	10.2	−1.1	+2.2	−3.3
1937	+28.1	43.4	24.4	19.0	+0.4	−5.1	+5.5
1938	−31.2	42.2	38.4	3.8	−0.8	+8.9	−9.7
1939	+12.4	47.2	29.9	17.3	+4.2	+0.4	+3.8
1940	+21.9	45.2	24.1	21.1	+2.2	−5.4	+7.6
Average		43.0	29.5	13.5			

[1]From Table 3. [2]At Meadow Valley (Table 16).

The above table gives the following correlation coefficients between mean temperatures and cranberry production:

(a)	$+0.648 \pm 0.065$
(b)	-0.695 ± 0.058
(a) − (b)	$+0.801 \pm 0.040$

TABLE 9.—RAINFALL IN MARCH AND APRIL AND MASSACHUSETTS CRANBERRY PRODUCTION.

Year	Rainfall March and April: Inches[1]	Rainfall March and April: Departure from Average	Potential Production, Departure from Average[2] (Percent)
1889	8.11	−0.23	−25.7
1890	12.65	+4.31	−6.9
1891	8.82	+0.48	+15.6
1892	7.06	−1.28	+10.7
1893	10.05	+1.71	+21.9
1894	5.60	−2.74	−24.7
1895	7.19	−1.15	+19.5
1896	6.66	−1.68	+9.7
1897	7.09	−1.25	−31.7
1898	8.64	+0.30	−30.4
1899	8.81	+0.47	−6.3
1900	6.10	−2.24	−8.3
1901	13.96	+5.62	+22.1
1902	9.53	+1.19	−15.0
1903	12.51	+4.17	+11.2
1904	10.38	+2.04	+51.9
1905	4.75	−3.59	−19.5
1906	9.96	+1.62	−3.0
1907	6.11	−2.23	−12.2
1908	6.26	−2.08	−30.1
1909	9.26	+0.92	+11.4
1910	4.50	−3.84	+30.0
1911	7.19	−1.15	−15.9
1912	10.59	+2.25	+11.0
1913	9.09	+0.75	−5.1
1914	8.91	+0.57	+11.9
1915	2.78	−5.56	+2.6
1916	8.59	+0.25	−11.6
1917	9.80	+1.46	−1.0
1918	6.83	−1.51	+41.3
1919	7.92	−0.42	−3.1
1920	10.01	+1.67	−25.0
1921	8.36	+0.02	−34.4
1922	8.28	−0.06	+0.4
1923	10.41	+2.07	+17.5
1924	9.43	+1.09	+7.5
1925	5.92	−2.42	+21.8
1926	5.26	−3.08	+3.7
1927	2.88	−5.46	−10.4
1928	7.75	−0.59	−20.3
1929	11.99	+3.65	+4.1
1930	3.93	−4.41	− 4.0
1931	10.41	+2.07	+9.2
1932	6.96	−1.38	+2.2
1933	14.31	+5.97	+18.4
1934	7.24	−1.10	−27.3
1935	6.64	−1.70	−5.3
1936	9.62	+1.28	−8.1
1937	8.63	+0.29	+24.8
1938	5.91	−2.43	−21.7
1939	12.43	+4.09	+4.9
1940	11.50	+3.16	−10.7
Average	8.34		

[1]From Table 12. [2]From Table 1.

Coefficient of Correlation $+0.234 \pm 0.088$

TABLE 9A.—RAINFALL IN JULY AND AUGUST AND SIZE OF MASSACHUSETTS CRANBERRIES.

Year	Rainfall[1] (Inches)			Departure of Rainfall from Average (Inches)			Size of Berries[2] ((All Varieties)	
	July	August	July and August	July	August	July and August	Index (Large less Small)	Departure of Index from Average
1925	3.01	2.37	5.38	−0.03	−1.12	−1.15	+46	+34
1926	3.27	2.86	6.13	+0.23	−0.63	−0.40	−21	−33
1927	4.58	9.37	13.95	+1.54	+5.88	+7.42	+27	+15
1928	4.20	1.40	5.60	+1.16	−2.09	−0.93	+27	+15
1929	2.35	4.62	6.97	−0.69	+1.13	+0.44	+28	+16
1930	2.32	2.40	4.72	−0.72	−1.09	−1.81	−9	−21
1931	3.99	4.44	8.43	+0.95	+0.95	+1.90	+47	+35
1932	1.94	4.55	6.49	−1.10	+1.06	−0.04	+1	−11
1933	3.67	3.73	7.40	+0.63	+0.24	+0.87	+45	+33
1934	1.26	2.17	3.43	−1.78	−1.32	−3.10	+4	−8
1935	4.83	1.55	6.38	+1.79	−1.94	−0.15	+17	+5
1936	1.87	5.79	7.66	−1.17	+2.30	+1.13	+20	+8
1937	1.02	4.31	5.33	−2.02	+0.82	−1.20	+4	−8
1938	4.81	1.41	6.22	+1.77	−2.08	−0.31	+12	0
1939	1.42	3.36	4.78	−1.62	−0.13	−1.75	−2	−14
1940	4.06	0.87	4.93	+1.02	−2.62	−1.60	−27	−39
1941	4.60	3.55	8.15	+1.56	+0.06	+1.62	+6	−6
1942	3.13	6.55	9.68	+0.09	+3.06	+3.15	+38	+26
1943	4.46	3.83	8.29	+1.42	+0.34	+1.76	+17	+5
1944	0.83	1.17	2.00	−2.21	−2.32	−4.53	−53	−65
1945	2.31	2.92	5.23	−0.73	−0.57	−1.30	+29	+17
Average	3.04	3.49	6.53				+12	

[1]From Table 12

[2]From Table 5.

Correlations between rainfall and cranberry size:

July .... +0.361 ± 0.128

August .... +0.432 ± 0.12

July and August ..... +0.554 ± 0.102

TABLE 10.—HOURS OF SUNSHINE AT BOSTON, MASSACHUSETTS.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1893	*144	161	221	212	219	222	289	241	231	219	184	130	2473
1894	135	159	222	208	260	286	340	275	216	165	143	148	2556
1895	143	218	215	202	287	254	253	289	255	208	110	123	2557
1896	155	167	208	246	263	260	235	262	191	132	110	184	2412
1897	136	159	165	227	196	258	220	270	258	230	119	132	2370
1898	164	142	194	174	198	234	252	242	266	171	126	153	2316
1899	185	160	163	292	292	323	316	210	216	150	164	180	2652
1900	154	146	237	234	232	311	320	261	225	146	120	142	2527
1901	134	208	158	106	212	332	266	223	218	236	134	121	2349
1902	152	170	187	175	295	295	253	304	190	196	120	142	2479
1903	149	174	203	261	347	183	300	249	289	212	180	168	2715
1904	151	164	197	211	281	249	277	262	229	184	141	107	2452
1905	150	188	224	261	298	268	319	271	191	224	179	127	2700
1906	144	192	223	254	307	293	289	292	271	173	130	81	2649
1907	91	141	192	204	211	284	336	312	159	199	103	129	2363
1908	171	186	196	254	267	366	314	255	243	206	166	138	2760
1909	102	155	223	237	283	361	374	314	213	225	119	157	2763
1910	123	171	259	236	233	259	338	282	208	210	101	127	2547
1911	110	141	238	300	329	306	228	281	241	175	171	135	2764
1912	136	202	238	234	281	390	339	301	224	226	170	160	2902
1913	141	203	193	236	272	353	335	287	224	90	150	140	2623
1914	106	192	166	217	252	279	254	201	274	209	148	122	2419
1915	134	166	292	220	299	291	275	256	275	200	160	138	2705
1916	149	144	228	206	274	278	260	306	275	232	160	167	2678
1917	118	171	224	204	214	257	306	307	267	186	193	112	2558
1918	165	170	248	250	311	304	271	264	207	165	143	110	2608
1919	134	213	173	185	276	330	301	260	193	134	125	126	2451
1920	147	143	237	183	252	238	343	246	226	228	88	152	2484
1921	163	159	210	174	288	332	274	339	269	224	94	132	2659
1922	172	114	178	248	332	251	294	224	252	214	139	96	2514
1923	116	160	193	241	291	281	255	286	222	200	145	118	2512
1924	162	199	234	224	225	289	347	275	222	251	171	122	2723
1925	141	156	210	261	274	311	301	294	209	145	160	134	2596
1926	106	126	211	236	283	270	268	200	215	196	160	130	2401
1927	133	118	255	343	218	306	241	233	266	253	132	152	2651
1928	191	201	247	279	262	249	298	242	193	230	105	171	2669
1929	171	162	211	182	326	346	367	296	205	193	136	118	2712
1930	113	181	236	293	271	306	274	294	275	195	155	130	2724
1931	208	170	193	275	284	268	244	240	243	223	149	125	2621
1932	96	137	222	257	338	291	343	339	268	174	165	150	2781
1933	175	207	195	197	282	289	291	239	200	218	149	95	2537
1934	118	183	237	278	311	287	286	241	120	187	130	140	2518
1935	142	132	225	162	254	207	248	267	163	251	90	126	2265
1936	175	167	204	192	320	289	369	254	212	198	148	115	2644
1937	121	163	236	208	244	241	309	257	259	162	141	150	2492
1938	121	114	176	233	279	302	242	326	213	178	160	126	2470
1939	119	135	180	177	276	295	325	260	230	150	170	108	2428
1940	174	153	214	197	221	275	293	305	224	213	96	93	2460
1941	127	170	217	257	262	259	243	294	290	205	217	125	2666
1942	181	188	183	214	160	208	262	281	214	215	129	110	2346
1943	133	166	222	240	255	315	255	241	192	140	158	155	2473
1944	161	190	204	211	310	217	293	310	187	209	130	177	2597
1945	170	166	214	227	168	228	240	254	187	178	122	142	2296
Mean	144	166	212	227	267	283	290	270	227	196	142	134	2558
Possible Hours	295	†297	371	401	452	455	461	429	374	343	295	284	4457

*No record—average substituted.
†Leap years not considered.

Table 11.—Mean Temperature at Middleboro, Massachusetts. (In Degrees F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1888	18.9	27.8	31.1	40.8	53.0	64.8	65.5	67.8	58.3	45.5	42.4	32.4	45.7
1889	33.1	24.5	36.3	46.5	58.0	66.5	68.5	66.2	62.2	48.2	42.7	36.2	49.1
1890	32.9	33.9	34.0	44.3	55.6	61.9	68.0	67.0	61.2	48.2	39.2	25.7	47.7
1891	30.2	32.5	33.6	47.0	54.2	62.8	65.7	68.6	64.2	49.4	40.3	39.3	49.0
1892	29.0	29.2	31.5	45.6	53.0	66.7	69.3	67.7	59.0	48.6	40.0	28.1	47.3
1893	18.9	26.7	32.8	43.0	55.5	63.9	68.6	68.0	56.7	51.9	39.1	29.3	46.2
1894	28.5	24.6	39.6	44.9	56.1	65.9	71.5	65.4	63.4	51.9	36.1	29.1	48.1
1895	26.6	22.1	33.6	44.1	57.4	66.0	66.6	68.0	62.9	46.1	43.6	33.4	47.5
1896	22.4	28.0	30.4	46.0	57.8	62.7	70.6	68.3	60.2	47.7	44.8	26.3	47.1
1897	26.4	28.2	35.5	46.1	56.2	60.5	70.8	66.9	59.9	50.8	39.8	32.3	47.8
1898	27.3	30.0	40.0	42.2	54.5	64.0	70.1	71.2	63.7	52.3	39.2	29.5	48.7
1899	26.4	24.5	34.0	45.0	55.6	67.2	69.4	66.8	59.8	51.7	39.0	32.7	47.7
1900	28.9	27.4	32.4	45.1	53.4	64.8	70.7	69.2	62.7	54.9	43.1	29.6	48.5
1901	26.2	21.3	35.3	43.7	54.1	65.1	71.7	69.0	62.9	50.5	34.6	30.5	47.1
1902	24.3	26.8	41.1	46.1	55.4	63.0	66.4	65.3	61.4	51.7	44.7	27.3	47.8
1903	27.6	29.0	42.5	45.6	56.3	58.9	69.2	62.2	60.0	50.8	36.4	25.9	47.0
1904	20.1	21.9	34.0	43.0	59.3	61.5	69.1	66.2	60.1	47.9	35.5	22.2	45.1
1905	24.5	21.8	35.5	45.1	56.2	62.9	70.6	66.2	59.8	50.7	39.0	33.3	47.1
1906	33.5	29.8	31.0	45.2	56.6	64.4	69.3	70.9	61.8	51.3	39.4	28.4	48.5
1907	27.2	19.7	36.4	42.2	51.3	61.2	69.9	66.4	63.6	47.0	41.1	34.1	46.7
1908	29.7	26.5	37.3	45.5	58.0	65.7	72.1	66.6	62.0	53.0	40.7	31.9	49.1
1909	31.3	32.8	35.5	45.8	53.7	64.6	67.1	64.6	59.4	48.2	43.0	27.8	47.8
1910	28.9	29.3	39.0	50.0	54.0	62.7	70.6	65.2	60.0	51.9	37.4	24.7	47.8
1911	31.0	26.3	33.3	42.7	59.6	63.7	72.4	67.3	59.9	49.8	40.3	36.3	48.5
1912	20.0	24.1	34.3	45.7	56.8	63.1	70.0	65.5	59.9	52.6	41.6	34.5	47.3
1913	37.6	26.8	40.9	46.8	53.4	63.6	70.2	67.8	59.2	55.7	44.0	35.3	50.1
1914	29.0	22.5	34.2	44.0	57.5	62.9	66.2	68.3	59.5	53.0	39.8	28.9	47.1
1915	30.6	31.6	32.8	47.1	53.6	62.1	67.8	66.8	64.0	51.8	41.5	30.0	48.3
1916	30.1	23.9	27.2	42.1	54.4	60.7	68.9	67.9	61.3	50.8	39.0	29.3	46.3
1917	26.9	23.6	33.6	41.2	48.1	64.0	70.5	70.2	56.4	48.1	34.7	22.7	45.0
1918	17.4	23.0	33.9	44.9	59.4	61.4	68.7	68.8	58.3	51.8	41.2	32.0	46.7
1919	30.7	29.8	38.1	43.9	56.3	64.1	70.3	65.4	61.5	52.1	40.2	26.0	48.2
1920	18.6	24.7	36.1	42.7	51.6	62.2	68.2	70.1	62.5	55.7	39.5	33.1	47.1
1921	28.4	29.5	42.7	49.0	54.5	64.2	71.9	65.6	65.1	51.9	39.9	29.3	49.3
1922*	25.0	29.2	37.0	45.2	58.0	68.0	70.1	69.2	63.3	53.5	42.5	30.2	49.3
1923*	27.4	21.8	33.8	47.7	56.1	65.4	66.2	65.1	62.1	51.0	40.2	37.0	47.8
1924	29.3	24.4	34.1	44.5	53.3	61.5	69.2	67.4	58.9	49.5	40.4	27.8	46.7
1925	24.5	35.1	39.4	46.7	53.4	67.9	68.5	68.1	61.9	45.4	39.5	31.2	48.5
1926	28.5	25.5	31.6	42.4	53.7	60.8	67.5	67.8	59.3	49.5	41.7	25.4	46.1
1927	28.2	30.5	38.6	44.6	52.9	61.1	69.3	64.8	61.5	54.5	46.1	33.7	48.8
1928	29.9	26.7	35.3	43.7	53.4	62.7	71.0	71.6	59.2	52.7	40.7	34.0	48.4
1929	26.3	28.1	39.5	44.8	56.8	65.2	68.8	65.9	62.5	49.6	40.6	30.3	48.2
1930	29.4	29.9	34.8	43.3	57.3	68.6	69.4	67.1	65.0	48.1	41.8	30.9	48.8
1931	27.1	28.5	36.3	46.8	57.6	64.3	71.4	69.5	64.2	54.0	46.0	34.1	50.0
1932	36.0	28.7	33.2	44.9	56.6	63.7	68.1	69.3	61.3	53.4	40.7	34.1	49.2
1933	35.1	30.2	34.5	45.7	58.6	65.3	68.3	68.8	62.7	50.4	36.0	25.8	48.4
1934	27.7	15.5	33.9	46.9	58.5	66.4	71.5	66.0	65.2	48.2	44.0	28.9	47.7
1935	22.8	26.8	38.3	44.5	54.0	64.1	72.0	68.2	60.0	50.8	45.5	27.0	47.8
1936	26.2	22.4	43.2	43.6	57.8	65.1	68.8	68.9	61.5	52.4	37.8	35.4	48.6
1937	36.6	33.5	32.6	44.4	57.9	65.1	70.7	74.0	60.6	50.6	41.8	30.1	49.8
1938	27.0	30.9	38.2	47.9	54.3	65.0	71.5	71.6	60.7	53.8	44.0	32.6	49.8
1939	26.4	31.7	33.1	43.5	55.6	63.4	69.6	72.5	61.2	52.1	37.7	30.9	48.1
1940	19.6	27.9	31.6	41.7	54.9	63.1	69.9	65.5	60.8	47.0	40.5	32.7	46.3
1941	24.8	27.2	32.3	48.8	56.6	64.8	69.5	66.9	61.8	52.8	43.7	33.4	48.5
1942	24.9	26.2	39.1	47.0	59.4	65.0	69.2	67.5	62.0	51.9	40.3	26.3	48.2
1943	25.1	28.1	34.5	41.1	56.4	69.4	71.6	68.6	60.6	52.8	41.0	26.8	48.0
1944	29.3	27.7	34.1	43.4	61.9	65.5	72.0	71.2	63.7	51.4	41.7	29.6	49.3
1945	22.6	28.4	44.3	51.7	54.6	65.5	71.1	67.7	65.8	50.2	43.4	26.1	49.3
Mean	27.3	27.1	35.6	45.0	55.7	64.1	69.5	67.8	61.4	50.8	40.7	30.4	47.9
Range of Means	20.2	19.6	17.1	10.9	13.8	10.5	6.9	11.8	9.4	10.3	11.5	17.1	
Change of Mean from Previous Month	−3.1	−0.2	+8.5	+9.4	+10.7	+8.4	+5.4	−1.7	−6.4	−10.6	−10.1	−10.3	

* The figures for June, 1922, to May, 1923, inclusive, are averages of the maximum temperatures at Brockton and minimum temperatures at Middleboro.

TABLE 12.—AVERAGES OF PRECIPITATION AT MIDDLEBORO, PLYMOUTH, AND HYANNIS, MASSACHUSETTS.
(INCHES)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1887*..	5.56	4.11	5.11	5.37	2.46	3.04	2.44	5.07	1.27	2.91	2.73	4.06	44.13
1888*..	3.83	3.53	5.27	2.08	4.94	1.22	3.61	5.40	8.05	3.52	9.04	4.03	54.52
1889*..	5.55	2.59	2.55	5.56	3.62	2.63	6.53	5.96	3.06	3.99	6.40	1.82	50.26
1890*..	2.57	3.25	9.41	3.24	5.20	3.46	1.32	3.20	6.76	9.96	0.90	3.84	53.11
1891*..	8.13	5.50	4.97	3.85	2.09	2.04	2.37	3.20	2.10	5.71	2.41	3.61	45.98
1892...	4.03	2.79	5.27	1.79	4.68	2.15	1.53	3.56	2.34	2.07	7.50	1.91	39.62
1893...	2.93	6.33	5.81	4.24	4.26	4.02	2.47	5.47	2.47	2.30	2.58	5.90	48.78
1894...	4.88	4.47	1.46	4.14	4.22	0.86	0.97	1.73	2.86	7.20	4.37	5.38	42.54
1895...	3.03	1.21	3.37	3.82	3.31	1.78	2.77	2.96	2.07	5.27	4.24	3.63	37.46
1896...	2.53	4.44	5.76	0.90	2.81	3.48	2.88	2.87	6.40	4.67	3.59	2.81	43.14
1897...	3.82	2.15	2.54	4.55	3.58	2.74	4.04	3.30	1.31	1.18	7.11	3.43	39.75
1898...	4.45	4.82	2.97	5.67	5.11	1.55	6.07	4.89	1.44	7.23	8.02	2.44	54.66
1899...	5.18	5.67	7.21	1.60	1.17	3.98	3.19	1.64	5.54	3.22	1.20	1.40	41.00
1900...	4.95	5.30	3.66	2.44	4.44	1.78	1.46	1.65	3.43	4.61	5.11	2.75	41.58
1901...	2.62	1.25	7.03	6.93	8.58	1.57	3.47	2.33	3.57	2.11	2.33	9.13	50.92
1902...	2.18	5.61	6.75	2.78	1.26	4.56	2.07	1.25	3.34	5.41	2.01	6.45	43.67
1903...	4.18	4.93	7.40	5.11	0.71	3.80	2.32	4.44	1.33	5.81	3.67	3.50	47.20
1904...	5.33	3.72	2.60	7.78	3.04	4.11	3.75	3.62	2.75	1.97	2.69	4.18	45.54
1905...	4.16	1.96	2.84	1.91	1.38	7.23	3.11	3.10	5.52	1.82	2.36	4.03	39.42
1906...	4.51	4.47	7.73	2.23	4.70	2.42	5.68	2.36	3.16	2.94	2.52	3.56	46.28
1907...	3.69	3.26	2.39	3.72	4.03	2.10	0.92	1.51	8.01	2.46	5.18	5.95	43.22
1908...	3.63	3.62	3.81	2.45	2.70	1.87	3.12	4.46	1.24	7.85	1.41	4.12	40.28
1909...	4.95	5.86	3.72	5.54	2.61	1.67	1.26	2.25	4.51	2.53	5.63	3.09	43.62
1910...	5.88	4.56	2.00	2.50	2.97	3.58	2.16	2.44	1.61	2.16	4.40	3.10	37.36
1911...	3.21	3.00	3.40	3.79	0.78	3.60	4.63	4.85	3.23	3.02	6.40	3.40	43.31
1912...	4.60	3.10	7.02	3.57	4.88	0.36	2.80	4.11	1.77	1.45	3.75	6.56	43.97
1913...	4.75	3.39	3.32	5.77	2.06	1.44	1.45	4.04	3.19	9.94	2.35	3.88	45.58
1914...	3.12	3.53	4.57	4.34	3.31	1.10	4.37	3.83	1.54	2.21	3.13	5.74	40.79
1915...	9.36	4.81	0.08	2.70	2.00	2.23	2.80	5.82	1.86	3.78	2.24	4.65	42.33
1916...	1.47	4.56	3.95	4.64	4.09	5.99	7.64	1.42	2.53	2.41	2.56	3.77	45.03
1917...	3.00	2.95	5.50	4.30	5.42	6.23	2.24	3.02	2.87	5.12	0.48	2.38	43.51
1918...	3.73	2.88	2.49	4.34	1.01	3.19	4.03	1.81	3.01	0.91	2.03	3.70	33.13
1919...	5.34	3.53	4.64	3.28	4.40	2.16	5.80	7.44	5.85	2.77	4.56	2.67	52.44
1920...	3.32	6.87	5.18	4.83	4.52	6.22	2.58	2.72	2.75	2.64	4.05	3.81	49.49
1921...	2.72	2.74	3.63	4.73	5.26	2.45	8.96	2.53	1.37	1.78	7.37	2.48	46.02
1922...	2.40	4.07	5.77	2.51	3.85	4.22	4.77	9.14	1.87	2.75	1.32	4.05	46.72
1923...	6.31	1.79	4.89	5.52	0.96	2.71	2.47	2.46	1.96	4.00	2.22	4.97	40.26
1924...	4.15	3.39	4.04	5.39	2.82	2.56	1.22	7.13	3.23	0.19	2.02	2.06	38.20
1925...	4.04	1.63	3.24	2.68	2.57	2.51	3.01	2.37	3.86	4.34	3.76	4.14	38.15
1926...	2.83	5.55	2.94	2.32	4.02	3.06	3.27	2.86	1.41	6.54	3.80	2.92	41.52
1927...	3.31	2.91	1.44	1.44	1.84	2.91	4.58	9.37	3.20	3.05	4.55	5.04	43.64
1928...	3.11	4.32	3.51	4.24	2.37	4.85	4.20	1.40	5.32	1.65	2.82	3.61	41.40
1929...	3.37	4.24	4.65	7.34	3.06	0.52	2.35	4.62	5.07	2.78	3.36	4.74	46.10
1930...	*3.50	3.81	2.76	1.17	2.47	2.62	2.32	2.40	0.30	3.89	4.30	3.77	33.31
1931...	3.70	3.18	7.07	3.34	4.93	7.28	3.99	4.44	2.06	4.25	0.83	3.36	48.43
1932...	6.52	2.97	5.35	1.61	1.94	2.74	1.94	4.55	5.86	5.59	6.00	2.57	47.64
1933...	2.96	3.98	6.53	7.78	2.29	2.09	3.67	3.73	13.69	4.97	2.38	4.30	58.37
1934...	3.74	3.78	3.58	3.66	2.19	4.07	1.26	2.17	2.56	4.13	2.85	3.53	37.52
1935...	5.51	2.98	2.06	4.58	1.85	5.11	4.83	1.55	4.66	2.11	6.49	1.54	43.27
1936...	7.31	2.42	6.47	3.15	1.42	4.46	1.87	5.79	7.44	3.12	1.61	9.23	54.29
1937...	4.34	1.46	3.73	4.90	2.32	3.23	1.02	4.31	4.67	4.38	4.92	3.95	43.23
1938...	3.79	3.15	2.67	3.24	3.81	7.78	4.81	1.41	6.92	3.39	3.98	3.60	48.55
1939...	3.81	4.16	7.51	4.92	1.56	3.35	1.42	3.36	2.69	5.23	1.68	2.19	41.88
1940...	2.42	6.56	4.08	7.42	5.02	2.16	4.06	0.87	4.37	2.10	6.46	3.06	48.58
1941...	4.54	1.93	3.27	2.83	2.96	6.09	4.60	3.55	0.36	2.70	2.08	2.99	37.90
1942...	3.29	3.36	8.03	0.86	1.53	2.86	3.13	6.55	3.14	4.55	5.06	3.84	46.20
1943...	4.00	1.94	3.02	3.35	5.18	1.72	4.46	3.83	2.30	4.03	2.75	1.29	37.87
1944...	2.56	2.06	4.90	4.16	0.44	3.55	0.83	1.17	7.47	*2.26	*8.49	3.32	41.21
1945*..	4.51	4.12	2.14	2.05	4.47	4.18	2.31	2.92	1.79	4.02	9.19	8.95	50.65
Mean..	4.12	3.67	4.39	3.85	3.18	3.21	3.21	3.60	3.56	3.74	3.89	3.90	44.31

*Figures for the years 1887, 1888, 1889, 1890, and 1891, for January 1930, for October and November 1944, and for the year 1945 are averages of only two of the three stations.

TABLE 13.—MEAN TEMPERATURES AT PHILADELPHIA, PA. (IN DEGREES F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1884	30.2	40.2	41.9	49.1	62.0	71.6	72.4	73.7	71.4	58.2	45.0	34.7	54.2
1885	30.2	24.4	30.8	50.6	60.1	71.0	78.2	73.2	66.6	55.4	45.0	37.0	51.9
1886	30.0	31.9	40.2	54.6	61.5	69.5	75.8	74.4	70.0	59.2	46.8	31.4	53.8
1887	31.6	36.2	36.4	50.8	68.1	71.6	80.6	74.0	64.6	56.4	46.0	37.1	54.4
1888	27.8	33.9	35.2	51.0	61.2	73.4	73.9	75.8	65.8	51.6	47.4	37.1	52.8
1889	38.7	29.5	42.2	53.2	64.7	71.4	75.3	72.8	66.4	52.8	47.0	43.6	54.8
1890	41.8	41.4	38.8	52.0	62.8	73.6	74.6	73.6	67.2	55.5	46.4	32.2	55.0
1891	36.4	39.6	38.0	54.3	61.0	71.8	71.9	74.3	71.6	54.9	44.2	42.8	55.1
1892	31.4	35.2	35.8	50.9	61.9	74.5	76.6	75.6	66.8	56.4	43.6	32.8	53.5
1893	24.0	32.0	39.2	50.8	61.0	72.2	76.6	75.6	65.8	57.6	44.0	36.4	52.9
1894	36.6	31.9	47.0	51.5	63.7	72.8	77.8	73.0	70.0	57.2	42.0	36.9	55.0
1895	30.6	25.4	38.1	51.6	62.4	74.1	73.2	77.4	72.4	52.6	46.8	39.2	53.6
1896	31.1	33.6	35.8	55.2	67.2	70.4	77.6	76.6	67.8	53.6	50.4	34.7	54.5
1897	30.8	35.8	43.1	52.6	62.6	68.9	76.4	74.4	68.4	58.2	45.9	38.1	54.6
1898	35.4	35.6	48.0	49.5	61.2	72.4	78.2	76.8	71.4	58.6	44.6	35.9	55.6
1899	32.3	28.2	40.7	53.4	63.2	74.9	76.7	74.8	67.0	58.6	46.3	37.5	54.5
1900	34.8	32.4	37.4	53.6	63.0	73.0	79.2	79.2	72.4	61.6	49.3	36.6	56.0
1901	33.1	27.2	41.8	50.1	60.5	72.6	79.2	76.9	69.5	57.1	41.2	35.9	53.8
1902	31.2	29.7	46.2	52.6	62.6	70.4	75.6	73.0	67.1	58.0	50.9	33.7	54.2
1903	32.6	36.5	49.4	53.2	65.6	65.8	76.4	71.0	67.6	57.8	42.5	31.8	54.2
1904	26.0	27.4	39.4	49.0	65.5	70.8	74.8	73.4	67.5	54.4	43.2	29.8	51.8
1905	29.8	26.3	42.9	52.6	63.5	70.8	76.9	73.6	68.6	57.9	45.2	39.2	53.9
1906	39.4	33.6	36.7	55.5	64.0	73.2	75.6	76.2	71.2	56.2	47.2	35.3	55.3
1907	34.2	27.0	44.1	47.4	57.6	66.8	76.9	73.4	69.6	54.1	46.4	39.3	53.1
1908	34.8	31.2	45.0	54.6	63.6	73.1	78.4	73.4	68.1	60.6	46.3	37.1	55.5
1909	35.6	41.2	41.4	53.2	63.2	72.8	75.3	73.0	67.2	55.0	50.2	33.3	55.1
1910	33.6	34.4	48.0	57.0	62.4	69.6	78.2	73.2	70.0	60.1	43.2	30.2	55.0
1911	37.1	34.8	40.0	50.0	67.9	71.6	78.5	74.6	68.6	57.4	43.5	41.5	55.4
1912	25.4	30.9	39.5	52.5	64.4	70.6	76.2	73.0	68.8	60.0	48.5	40.3	54.2
1913	42.2	34.4	47.6	54.5	63.6	72.5	78.0	74.6	67.0	60.0	48.9	40.3	57.0
1914	35.4	29.0	38.8	51.0	66.8	72.0	74.0	76.2	67.2	61.2	46.2	33.3	54.3
1915	36.6	38.8	38.7	57.3	60.9	69.6	76.0	73.1	71.4	59.4	47.4	35.0	55.4
1916	38.2	31.3	35.4	51.4	64.7	67.9	76.8	76.4	68.5	58.6	46.8	35.7	54.3
1917	35.2	31.4	42.0	52.3	57.2	72.2	76.4	76.7	64.4	53.8	43.4	28.0	52.8
1918	24.2	33.4	44.4	52.2	67.2	69.6	75.4	77.6	65.1	60.6	47.6	40.9	54.8
1919	37.7	37.6	45.4	52.4	64.0	72.0	77.2	73.3	68.8	61.2	46.8	32.5	55.7
1920	26.8	31.4	43.8	51.4	60.4	71.2	75.6	74.3	69.6	62.4	46.0	39.8	54.4
1921	36.0	37.6	52.5	58.5	62.4	73.4	78.6	72.7	72.8	57.7	46.8	35.6	57.0
1922	31.2	36.7	43.6	54.0	66.4	73.6	75.5	73.0	69.7	60.6	48.1	36.1	55.7
1923	34.4	30.0	41.2	52.6	62.6	75.8	75.2	73.8	69.6	57.2	46.4	44.6	55.3
1924	34.6	32.5	41.6	51.2	59.2	69.3	75.6	75.0	65.0	58.6	46.4	36.2	53.8
1925	31.8	42.2	46.4	54.9	61.6	78.0	76.2	74.8	71.2	52.2	45.4	36.6	55.9
1926	34.3	33.6	39.0	50.4	63.0	68.0	75.7	75.4	67.6	57.0	46.4	32.3	53.6
1927	32.6	40.6	46.4	50.9	61.6	68.6	75.8	70.2	69.4	60.4	50.9	38.9	55.5
1928	35.6	35.1	42.0	50.6	62.4	69.8	77.4	77.2	65.4	59.9	49.0	40.8	55.4
1929	34.2	35.2	48.4	55.2	62.8	72.8	76.8	73.2	70.3	55.8	47.4	38.2	55.9
1930	35.6	40.1	43.7	51.2	66.4	75.2	78.0	75.7	74.1	56.7	47.6	36.6	56.7
1931	36.2	37.4	42.3	53.2	64.2	72.9	79.8	76.3	74.1	62.6	54.0	44.2	58.1
1932	46.2	39.6	39.4	52.0	63.4	72.6	77.3	77.7	70.8	59.6	45.8	40.4	57.1
1933	42.6	36.7	41.4	53.8	66.3	74.4	76.6	76.0	71.2	57.8	44.1	36.2	56.4
1934	37.8	22.2	39.9	53.2	66.1	76.2	79.3	73.2	70.8	56.0	50.6	35.9	55.1
1935	31.0	33.0	46.2	51.6	60.6	71.5	78.2	77.3	66.0	57.8	50.0	31.5	54.4
1936	29.9	27.6	48.3	50.2	65.8	71.8	77.3	76.0	69.5	58.6	43.5	39.6	54.8
1937	41.4	35.8	38.7	51.2	65.3	72.6	77.1	77.2	66.4	55.0	46.2	36.0	55.2
1938	33.6	37.4	45.8	55.2	61.5	71.3	77.2	78.4	66.3	59.3	48.6	37.6	56.0
1939	34.4	39.4	41.7	50.4	66.4	73.2	76.2	77.8	69.2	57.6	44.9	38.1	55.8
1940	25.3	34.8	37.5	48.2	62.4	71.4	77.2	72.0	67.4	54.3	46.4	40.4	53.1
1941	31.8	31.8	37.4	59.2	66.3	72.1	76.4	75.3	71.3	62.8	50.4	39.8	56.2
1942	32.5	31.7	44.8	56.2	67.2	72.6	78.0	74.1	69.5	59.0	47.8	32.7	55.5
1943	32.6	35.8	42.5	47.8	63.9	77.2	77.6	77.9	68.0	56.2	45.9	35.1	55.0
1944	36.0	35.6	40.0	50.2	68.2	72.6	79.4	76.8	70.0	57.2	47.3	33.7	55.6
1945	26.8	36.2	53.6	57.1	61.2	73.0	76.0	74.1	70.9	57.2	48.6	32.0	55.6
Mean	33.6	33.8	42.0	52.5	63.4	72.0	76.7	74.9	68.8	57.6	46.6	36.5	54.9
Range of Means	22.2	20.0	22.8	11.8	11.0	12.2	8.7	9.0	9.7	11.2	9.7	16.6	
Change of Mean from Previous Month	−2.9	+0.2	+8.2	+10.5	+10.9	+8.6	+4.7	−1.8	−6.1	−11.2	−11.0	−10.1	

TABLE 14.—PRECIPITATION AT INDIAN MILLS, NEW JERSEY.
(INCHES)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901...	*2.86	* .87	*3.98	*5.88	5.77	1.55	5.05	10.25	4.92	1.59	3.79	7.04	53.55
1902...	2.89	6.40	4.22	3.34	1.52	8.58	5.08	2.70	5.01	5.61	3.31	7.84	56.50
1903...	3.60	4.76	4.69	3.33	.27	4.57	4.15	5.14	3.28	7.89	1.18	4.07	46.93
1904...	2.43	2.51	3.50	2.61	2.02	2.63	4.06	4.30	6.03	3.39	2.05	3.77	39.30
1905...	3.54	3.82	5.06	3.27	1.51	3.74	2.20	8.02	4.26	2.43	1.96	4.26	44.07
1906...	3.13	2.20	5.79	2.92	3.35	4.25	4.69	12.48	.92	5.63	1.99	3.87	51.22
1907...	3.18	3.45	2.93	4.61	6.03	4.73	3.06	5.53	10.51	4.37	4.94	4.71	58.05
1908...	4.12	4.27	2.66	2.68	7.14	2.79	6.58	6.09	2.08	2.76	1.29	4.59	47.05
1909...	3.66	5.35	3.45	5.28	1.94	2.08	2.95	2.86	3.20	1.52	3.45	4.93	40.67
1910...	4.47	1.39	1.32	5.08	2.01	7.43	2.12	4.85	1.67	4.31	3.10	3.32	41.07
1911...	5.34	2.63	3.43	4.43	1.19	6.66	4.04	13.87	4.44	3.46	5.58	3.70	58.77
1912...	3.76	2.63	8.21	3.16	3.40	2.47	8.06	3.63	4.06	2.89	2.89	5.80	50.96
1913...	3.57	2.26	3.92	7.28	4.80	1.03	2.42	4.69	4.42	5.94	2.79	2.44	45.56
1914...	4.16	2.86	4.26	3.31	2.52	3.47	6.97	3.03	.36	1.54	1.95	7.33	41.76
1915...	7.46	5.60	1.17	3.45	4.14	3.66	3.58	9.70	.97	3.93	1.34	4.65	49.65
1916...	2.07	4.97	4.76	2.76	3.65	4.50	6.35	1.54	1.96	1.44	2.07	5.90	41.97
1917...	3.19	2.65	6.11	3.17	3.45	4.91	7.93	2.25	4.37	9.38	.32	2.64	50.37
1918...	5.10	1.45	3.08	3.55	5.54	1.94	7.44	2.87	3.58	1.03	1.55	4.00	41.13
1919...	3.93	3.30	4.62	2.98	4.88	3.83	9.11	7.84	1.43	2.65	3.26	4.08	51.91
1920...	3.29	4.62	4.12	4.18	3.15	7.44	3.28	7.38	2.07	1.87	4.03	5.15	50.58
1921...	2.34	4.38	3.28	4.71	2.60	2.80	3.58	4.16	1.87	.64	3.16	2.62	36.14
1922...	3.31	3.30	3.42	2.34	3.01	4.47	6.33	5.58	1.74	1.52	.69	4.38	40.09
1923...	6.78	3.02	4.97	3.55	1.03	1.18	5.40	2.83	4.76	3.06	2.26	4.44	43.28
1924...	4.66	6.11	4.51	7.87	5.79	5.83	2.20	4.85	5.86	.15	2.35	3.05	53.23
1925...	4.49	2.38	2.61	3.35	2.80	2.61	9.62	2.04	3.41	5.69	3.67	2.24	44.91
1926...	3.53	4.81	2.63	2.97	2.86	4.73	7.13	5.90	3.92	2.93	4.10	4.16	49.67
1927...	2.86	3.24	2.73	2.56	2.12	2.89	4.48	9.89	3.30	7.09	2.93	4.79	48.88
1928...	3.78	4.09	3.05	5.52	2.98	6.74	4.89	7.80	5.96	1.06	2.76	2.68	51.31
1929...	4.19	5.00	4.01	6.02	1.83	3.91	1.44	3.97	4.72	5.28	2.99	2.39	45.75
1930...	3.64	3.78	2.35	1.72	3.54	4.38	2.84	3.73	1.74	3.03	2.07	3.33	36.15
1931...	2.29	2.15	5.16	2.83	3.48	4.71	1.85	7.36	1.63	3.63	1.18	2.31	38.58
1932...	5.11	1.70	7.35	3.69	3.14	4.36	3.22	2.87	2.72	6.29	8.26	3.53	52.24
1933...	3.71	3.93	5.33	4.59	5.31	5.30	4.86	14.35	3.68	1.27	1.84	2.67	56.84
1934...	2.60	3.22	3.83	4.50	4.12	4.89	3.06	7.66	8.19	2.46	3.56	3.27	51.36
1935...	5.31	2.96	2.66	2.66	2.77	4.30	2.16	6.34	6.15	6.17	5.04	1.85	48.37
1936...	5.15	3.55	5.15	2.05	1.19	5.44	4.04	3.53	6.11	3.31	.97	5.66	46.15
1937...	8.31	2.80	3.19	4.75	4.50	5.60	2.10	6.29	1.86	5.61	5.20	1.22	51.43
1938...	3.39	2.68	1.98	1.98	3.83	10.86	7.08	1.93	11.00	3.52	3.49	2.23	53.97
1939...	4.83	5.57	5.68	4.98	4.68	4.73	2.20	9.09	.53	4.90	1.67	1.10	49.96
1940...	1.51	3.00	4.48	5.08	8.49	2.94	1.83	8.40	6.28	2.19	4.70	2.92	51.82
1941...	3.79	2.67	2.52	2.42	1.63	5.01	8.12	3.79	.04	1.90	2.45	3.07	37.41
1942...	2.60	2.81	5.71	1.50	1.39	1.50	7.92	5.72	3.39	3.41	2.83	3.85	42.63
1943...	3.25	1.95	3.01	3.29	3.24	2.88	5.07	.57	1.02	7.55	2.44	1.80	36.07
1944...	3.78	2.17	6.35	4.92	1.94	1.93	1.67	3.25	7.08	2.49	5.77	2.56	43.91
1945...	2.70	3.57	2.65	2.51	2.88	3.73	11.15	4.02	1.82	2.04	5.41	5.95	48.43
Mean..	3.86	3.40	4.00	3.77	3.32	4.22	4.74	5.67	3.74	3.57	2.99	3.83	47.11

*Computed by Weather Bureau

TABLE 15.—HOURS OF SUNSHINE AT LACROSSE, WISCONSIN.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1904	155	149	162	261	297	310	321	285	201	140	137	110	2,528
1905	155	183	166	252	243	399	342	302	257	219	152	136	2,806
1906	124	190	200	276	253	319	362	280	221	152	81	86	2,544
1907	103	192	167	227	252	324	343	263	225	191	138	101	2,526
1908	146	160	210	252	253	280	309	270	271	202	125	123	2,601
1909	119	101	179	165	270	276	279	269	182	163	114	89	2,206
1910	121	173	301	253	278	388	366	286	216	224	111	147	2,864
1911	97	131	199	209	303	316	349	299	202	143	71	79	2,398
1912	180	139	229	254	259	317	320	213	225	233	173	145	2,687
1913	118	180	157	242	206	354	334	279	216	176	122	143	2,527
1914	66	187	219	199	297	297	396	292	225	194	170	123	2,665
1915	124	126	213	236	172	261	230	254	137	171	116	94	2,134
1916	132	174	206	196	256	253	383	307	201	197	148	157	2,610
1917	184	194	216	201	325	231	326	302	214	108	117	101	2,519
1918	147	171	260	247	253	243	326	256	204	169	123	61	2,460
1919	151	153	190	171	277	240	350	332	203	156	121	97	2,441
1920	137	143	241	244	346	325	376	336	258	247	89	78	2,820
1921	130	135	191	238	262	350	400	315	241	172	90	89	2,613
1922	166	178	190	188	277	313	233	302	270	209	59	138	2,523
1923	86	159	214	232	323	297	374	263	205	183	154	147	2,637
1924	194	150	183	222	230	232	340	285	190	261	136	144	2,567
1925	170	131	243	255	337	304	301	328	211	83	141	117	2,621
1926	147	118	192	310	323	319	284	237	142	144	80	112	2,408
1927	149	184	212	184	174	292	311	291	191	203	74	99	2,364
1928	173	171	229	238	335	217	317	281	266	196	121	122	2,666
1929	175	201	200	220	316	318	359	313	220	180	135	117	2,754
1930	171	138	220	249	249	262	356	303	293	164	172	100	2,677
1931	100	174	193	298	267	324	385	310	225	162	109	82	2,629
1932	75	151	174	236	256	292	376	263	293	110	111	142	2,479
1933	127	187	195	234	247	406	367	349	232	193	110	92	2,739
1934	92	201	236	262	392	357	321	277	156	206	91	80	2,671
1935	133	111	188	229	262	260	348	304	226	168	88	67	2,384
1936	146	194	206	233	338	337	399	282	231	154	166	111	2,797
1937	156	179	266	196	329	365	418	363	284	174	145	89	2,964
1938	150	135	263	260	256	339	339	319	195	229	153	119	2,757
1939	123	184	242	232	374	321	380	320	281	190	179	152	2,978
1940	174	159	226	239	307	328	349	241	276	192	84	84	2,659
1941	110	179	223	276	339	297	334	311	198	169	116	90	2,642
1942	158	100	113	264	195	274	312	297	168	215	145	85	2,326
1943	126	204	226	254	224	295	348	262	209	211	107	198	2,664
1944	170	195	203	245	234	295	340	312	204	223	58	109	2.588
1945	123	140	214	204	237	259	320	306	193	221	71	88	2,376
Mean	138	162	208	235	277	304	341	292	220	183	119	111	2,591
Possible Hours	289	294	370	404	458	463	468	433	375	341	289	278	4.462

TABLE 16.—MEAN TEMPERATURES AT MEADOW VALLEY, WISCONSIN
(IN DEGREES F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1904	5.4	5.0	26.8	39.8	57.0	64.6	66.3	63.2	58.8	47.8	36.4	17.6	40.7
1905	4.6	7.6	31.9	42.6	52.9	64.0	68.6	67.4	61.6	46.3	33.6	23.4	42.0
1906	19.0	13.9	21.0	48.4	55.0	64.3	67.6	70.5	62.9	46.6	33.2	21.6	43.7
1907	12.1	17.9	33.5	36.2	48.4	63.4	68.7	65.6	58.2	45.8	33.0	23.0	42.2
1908	19.1	19.7	32.0	45.2	57.1	63.8	69.3	65.8	65.6	49.0	35.6	20.0	45.2
1909	16.6	19.2	26.2	38.4	54.4	65.2	68.8	70.8	58.6	44.4	38.6	13.8	42.9
1910	13.7	12.8	43.2	49.8	51.6	67.1	71.2	68.0	57.9	51.0	27.6	15.7	44.1
1911	14.4	23.6	33.8	43.7	61.6	70.5	69.6	65.6	58.4	45.5	26.0	25.1	44.8
1912	−4.6	12.1	22.0	46.6	57.4	63.6	69.4	64.4	60.4	48.8	36.2	25.4	41.8
1913	15.4	12.6	26.7	46.4	55.4	68.4	68.8	67.6	60.2	46.5	39.3	29.2	44.7
1914	23.3	9.3	28.8	43.7	59.0	64.8	72.0	67.9	59.6	54.0	34.4	12.6	44.1
1915	13.0	25.0	27.0	53.6	50.8	60.4	65.4	62.1	60.1	49.6	34.8	20.7	43.5
1916	15.7	13.7	26.5	43.7	55.0	60.5	76.6	70.0	57.8	47.7	31.2	13.0	42.6
1917	9.0	5.6	27.0	41.8	51.2	60.6	70.1	64.0	57.2	37.0	36.5	11.8	39.2
1918	3.0	15.5	36.3	41.0	60.0	65.4	67.5	69.5	52.2	49.8	37.9	28.3	43.9
1919	21.9	21.0	31.9	44.8	54.0	68.8	71.4	65.8	62.4	47.1	29.6	9.1	44.0
1920	7.1	14.6	31.6	39.2	55.4	68.0	67.2	65.8	62.6	54.6	32.6	23.5	43.5
1921	23.0	23.9	36.0	50.2	59.2	70.0	75.8	69.0	63.8	48.6	27.8	20.2	47.3
1922	10.9	15.3	30.8	45.0	61.8	66.0	66.6	69.0	63.2	50.9	39.8	18.6	44.8
1923	18.2	9.4	21.9	42.1	56.2	69.9	73.6	65.4	59.5	46.3	37.2	30.3	44.2
1924	3.6	18.4	25.6	42.6	49.4	61.5	66.6	65.4	54.4	54.2	33.7	11.0	40.5
1925	15.2	21.6	33.1	50.0	52.6	65.8	67.9	68.2	63.2	37.0	31.7	14.4	43.4
1926	15.2	21.4	20.6	40.8	58.0	60.2	68.0	67.1	56.9	44.8	26.9	13.8	41.1
1927	11.9	23.0	35.0	43.1	52.6	61.6	65.5	61.4	61.5	50.4	32.7	10.4	42.4
1928	16.7	19.4	29.2	36.7	55.5	58.8	67.8	65.8	53.4	50.1	34.5	23.2	42.6
1929	1.2	7.0	30.9	45.8	51.4	61.5	68.8	64.7	59.6	47.5	29.8	20.4	40.7
1930	7.4	26.3	30.8	46.5	57.0	66.3	71.2	68.6	60.2	47.1	37.0	23.5	45.2
1931	27.2	29.2	30.4	46.2	54.4	70.8	73.0	67.2	65.2	51.4	40.8	29.7	48.8
1932	20.8	20.8	22.5	40.4	56.6	68.0	70.4	68.4	56.2	44.9	28.8	17.8	43.0
1933	25.6	15.8	28.6	42.0	57.6	73.4	72.2	66.1	64.2	45.0	30.9	19.0	45.0
1934	23.6	17.4	27.2	43.5	63.4	70.1	71.4	65.0	57.9	50.7	36.6	15.5	45.2
1935	11.0	20.2	31.8	42.4	51.4	61.4	75.0	67.9	59.4	47.7	30.4	18.8	43.1
1936	8.0	2.4	31.7	38.2	60.2	62.6	75.8	71.8	62.8	44.2	29.6	23.2	42.5
1937	9.6	13.8	24.4	43.6	58.6	64.9	72.3	73.6	61.2	43.2	30.2	17.4	42.7
1938*	14.6	24.2	38.4	46.7	56.5	64.8	71.1	71.3	60.5	54.4	32.8	21.1	46.4
1939*	22.9	16.1	29.9	43.4	62.4	66.1	72.1	68.5	61.9	48.1	33.4	27.3	46.0
1940*	9.3	16.1	24.1	42.2	55.0	65.7	72.0	66.7	61.1	51.3	28.6	22.7	42.9
1941*	18.3	15.7	25.5	51.2	60.9	66.2	69.6	68.0	59.2	47.4	37.6	28.0	45.6
1942*	17.2	16.6	33.6	50.7	54.5	64.2	68.9	67.7	56.8	49.3	31.8	14.5	43.8
1943*	9.2	17.3	21.8	42.2	54.7	67.8	72.4	69.0	55.3	48.4	27.1	22.4	42.3
1944*	24.5	18.8	24.6	42.1	60.0	67.0	68.4	69.3	59.6	46.6	38.9	17.7	44.8
1945*	13.1	16.0	40.4	44.8	52.2	61.3	66.2	66.4	58.1	46.0	31.7	13.4	42.5
Mean	14.0	16.6	29.4	44.0	55.9	65.2	70.0	67.3	59.8	47.8	33.3	19.7	43.6
Range of Means	31.8	26.8	22.6	17.4	15.0	14.6	11.2	12.2	13.4	17.6	14.8	21.2	
Change of Mean from Previous Month	−5.7	+2.6	+12.8	+14.6	+11.9	+9.3	+4.8	−2.7	−7.5	−12.0	−14.5	−13.6	

*The figures for the following months were computed from the monthly means at Mather, Wisconsin: May–December, inc., 1938; all of 1939 and 1940; January, 1941; April, July, August, and October, 1942; September, 1943; August, 1944; January, June, and November, 1945.

Table 17.—Averages of Precipitation at Meadow Valley, Neillsville, and Wisconsin Rapids, Wisconsin.
(Inches)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1903...	0.30	1.09	1.91	2.98	6.29	1.45	6.34	6.56	5.76	2.26	1.01	0.72	36.67
1904...	0.20	0.86	2.13	1.74	5.53	5.00	1.91	1.66	5.25	4.44	0.27	2.01	31.00
1905...	0.61	1.25	1.55	1.00	5.14	8.03	2.84	5.30	3.58	2.84	1.88	1.25	35.27
1906...	2.06	0.65	2.28	1.33	4.70	5.05	2.26	2.70	3.53	2.54	3.31	1.11	31.52
1907*..	1.83	0.47	2.04	2.49	2.80	3.51	7.20	4.97	3.27	0.97	0.98	1.25	31.78
1908...	0.55	1.09	2.32	3.26	5.24	4.00	4.97	2.06	3.09	1.29	1.54	0.91	30.32
1909...	0.79	1.72	1.35	4.16	3.01	2.56	1.44	2.89	3.42	1.50	4.20	1.59	28.63
1910...	0.99	0.65	T	3.97	1.67	0.51	1.96	4.34	3.71	1.32	0.66	1.12	20.90
1911...	1.25	0.93	2.13	1.48	6.96	5.83	3.38	3.89	7.07	7.87	2.15	2.36	45.30
1912...	0.99	0.34	0.82	2.23	6.20	0.45	8.37	7.24	3.18	1.26	0.88	1.94	33.90
1913...	0.67	0.88	3.66	2.24	6.30	2.47	5.82	2.06	3.25	3.30	1.56	0.27	32.48
1914*..	1.25	0.43	1.20	3.82	3.66	8.78	2.10	3.08	4.19	2.22	0.66	0.60	31.99
1915*..	1.20	2.68	0.44	0.91	5.74	3.29	4.26	2.99	5.73	1.81	2.86	0.76	32.67
1916...	2.49	0.97	1.58	2.69	3.96	5.94	1.62	2.89	5.66	3.01	1.57	0.79	33.17
1917*..	1.86	0.86	2.52	2.71	2.15	5.16	3.51	3.53	2.16	2.91	0.13	0.51	28.01
1918...	1.30	0.87	1.48	2.13	7.47	2.32	2.27	4.61	1.60	2.10	2.47	1.57	30.19
1919...	0.84	1.51	1.93	3.90	3.64	5.71	3.62	2.87	3.24	4.16	2.90	0.79	35.11
1920...	1.95	0.48	3.04	2.11	3.26	6.98	1.30	2.45	1.74	2.05	3.27	1.96	30.59
1921...	0.50	0.59	1.36	3.28	2.99	2.33	3.24	2.30	3.80	1.35	1.30	1.77	24.81
1922...	0.90	3.79	1.55	4.65	3.49	5.98	4.09	1.47	4.22	0.61	3.48	0.69	34.92
1923...	1.04	0.83	1.93	2.68	2.00	6.02	1.17	3.51	5.67	0.46	0.61	1.97	27.89
1924...	0.79	1.18	2.23	4.39	3.81	5.34	3.31	8.83	4.62	0.34	1.71	1.24	37.79
1925*..	0.37	0.61	0.72	2.24	1.07	9.57	5.64	1.34	5.59	1.86	1.35	1.65	32.01
1926*..	0.47	1.75	1.19	1.44	4.54	3.59	3.47	7.12	5.66	2.67	1.84	1.40	35.14
1927...	0.85	0.22	2.02	1.58	3.82	3.38	4.57	1.00	4.97	3.03	2.38	1.37	29.19
1928...	0.32	1.85	0.92	1.88	1.90	3.16	4.15	7.54	6.11	3.65	1.03	0.62	33.13
1929...	3.15	1.21	1.80	3.40	2.82	4.28	2.15	2.88	2.98	1.78	0.46	0.33	27.24
1930...	1.16	1.08	1.34	0.87	3.39	7.96	2.85	1.04	1.87	2.81	1.40	0.28	26.05
1931...	0.44	0.62	1.52	1.49	1.75	4.11	1.49	3.01	6.20	2.90	4.86	0.93	29.32
1932*..	2.02	1.69	0.69	2.34	4.28	4.27	3.38	3.46	2.14	1.05	1.96	1.94	29.22
1933...	1.32	0.99	1.66	2.84	6.21	1.23	2.61	1.34	2.82	2.25	0.49	0.62	24.38
1934...	1.10	0.18	1.58	1.64	1.14	7.04	2.69	3.22	6.97	2.75	5.78	0.99	35.08
1935...	2.11	0.76	1.12	3.39	2.94	6.28	5.17	4.71	4.16	2.94	1.59	0.83	36.00
1936...	0.73	1.25	1.91	1.41	3.20	2.31	1.09	4.89	2.95	3.15	0.83	1.40	25.12
1937...	1.89	2.10	0.66	2.91	3.81	3.69	2.15	2.87	2.40	4.29	1.58	0.48	28.83
1938*..	1.10	2.36	1.77	3.63	5.37	6.72	4.15	5.22	10.07	1.50	2.00	1.08	44.97
1939*..	1.26	1.56	0.88	1.94	2.04	5.25	1.80	4.64	3.05	1.38	0.38	0.95	25.13
1940*..	0.48	0.42	1.50	2.24	4.30	9.42	1.33	4.03	1.78	2.38	3.92	1.88	33.68
1941*..	1.18	0.35	1.46	2.59	6.15	2.78	2.72	2.59	7.54	5.70	1.29	1.88	36.23
1942*..	0.24	0.60	2.79	1.78	7.33	6.15	3.93	1.56	6.89	2.75	1.96	1.71	37.69
1943*..	1.47	0.34	1.45	1.65	6.27	5.33	1.64	6.39	2.17	3.07	2.14	0.01	31.93
1944...	0.79	1.59	1.66	2.42	3.17	7.50	2.47	4.53	2.62	0.27	2.05	0.70	29.77
1945*..	0.73	2.36	2.26	3.90	5.79	3.78	2.81	5.69	3.24	0.62	4.94	1.63	37.75
Mean..	1.11	1.12	1.64	2.51	4.12	4.76	3.24	3.75	4.18	2.40	1.94	1.16	31.92

*The figures for the following months are averages of only two of the three stations: December, 1907; October, 1914; January-May, inc., 1915; November and December, 1917; September and October, 1925; January and February, 1926; January, 1932; May-December, inc., 1938; all of 1939 and 1940; January and February, 1941; July, August, and October, 1942; August, September, and December, 1943; January, June, November, and December, 1945.

TABLE 18.—SUNSHINE, MEAN TEMPERATURE, AND PRECIPITATION OF MARCH, AND SIZE AND KEEPING QUALITY OF MASSACHUSETTS CRANBERRIES

Year	Sunshine at Boston[1] (Hours) S	Temperature[2] (Degrees F.) x 6 T	x 3 T'	S-T	Size of Berries (Departure of Index from Average)[3]	Precipitation[4] (Inches) x 20 P	S−(T'+P)	Keeping Quality[5] Early Black	Howes
1912..	238	206	103	+32		140	−5	Poor	Poor
1913..	193	245	123	−52		66	+4	Good	Good
1914..	166	205	103	−39		91	−28	Very poor	Very poor
1915..	292	197	98	+95		2	+192	Fair[6]	Poor[6]
1916..	228	163	82	+65		79	+67	Good	Good
1917..	224	202	101	+22		110	+13	Good	Good
1918..	248	203	102	+45		50	+96	Good	Good
1919..	173	229	114	−56		93	−34	Poor	Poor
1920..	237	217	108	+20		104	+25	Very good	Very good
1921..	210	256	128	−46		73	+9	Fair	Fair
1922..	178	222	111	−44		115	−48	Very poor	Very poor
1923..	193	203	101	−10		98	−6	Good	Good
1924..	234	205	102	+29		81	+51	Good	Good
1925..	210	236	118	−26	+34	65	+27	Good	Good
1926..	211	190	95	+21	−33	59	+57	Good	Poor[6]
1927..	255	232	116	+23	+15	29	+110	Good	Fair
1928..	247	212	106	+35	+15	70	+71	Very good	Good
1929..	211	237	119	−26	+16	93	−1	Poor	Poor
1930..	236	209	104	+27	−21	55	+77	Poor	Poor
1931..	193	218	109	−25	+35	141	−57	Very poor	Very poor
1932..	222	199	100	+23	−11	107	+15	Good	Good
1933..	195	207	104	−12	+33	131	−40	Very poor	Very poor
1934..	237	203	102	+34	−8	72	+63	Good	Good
1935..	225	230	115	−5	+5	41	+69	Good	Good
1936..	204	259	130	−55	+8	129	−55	Good*	Good*
1937..	236	196	98	+40	−8	75	+63	Good*	Good*
1938..	176	229	115	−53	0	53	+8	Fair*	Fair*
1939..	180	199	99	−19	−14	150	−69	Good*	Good*
1940..	214	190	95	+24	−39	82	+37	Good*	Good*
1941..	217	194	97	+23	−6	65	+55	Good*	Good*
1942..	183	235	117	−52	+26	161	−95	Very poor	Very poor
1943..	222	207	103	+15	+5	60	+59	Good*	Good*
1944..	204	205	102	−1	−65	98	+4	Fair*	Fair*
1945..	214	266	133	−52	+17	43	+38	Good*	Good*

1 From Table 10. 2 From Table 11.
3 From Table 5 4 From Table 12.
5 From Table 6. 6 Probably unsound appraisals.
Most of these appraisals are from page 73 of Bulletin 402. Those marked * are made from data of November growers' reports, provided by C. D. Stevens.

OBSERVATIONS ON FLOODING WATERS USED IN CRANBERRY CULTURE

By Neil E. Stevens[1]

The importance of flooding water in cranberry culture has long been recognized. Within the last five years several papers have appeared presenting evidence that in Wisconsin the composition of the water used in flooding, particularly its alkalinity, is of great importance. That cranberries are grown in Wisconsin under a much wider variety of conditions than in the eastern states is well known. In no way is this more strikingly shown than in the range of acidity of the water used in flooding. This contrast is clearly shown in Table 1 based on analyses of practically all the reservoir waters in Wisconsin (about 100) and the first 100 water supplies tested in Plymouth and Barnstable counties, Massachusetts, during the summer of 1945. Obviously only a very few of these Cape Cod water supplies are even a little above pH 7, and all have very low alkalinities. It should thus be clear at the outset that the conditions observed to be harmful in Wisconsin have not been found to exist on any Massachusetts bog now in cultivation.

On the other hand, in the opinion of Dr. Franklin, the facts discovered in Wisconsin would be of interest in Massachusetts and might well become of vital importance in case of wide geographical expansion of the industry in New England. Massachusetts cranberry growers will not be surprised to learn that Lawrence M. Rogers was the first to call public attention to the apparent relation between alkaline flooding water and certain cranberry problems. During the years he worked in Wisconsin he became convinced of its importance. In 1936 he turned over to me the evidence he had accumulated and we discussed the problem at length. The first paper[2] relating to this matter was revised by him after his retirement. In this paper the conditions observed on the three or four cranberry marshes having water with pH 8.4 or 8.6, which were still in cultivation in 1930 to 1940, are described as follows:

> These marshes have been observed closely over a period of ten or twelve years and have never during this time produced a really satisfactory crop of fruit, even though they have had adequate frost protection and no unusual losses from insects and disease. As already stated, we have no proof that this condition is due to the alkalinity of the flooding water, but there are certain pathological conditions which are observed on these marshes, not often found on those with acid water.
>
> In general, the effect one gets from observing such a marsh is that the vines are constantly over-fertilized and over-stimulated. Vegetative growth is much too abundant and many of the berries actually produced are abnormally large. Growth in the spring is unusually vigorous and rapid and is frequently associated with a condition that we have come to call "flower bud absorption." This is a condition in which uprights develop from fruit buds on which the blossom buds have aborted and fail to grow away from enclosing bud scales, although growth of the upright proceeds normally in other respects. The general appearance suggests frost injury, but repeated observations have convinced us it is not due to frost in these cases and may be associated with water. At any rate, this condition is much more common on marshes with alkaline water.
>
> On such marshes in the fall fruit buds tend to overgrow, that is develop beyond the point normal for the resting period, and are thus more subject to injury, frequently to complete killing, during the winter submergence.

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[1]Professor of Botany, University of Illinois; Cranberry Specialist in the Wisconsin Department of Agriculture summers.

[2]Stevens, N. E., Rogers, L. M., and Bain, H. F. Alkaline flooding water in cranberry growing. Trans. Wis. Acad. Sci. 32:351-360. 1940.

That these abnormalties are due to alkaline water is not proved, but they are certainly associated with it. In the absence of experimental evidence, present opinion must rest on the study of the development of the cranberry industry in Wisconsin and the records and present condition of certain cranberry properties in that State. In other words, we were forced to deal almost wholly with what physicians refer to as "case histories." The success of this method depends on there being made available accurate information regarding yield and management problems. Such information can certainly not be published except in the most general terms.

Field Evidence in Wisconsin

When the pH readings of most of the water sources used in Wisconsin had been tabulated, as in columns one and two of Table 1, it became evident that nearly three-fourths of all the cranberry properties in the State were using water with pH of 7 or below. On an acreage basis the proportion having neutral to acid flooding water was much greater. It was also apparent that between this group and those mentioned above as having very alkaline water were a number of properties using water with pH from 7.2 to 7.8, some of which produced good crops but on which the general management problems, including weed control, were decidedly aggravated. At the very bottom of the list were a few properties on which, as already stated in the above quotation, no really satisfactory crop of fruit had been produced during the fifteen years of our observation. This group also included several abandoned properties.

TABLE 1.—COMPARISON OF FLOODING WATER USED ON CRANBERRIES IN WISCONSIN AND MASSACHUSETTS.

pH	Number of Properties Using Water of the pH Indicated		Range of Alkalinity of Water in the Classes Indicated (Expressed as Bound CO_2)	
	Wis.	Mass.	Wis.	Mass.
4.2-5.0	13	5		1-3
5.1-6.0	16	35	5-10	2-6
6.1-7.0	43	56	6-23	2-6
7.1-7.5	10	4	17-23	3-6
7.6-7.9	14		30-55	
8.0-8.7	6		35-80	

During the years 1937-1944, many readings were made on Wisconsin cranberry waters not only for pH but also for alkalinity, expressed here as bound CO_2. There is some reason to believe that, of the two readings, the latter is more indicative of the suitability of water for use in cranberry culture. It is certainly subject to smaller fluctuations than is pH. Obviously (see Table 1, column 4) the amount of bound CO_2 is usually greater in water with a higher pH. The correlation is not uniform but is sufficiently good for all practical purposes, and in the present state of our knowledge both readings should be considered.

To the list of Wisconsin properties with very alkaline water were later added two bogs in another state, both of which had failed to produce good crops even under experienced management. One of these had a flooding water with a pH of 7.8 and a bound CO_2 content of 100 p.p.m. The other had a pH of 8.7 and a bound CO_2 content of 37 p.p.m.

Bogs Under the Same Management

Management plays so large a part in the success of any cranberry property that it seemed particularly desirable to get records of bogs with different water supplies which had been under the same management for a considerable period of years. Finally five such pairs were assembled and the information on them is presented in Table 2.

TABLE 2.—WISCONSIN CRANBERRY PROPERTIES, UNDER THE SAME MANAGEMENT, BUT WITH DIFFERENT WATER SUPPLIES.

(Bogs in the same horizontal line are known to have been under the same management for a considerable period. pH represents an average of all available readings for the water supply, and the success of the property is indicated in very general descriptive terms.)

pH		pH	
6.4	Profitable for three generations	7.4	Abandoned
6.4	Very profitable	8.2-8.7	Has never paid expenses
6.7	Profitable for twenty years	7.6	No profit yet
6.6	High yield for fifty years	7.6	Yield per acre less than half that in opposite column
6.8-7.0	Average yield per acre 1940-1944; 3x	7.8	Average yield per acre 1940-1944, 2x

History of the Berlin Area

Cranberry culture in Wisconsin began in the region north of Berlin during the early 1860's and developed to a "boom" in 1872. This stimulated the cultivation of cranberries in the Wisconsin Valley where the crop is still important. The history of the industry in the Berlin area has been told in detail.[3] The facts relevant to the present subject can be summarized briefly. From the peak of 30,000 barrels in 1872-74, production fell off rapidly for at least ten years until (see Table 3) the crop was only 1,000 barrels. By the opening of the present century only a few properties continued in cultivation. In 1916 there was only one.

TABLE 3.—REPORTED CRANBERRY PRODUCTION IN THE BERLIN, WISCONSIN, AREA.

Year	Barrels	Year	Barrels	Year	Barrels
1870	10,000	1874	30,000	1882	5,000
1871	20,000	1879	16,000	1883	"very poor crop"
1872	30,000	1881	6,000	1884*	3,000

*"Cranberry picking occupied only two or three days last week." *Courant.*

During the years of peak production, the only water used for flooding of cranberries was that from the marsh itself; that is, it was largely rain or melted snow held in ditches or behind dikes. In 1873 a canal was dug bringing in water from Willow Creek. This was followed in 1883 by another, several miles east, also from Willow Creek. In 1885 a much larger one was dug from the Fox River.

[3]Stevens, N. E., and Nash, Jean. The development of cranberry growing in Wisconsin. Wis. Mag. of History 72:276-294. 1944.

The water of these streams is very hard: Willow Creek — pH 8.2-8.4, bound CO_2 80 p.p.m.; Fox River — pH 8.1-8.3, bound CO_2 75 p.p.m. To one tracing the history of the industry of this region, the conclusion appears inescapable that the introduction of large amounts of alkaline water was, at least in large part, the cause of the decline of the industry. All the individual holdings were really parts of one large marsh near the town of Aurora. Production fell off first in the region served by the first canal. Profitable production continued longest in the regions more remote from this canal.

Recent History of the Berlin Marsh

It is certainly not revealing any confidential information to state that, during the two decades ending in 1940, the one property kept in cultivation in the Berlin area had not produced profitable crops. Beginning in 1942[4], under new ownership and management, the methods of handling the bog were changed in several respects. Most conspicuous was the handling of the water. So far as possible river water was excluded. The reservoir dikes were raised and flooding operations were conducted chiefly with water held in the reservoirs. To a very large extent the water used in flooding the vines was pumped back into the reservoirs. Readings made during the growing seasons of 1943 and 1944 showed that the pH of the reservoir water averaged from 6.6 to 6.8 in contrast to pH 8.1 to 8.3 for the Fox River. The bound CO_2 content of the reservoir water was about half that of the river water. Under these conditions very satisfactory crops were produced in 1943 and 1944. Here again, there is no proof that the change in water handling produced the changes in the crop, but the results are as recorded.

The Effect of Alkaline Water on Cranberry Soils

In general on Wisconsin cranberry properties, alkaline flooding water and the less acid soils are found together; acid flooding water and more acid soils tend to be found together. There are some exceptions, particularly on bogs only a few years old. This inevitably raised the question, to what extent repeated flooding with alkaline water might change the soil.

Obviously, the quickest way to test this was to set up an experiment in a greenhouse.[5] Six samples of peat from Wisconsin bogs were chosen. Two were from bogs under construction on areas on which no cranberries had been grown; two were from areas formerly cultivated but now being rebuilt; and two were from old bogs.

Two 2-gallon earthenware jars were filled with soil from each sample, and cranberry vines were planted in the jars, which were then placed in a greenhouse. For one year they were irrigated with water from Lake Mendota, Wisconsin, which has a pH of 7.8 to 8.4 and an alkalinity expressed as bound CO_2 of 70 to 74 p.p.m. In September 1942, they were moved to Urbana, Illinois, and irrigated for the next year with water having a pH of 7.4 to 7.6 and an alkalinity expressed as bound CO_2 of 145 to 154 p.p.m. In all cases the pH was decidedly raised and the amount of exchangeable calcium and magnesium was increased. The changes which occurred in three representative samples are shown in Figure 1.

[4]Stevens, N. E. Further observations on alkaline flooding waters in cranberry growing. Trans Wis. Acad. Sci. 36 (1944):395-398. 1946.

[5]Hull, H. H., and Stevens, N. E. Changes in pH and in base-exchange properties of cranberry soils following the use of alkaline water. Soil Sci. 58:405-408. 1944.

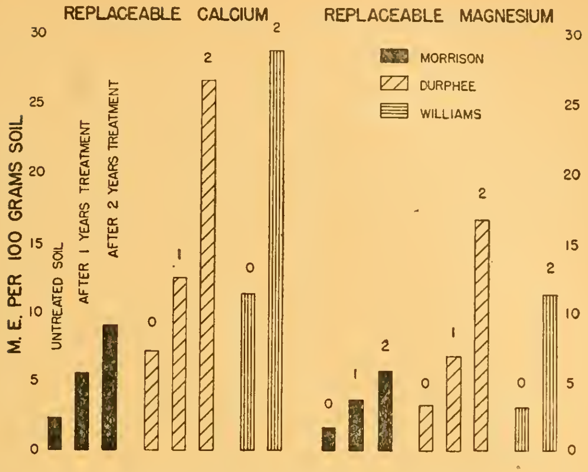

Figure 1. Changes in Replaceable Calcium and Replaceable Magnesium in Three Cranberry Soils following the Use of Alkaline Water.

Summary of Conditions in Massachusetts

A survey of the water being used for flooding cranberries in Massachusetts was made during July and August 1945. With this were included a small number of ponds not now used in cranberry culture. The results of this survey are presented in detail on pages 44-47. While this survey is not complete, the water tested must be representative. It is obvious that in southeastern Massachusetts, by far the largest cranberry producing region in the world, there is no water of an alkalinity comparable to many found in Wisconsin.

Most of the water in the clear ponds of Plymouth and Barnstable counties is essentially rain water stored in hard sand, largely quartz sand. A long acquaintance with Cape Cod cranberry growers has developed a great respect for their resourcefulness. I sincerely doubt, however, whether they could maintain their bogs so free from weeds if they used alkaline water in flooding.

Three facts regarding the Massachusetts situation seem, however, to warrant special mention: the danger involved in the use of very acid water on Cape Cod; the occurrence of at least two ponds which at times show relatively high pH; and the fact that in other parts of New England, in regions apparently otherwise suitable to cranberry culture, there exist waters of an alkalinity so great as to make cranberry growing probably hazardous.

Very Acid Water

It has been known for some time[6] that the water of certain reservoirs in Wisconsin is so very acid and so low in carbonates and oxygen content that flooding for the control of insects is extremely hazardous. On such bogs submergence during July for as little as ten hours may kill 25 percent or more of the buds. A few such reservoirs are also found in Massachusetts. These are usually characterized by very low pH, 4.5 or below. In all cases the owners and managers of

[6]Stevens, N. E., and Thompson, N. F. Factors influencing injury to cranberry plants during flooding. Trans. Wis. Acad. Sci. 34:73-81. 1942.

properties with such water have long recognized that it is necessary to use the very greatest care while flooding in order to avoid injury to the cranberry plants themselves.

Ponds with Varying pH, Occasionally 8

Two ponds were found in Barnstable county, Santuit and Mashpee, having water which varies considerably in pH yet maintains a consistently low alkalinity. During the period from July 7 to August 16, pH readings fluctuated between 6.6 and 8.2. This condition might well repay further study.

Water Conditions in Northwestern Massachusetts

During a brief visit to Vermont and adjacent Massachusetts a number of readings were made which indicated that in this region there exist waters so alkaline as to render cranberry culture something quite different from that in the southeastern part of the state. An attempt to grow cranberries in this region might well be a hazardous experiment. (See Table 4.)

TABLE 4.—pH AND ALKALINITY OF WATER IN NORTHWESTERN MASSACHUSETTS AND VERMONT.

Water	pH	Bound CO_2 p.p.m.	Date	Time	Weather
Willoughby Lake, Vermont	7.5	15.0	8/25/45	Noon	Cloudy
Winooski River below Plainfield, Vermont	8.3	33.5	8/25/45		
2d Branch of White River at East Randolph, Vermont	7.9	52.5	8/25/45	p.m.	Cloudy
Franklin Pond South Guilford, Vermont	7.2	17.5	8/25/45	4:00 p.m	Rainy
Shattuck Brook North Bernardston, Mass.	7.3	20.0	8/25/45	4:30 p.m.	Cloudy, rainy

Water Conditions in Southern New England

During 1946 the survey was extended to various parts of southern New England not reached in 1945.[7] The results of observations outside the principal cranberry regions are shown on the map (Figure 2).

Present information indicates that in the five smaller New England states surface waters in the western part are often higher in pH and alkalinity than farther east.

[7]Dr. R. B. Stevens assisted in the field work and in making the determinations.

Figure 2. Outline Map of the Five Smaller New England States.
(Triangles) Waters which were tested in 1945 or 1946 and found to have a pH of 7 or above and bound CO_2 content of 10 or more parts per million.
(Circles) Waters with pH less than 7 and bound CO_2 less than 9 p.p.m.
(Crosses) Cranberry water supplies with a pH less than 7 and bound CO_2 less than 9 p.p.m.

pH and Alkalinity of Water Supplies in Eastern Massachusetts, 1945.

Water	pH	Bound CO_2 p.p.m.	Date	Time	Weather
		Plymouth County			
Burgess (Center Carver)	5.4	6.5			
Blackmore Pond (South Wareham)	6.4	5.0	July 5	10:00 a.m.	Clear
Morse Swamp (West Wareham)	5.1	5.0	July 6	10:30 a.m.	Cloudy
Saw Mill Bridge (West Wareham)	5.3	5.0	July 6	10:30 a.m.	Cloudy
Bog Reservoir (Rochester)	4.3	3.5	July 6	11:15 a.m.	Cloudy
Spectacle Pond State Bog (East Wareham)	6.5	4.5	July 7		
Tihonet Brook (Wareham)	6.4	4.5	July 6		
Marys Pond (Rochester)	6.3	3.0	July 9	10:00 a.m.	Clear, warm
Tan Yard (Lakeville)	6.2	5.5	July 10	12:00 m.	Partly cloudy
Hammonds Smalley (Wareham)	5.7	4.0	July 9	10:15 a.m.	Clear
Hammonds Tobey (Warehem)	5.3	5.0	July 9	10:15 a.m.	Clear
Assawamsett Pond (West Lakeville)	6.1	3.5	July 16		Clear, rainy
Loon Pond (Lakeville)	5.5	2.0	July 16		Cloudy rain
Long Pond (Lakeville)	6.1	2.5	July 16		Cloudy, rainy
Goodhue-Woods Bog (Freetown)	5.7	5.5	July 16		
Goodhue Screenhouse Bog (Freetown)	5.8	6.0	July 16	11:00 a.m.	Cloudy
Sampsons Pond (Beach) (South Carver)	6.3	3.0	July 18	2:30 p.m.	Hot sunny
Tihonet Pond (Wareham)	6.1	3.5	July 18	2:00 p.m.	Hot sunny
Bog in Carver	4.5	1.5	July 18	3:30 p.m.	
Wenham Pond (East Carver)	6.2	5.0	July 18	4:00 p.m.	
Meadow Lee Bog (D. Bailey) (South Easton)	5.2	3.5	July 19		
Waterville Pond (East Middleboro)	5.9	4.5	July 26	10:00 a.m.	No direct sun
Waterville Reserve Reservoir (East Middleboro)	5.4	3.0	July 26		Cloudy
H. Atwood (West Carver)	5.5	3.0	July 26	10:30 a.m.	
Weweantit River (near source)	5.5	3.5	July 26		
South Pond Bog (Plymouth)	6.0	2.0	July 27	11:00 a.m.	Cloudy
Half Way Pond (Plymouth)	6.7	3.0	July 27	11:00 a.m.	Partly cloudy
White Island Pond (Plymouth-Wareham)	6.7	3.5	July 27	11:00 a.m.	Partly cloudy
F. Baileys Black Water Bog (Kingston)	5.5	2.5	Aug. 2	11:00 a.m.	Sunny
Chandler's Champion Bog (Center Carver)	5.5	3.0	Aug. 2	11:00 a.m.	Bright sun
Pine Brook (Duxbury)	6.0	3.0	Aug. 2	12:00 m.	Sunny

pH and Alkalinity of Water Supplies in Eastern Massachusetts, 1945. (Continued.)

Wate	pH	Bound CO_2 p.p.m.	Date	Time	Weather
Plymouth County — Continued					
Island Creek Bog (Arthur Jakinen)	5.4	3.0	Aug. 2	12:00 m.	Clear
Duxbury Cranberry Bog (Duxbury)	7.0	5.0	Aug. 2	1:00 p.m.	
Bog Reservoir (Kingston)	4.5	2.0	Aug. 2	2:00 p.m.	
Indian Pond (Kingston–Plympton)	4.9	0.3	Aug. 2	2:30 p.m.	
Lewis Billings Bog (Plympton)	6.3	4.0	Aug. 2	3:00 p.m.	Clear
Round Pond (near Island Pond) (South Plymouth)	5.5	2.5	Aug. 6		
Island Pond (South Plymouth)	6.1	2.0	Aug. 6		
Smith-Hammond Racoon Reservoir (Carver)	5.1	2.0	Aug. 8	9:00 a.m.	
Carver Bog (Smith-Hammond) (Carver)	5.7	3.0	Aug. 8		
Barrows Brook (Kingston)	5.8	3.0	Aug. 2		Sunny
Poirer Bog (on Middleboro Road)	5.9	4.5	Aug. 11	10:30 a.m.	Clear, warm
Kelley Bog (on 28) (South Middleboro)	5.4	2.0	Aug. 11		Clear, warm
Weweantit River (at Tremont)	5.9	4.0	Aug. 11	11:00 a.m.	Clear, warm
Agawam River (at East Wareham)	6.5	3.0	Aug. 11	11:00 a.m.	Clear, warm
Flax (or Union) Pond (East Wareham)	6.8	4.0	Aug. 15	8:00 a.m.	
Dicks Pond (East Wareham)	5.9	4.5	Aug. 15	8:00 a.m.	
U. C. C. C. Co. Bog (Plympton)	6.3	2.0	Aug. 15	9:30 a.m.	Fair
H. F. Whiting's Reservoir (Plympton)	6.5	4.0	Aug. 15	10:30 a.m.	Clear
Monponsett Pond (Halifax)	6.3	2.0	Aug. 15	11:00 a.m.	Clear
Joe Kelley's Home Bog (East Wareham)	5.1	2.5	Aug. 28	9:30 a.m.	Clear
U. C. C. C. Co. Columbia Bog (Bryantville)	6.3	2.5	Aug. 15	11:00 a.m.	Clear
Indian Trail Cranberry Bog (Miss E. Stillman, Hanson)	6.3	2.5	Aug. 15	11:00 a.m.	Clear
U. C. C. C. Co. Burrage Bog (Halifax)	6.1	2.0	Aug. 15	11:15 a.m.	Clear
U. C. C. C. Co. Halifax Bog (Halifax)	5.5	2.5	Aug. 15	11:30 a.m.	Clear
U. C. C. C. Co. Mayflower Grove (Bryantville)	6.9	2.5	Aug. 15	12:00 m.	Clear, sunny
A. D. M. Pierceville Bog (Rochester)	6.3	3.0	Aug. 16		
Beatons Eldredge Bog (Rochester)	6.1	2.0	Aug. 16		Clear
Federal Cranberry Company (South Carver)	6.3	2.0	Aug. 16		
Dunham Pond (South Carver)	6.5	1.5	Aug. 16		

pH and Alkalinity of Water Supplies in Eastern Massachusetts, 1945. (Continued.)

Water	pH	Bound CO_2 p.p.m.	Date	Time	Weather
Plymouth County—Continued					
East Head (South Carver)	6.1	3.0	Aug. 16	11:00 a.m.	Clear
Frog Foot Stream (Wareham)	6.0	2.5	Aug. 16	12:30 p.m.	Clear
Barnstable County					
South Yarmouth	6.4	5.0	July 20		
Wakeby Pond (Wakeby)	6.6	6.5	July 12	9:30 a.m.	Clear, cool
Mashpee Brook (Head) (Mashpee)	7.2	4.5	July 12	10:30 a.m.	Clear
Lovells Pond (Santuit)	6.6	4.0	July 12	11:00 a.m.	
Santuit Brook (by Highway 130)	6.3	5.5	July 12	11:30 a.m.	Clear
Arthurs Pond (Brewster)	6.1	5.0	July 13	10:30 a.m.	Clear
Robinson Cranberry Company (Brewster)	6.1	6.0	July 13	11:00 a.m.	
Ministers Pond (East Harwich)	5.8	3.5	July 13	1:00 p.m.	
Long Pond (Harwich)	6.1	3.0	July 13	3:00 p.m.	
Shady Pond (North Harwich)	6.3	2.5	July 13	4:30 p.m.	
Fred S. Jenkins (West Barnstable)	5.1	2.0		9:30 a.m.	Partly cloudy
Wequoquet Lake or 9-mile Pond (Centerville) East side	7.1	3.0		10:00 a.m.	Partly cloudy
West side	6.7	2.5	Aug. 10	10:00 a.m.	Clear, sunny
Lower Plash Pond (Dennisport)	5.5	4.5	July 20	2:30 p.m.	Partly cloudy
Mashpee Brook (by Fuller Hammond Bog) (Mashpee)	6.5	5.0	July 26	10:30 a.m.	Cloudy
Mill Pond (Marstons Mills)	6.5	6.0	Aug. 10	10:30 a.m.	Clear
Clear Lake (North of Marstons Mills)	7.5	9.5	Aug. 10		
Mystic Lake (by Crocker Bog) (by Pondsville, Marstons Mills)	6.9	5.0	Aug. 10	11:30 a.m.	Clear
Pondsville Pond (north of road) (Marstons Mills)	4.9	1.0	Aug. 10	11:30 a.m.	Clear
Lawrence Pond (Forestdale)	6.2	3.0	Aug. 10	12:00 m.	Clear
Long Pond (Sandwich)	6.7	2.0	Aug. 14		
Percival Pond (South Sandwich)	6.7	1.5	Aug. 14	10:30 a.m.	Clear
Triangle Pond (Sandwich)	6.6	1.5	Aug. 14	11:00 a.m.	
Peters Pond (north end) (Forestdale)	6.7	3.0	Aug. 14	9:00 a.m.	Hazy

pH and Alkalinity of Water Supplies in Massachusetts, Outside of Plymouth and Barnstable Counties, 1945.

Water		pH	Bound CO_2 p.p.m.	Date	Time	Weather
Fuller-Hammond (Norton)		6.1	7.5	July 7		
Frank Crandon (Acushnet)		6.5	6.0	Aug. 3		
Handy's (Foxboro)		6.2	3.0	Aug. 1	12:00 m.	Cloudy
Morse's (Sharon)		6.1	4.5	Aug. 1	11:00 a.m.	Cloudy
Five Mile Pond (Wilbraham)		6.6	10.0	Aug. 7	8:00 a.m.	Cloudy
White Brook	Above Swamp	6.8	7.5	Aug. 7		
(West Brimfield)	Below Swamp	6.3	6.5	Aug. 7		
Spring (West Brimfield)		5.6	6.0	Aug. 7		
French River (North Oxford)		6.3	5.0	Aug. 7		
Water Supply (City of Marlboro)		6.7	11.0	Aug. 7		
Walden Pond (Concord)		6.7	3.0	Aug. 7	2:00 p.m.	
Lowell Cranberry Co.	Lower Reservoir	6.4	4.0	Aug. 7		
(Carlisle)	Upper Reservoir	6.5	5.0	Aug. 7		
Hart or Baptist Pond (Chelmsford)		6.5	5.0	Aug. 7	3:30 p.m.	Cloudy
Lubber Brook (Wilmington)		6.0	5.0	Aug. 7	4:00 p.m.	Cloudy
Nantucket						
Maglathlins	Big Reservoir	5.1	1.0	Aug. 11		
	Reservoir by house	5.1	1.5	Aug. 11		
Gibbs Pond		5.5	2.0	Aug. 11		
Long Pond (north end)		6.1	2.0	Aug. 11		

pH and Alkalinity of Waters in 1946

Water	pH	Bound CO_2 p.p.m.	Date
Massachusetts			
Concord River at Bedford Bridge	6.5	6.0	Aug. 16-17
Seven-mile River in East Brookfield	6.3	6.0	Aug. 16-17
Swift River near Route 9 below dam in Ware	6.4	7.5	Aug. 16-17
Flat Brook near Route 9 in Ware	6.5	6.5	Aug. 16-17
Muddy Brook at Route 9 in West Brookfield	6.3	5.5	Aug. 16-17
Brook at Beaman place and Route 9 in West Brookfield	6.5	6.0	Aug. 16-17
Brook at Bliss place in Warren	5.5	4.5	Aug. 16-17
Brook at Milford-Hopedale line on Route 140	5.5	4.5	Aug. 16-17
Weston Bog Reservoir at Milford Road, Holliston	6.0	5.5	Aug. 16-17
Phillips Brook, North Westminster	6.2	7.0	Aug. 22, noon
Brook coming from Bog in Middlesex County	6.6	17.5	Aug. 23
West Branch of Farmington River at Otis, Route 8	7.0	11.0	Aug. 29
Westfield River, Cummington, Route 9	7.2	9.5	Aug. 30

pH and Alkalinity of Waters in 1946 — Continued

Water	pH	Bound CO_2 p.p.m.	Date
Massachusetts — Continued			
Swift River on Route 9 at Swift River	7.1	11.0	Aug. 30
Crosby Brook at Swift River	7.0		Aug. 30
West Branch Mill River, Williamsburg, Route 9	7.1		Aug. 30
East Branch Mill River at Williamsburg, just above confluence	7.1	12.5	Aug. 30
Beaver Brook, Haydenville, towards Northampton, Route 9	7.2		Aug. 30
Palmer River, Rehoboth, Route 44	5.6	7.0	Aug. 30
Segreganset River at Walkers Corner, Dighton, Route 44	5.3	7.5	Aug. 30
Three Mile River, Route 44	6.3	12.0	Aug. 30
Bog in Raynham, Route 44	4.6	4.5	Aug. 30
Connecticut			
Great Brook on Route 84, Groton	6.4	7.5	Aug. 28
Outlet, Samson Bog, Groton	6.0		Aug. 28
Stream, C. W. Brown's bog, Ledyard	6.0		Aug. 28
Bartlett Brook on Route 2, Lebanon	6.0	8.0	Aug. 28
Meadow Brook on Route 16, Colchester	6.2	8.5	Aug. 28
Salmon River on Route 16, East Hampton	6.8	9.0	Aug. 28
Five-Mile Brook on Route 15, New Haven	7.1	35.0	Aug. 29
Outlet, Killingworth Bog, Evarts & Jannsen	5.9	6.5	Aug. 29
Bantam River on Route 63, Litchfield	7.6	20.5	Aug. 29
Brook at Newbury's Corners, Route 25, Torrington	7.2	21.0	Aug. 29
Still River, Route 8, Winchester	7.2	16.0	Aug. 29
Sandy River, Route 8. Colebrook	7.0	11.0	Aug. 29
Lewer's Brook, Route 20, Somers	6.4	7.5	Aug. 30
Crystal Lake Brook, Route 20, West Stafford	6.7	8.0	Aug. 30
Middle River, Route 20, Stafford	6.6	6.5	Aug. 30
Roaring Brook, Route 32, Willington	6.9	9.0	Aug. 30
Fenton River, Route 74, Willington	6.8	9.5	Aug. 30
Mount Hope River, Route 44, Warrenville	6.8	8.5	Aug. 30
Bigelow Brook on Route 44, near Phoenixville	6.9	8.5	Aug. 30
Mashamoquet Brook on Route 44, Abington	6.8	7.0	Aug. 30
Little River, on Route 44, Putnam	6,8	9.0	Aug. 30
Mary Brown Brook, on Route 44, East Putnam	6.6	6.0	Aug. 30
New Hampshire			
Daymond Pond Brook on Route 12, Fitzwilliam	5.5		Aug. 22 p. m.
Brandy Brook on Route 12, Troy	5.2		Aug. 22 p. m.
Beaver Brook on line between Roxbury and Keene, Route 9	6.6	7.0	
North Branch of Contoocook at Twin Bridges, Antrim, Route 9	6.3	6.0	
Same River, several miles farther east at Hillsboro, Routes 9 and 202	6.2	5.5	
Kimball Lake on Routes 9 and 202, Hopkinton	6.4	7.5	
Elm Brook, west of Concord on Routes 9 and 202 (Brook runs through field)	6.6	8.5	
Suncook River, on Route 4, Epsom	6.3	8.0	
Northwood Lake, on Route 4, Northwood	6.1	5.5	
North Riner Lake, on Routes 4 and 202, Barrington	6.5	5.5	
Isinglass River, on Route 202, Barrington	6.3	4.5	
Rhode Island			
Wyeth (Green) Main Reservoir	5.7	3.5	Aug. 12
Wyeth (Green) Wickford Reservoir	5.7	4.5	Aug. 12
Wyeth (Green) Little Grass Reservoir	5.6	3.5	Aug. 12
Tiogue Lake, on Route 3, Coventry	6.4	6.0	Aug. 28
Wood River, on Route 3, Hopkinton	6.1	5.5	Aug. 28
Pawcatuck River, on Route 84, State Line	6.3	7.0	Aug. 28
Waterman Reservoir, Greenville, on Route 44 between Harmony and Smithfield	6.7	6.0	Aug. 30

4 9 ?

ADDENDUM TO "CRANBERRY ICE"[1]

By Henry J. Franklin,
Research Professor in charge of the Cranberry Station

Winterkilling

Cranberry winterkilling in Massachusetts in the winter of 1943-44 was the most extensive and severe in the memory of the oldest growers, causing an estimated reduction in the 1944 crop of at least 30 percent. The vines on many bogs were all killed down to the ground. The extent of this damage was not surprising, for a much larger cranberry acreage than usual failed to be flooded when it should have been because of the lack of enough rain to build up water supplies in the fall and early winter.

The severe frost of May 18-19, which cut off all the new growth that had developed on the winterkilled bogs up to that time, and the severe drouth that prevailed most of the summer were very unfavorable to good recovery of the injured vines. In spite of this, the new vine growth by fall was satisfactory on nearly all of the damaged areas.

Some growers tried to help the recovery of their bogs by mowing off the dead vines, resanding, or fertilizing, but there is little evidence that any of these measures was definitely beneficial. They generally resulted in an undesirable overgrowth of runners.

Frost

The frost on the night of May 18-19, 1944, considering the date of its occurrence and the minimum bog temperatures reached (from 14° to 25°F.), was one of the most severe in Massachusetts cranberry history. The estimated damage to the crop was 18 percent of the potential crop, had there been no winterkilling and no harmful frost. It doubtless would have taken fully half the crop if it had not been preceded by the winter injury. It killed all the season's new cranberry growth on many bogs and caused the old cranberry foliage on a few small areas to turn dark again as in winter. Further evidence of its severity is the fact that in some places it killed oaks, some of them 20 feet tall, so completely that they showed no recovery afterward.

The extensive cranberry injury from this frost was due partly to lack of water for flooding and partly to freezing of the vines over the frost flood on some of the colder bogs. Also, since most of the bogs were very dry and absorbed much more water than usual, many with enough water did not get flooded as soon as they should have.

This was essentially a "black frost" or "freeze", as little or no frost formed on most bogs. The wind was dusty near the ground in many places and blew strongly all day and considerably during the night but calmed toward sunrise. There was no ground fog and the sky was very clear during the night.

Preceding conditions were probably on the whole more favorable to the occurrence of this frost than to that of any previous one in Massachusetts cranberry history. The mean annual temperature of 1943 in northern[2] New England had been 1.2 degrees and in southern[2] New England 0.6 degrees below normal. The

[1]Mass. Agr. Expt. Sta. Bul. 402, 1943, pp. 25-67. (Copies in the Middleboro library).

[2]Northern New England: Maine, New Hampshire, and Vermont; Southern New England: Massachusetts, Rhode Island, and Connecticut (as defined in Climatological Data).

average of the mean temperatures at New Bedford, Taunton, Middleboro, Plymouth, East Wareham, and Hyannis in the 10-day period preceding the day of the frost was 8.53°F. higher than is normal for the period; and the average of the rainfall at these places during the 24 days before the frost was only .05 of an inch.

FORMULAS FOR RECKONING MINIMUM BOG TEMPERATURES

Further studies have produced additional material which is included in the revision of the formulas for use in reckoning minimum bog temperatures with the 7 p.m. weather data. The following should replace page 41 of Bulletin 402.

Formulas for Reckoning Minimum Bog Temperatures at 7 p.m. (Eastern Standard Time)

Let: T be the minimum bog temperature to be computed,
DG the shelter dry-bulb temperature at East Gloucester,
DW the shelter dry-bulb temperature at Worcester,
DEW the shelter dry-bulb temperature at East Wareham,
WW the shelter wet-bulb temperature at Worcester,
GP the dew point at East Gloucester,
EWP the dew point at East Wareham,
WP the dew point at Worcester,
X the average between the wet-bulb temperatures at East Wareham and Worcester, and
M the lowest of the dew points at Carlisle, East Gloucester, East Wareham, and Worcester.

Then:

In April (last third)........... $T = \frac{DG + 1.5\ M + 30}{6}$ or $\frac{X - 2}{2}$ or $.29\ (WW + WP)$

In May (1st half)............... $T = \frac{DG + 1.5\ M + 45}{6}$ or $\frac{X + 3}{2}$ or $.30\ (WW + WP)$

In May (last half)............. $T = \frac{DG + 1.5\ M + 57}{6}$ or $\frac{X + 7}{2}$ or $.31\ (WW + WP)$

In June................................ $T = \frac{DG + 1.5\ M + 64}{6}$ or $\frac{X + 9}{2}$ or $\frac{DEW + EWP + 75}{6}$

In late August and September (1st half)...... $T = \frac{DG + 1.5\ M + 54}{6}$ or $\frac{X + 7}{2}$ or $\frac{EWP + 8}{2}$

In September (last half) $T = \frac{DW + GP + 11}{4}$ or $\frac{X + 5}{2}$ or $\frac{EWP + 6}{2}$

In October (1st half)......... $T = \frac{DW + GP + 7}{4}$ or $\frac{X + 3}{2}$ or $\frac{EWP + 4}{2}$

In October (last half)........ $T = \frac{DW + GP + 5}{4}$ or $\frac{X + 2}{2}$ or $\frac{EWP + 3}{2}$

Add 2 degrees to the computed temperature when the 7 p.m. wind velocity at Worcester is over 7 miles an hour and the barometer does not rise more than .07 of an inch from 4 to 8 p.m.; but subtract 1 degree if the wind velocity at Worcester is not over 9 miles an hour and the barometer rises more than .08 of an inch from 4 to 8 p.m. If, as sometimes occurs in April and October, the barometer rises .15 of an inch or more from 4 to 8 p.m. with the wind velocity at Worcester not over 7 miles an hour at 7 p.m., subtract 2 degrees.

NOTES:-In predicting, it is best to average the results of the different formulas in each period.

If at any time in the frost seasons the 7 p.m. dew point at Worcester, Carlisle, Milton, or Gloucester is below 20 degrees, the chances are 5 to 1 that the minimum temperature will also fall below 20 degrees on some bogs in the cranberry district.

Temperatures on cold clear nights on most of the Massachusetts cranberry bogs fall at an average rate of about one degree an hour till sunrise after it has been calm for two hours.

A clear sky in the evening at all or most of the observing stations is good evidence that it will be as cold as other data indicate. A damaging frost rarely occurs when it is entirely cloudy at all inland stations and partly or entirely cloudy at East Wareham at 7 p.m., unless the barometer rises sharply from 4 to 8 p.m.

Wind direction is generally of little value in frost predicting on Cape Cod; but, if the wind is from the north or northwest at East Wareham at both noon and 7 p.m. (E.S.T.), it is especially likely to be as cold as other conditions indicate it will be.* The barometer usually rises sharply in the evening with this wind condition. A west wind in the evening is probably safer than any other.

*Weather forecasting in the United States. W. B. No. 583, 1916, pp. 199, 201, and 208. The more severe frosts on Nantucket usually come with a dying easterly wind.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 434 JUNE ,1946

Mushrooms
For Food and Flavor

By William B. Esselen, Jr., and Carl R. Fellers

Laboratory studies prove that mushrooms, besides serving as a flavor or garnish for other foods, are a nutritious food in themselves.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MUSHROOMS — FOR FOOD AND FLAVOR

By William B. Esselen, Jr., Assistant Research Professor and Carl R. Fellers, Head of the Department of Food Technology

This bulletin represents a summary of work carried on in this laboratory during the past five years for the purpose of determining the food value of the commercially grown mushroom, *Agaricus campestris*. Up to the time this investigation was initiated but little information was available on the nutritive value of this food. The results obtained show that when we eat mushrooms for their pleasing flavor and as a garnish for other dishes, we are at the same time helping ourselves to a nutritious food, particularly rich in the B vitamins.

Mushroom Growing and Use

For centuries mushrooms have been highly esteemed as a food. The Pharaohs of Egypt knew and prized the mushroom and believed that it grew up over night, magically. In fact, during the reign of the Ceasars in Rome there was a law concerning the grading and selling of mushrooms — a forerunner of our present food laws. Mushrooms were thought to provide warriors with unusual strength in battle. The Romans called them "food of the gods" and they were usually served only on festive occasions. The fine qualities of mushrooms were eulogized by the poet Horace before the Christian era.

Up to the 17th century the use of mushrooms was confined to the wild types, found growing in meadows and pastures. During the reign of Louis XIV mushroom culture was introduced in France. Parisian market gardeners made every effort to learn the secrets of successful mushroom culture. In 1749 caves and cellars were employed as locations for mushroom beds and the results showed such an improvement over former methods that a new impetus was given to mushroom culture. Thus a large mushroom industry was developed in France that amounted to as much as $2,000,000 annually. Dried and canned mushrooms were imported into this country in large amounts from about 1850 up to World War I.

A little over fifty years ago the art of mushroom culture was introduced to American growers and since then marked improvements have been made over former methods. About 1918 the development of commercial methods for the production of pure culture mushroom spawn did much to stimulate commercial mushroom growing.

In the United States mushrooms are usually grown commercially in especially constructed growing houses or buildings that are long and windowless and protected against severe temperature changes. The mushrooms are grown under conditions of controlled temperature and humidity in beds of rich humus. The humus of the beds is inoculated with pure cultures of the mushroom spawn. It takes about six weeks from the time the beds are inoculated before the mushrooms show up in definite "breaks". The mushrooms are usually gathered daily when they are of medium size and before the veil (the thin membrane under the cap stretching from the edge of the cap to the stem covering the gills) breaks.

After being picked the mushrooms are sorted and graded in packing rooms, according to Rettew, Gahm and Divine (20). They are usually sorted into four grades and may be graded as follows:

[1]Acknowledgement is due the Cultivated Mushroom Institute of America, New York, N. Y., for their interest and assistance in the preparation of this bulletin: and to Mr. G. R. Rettew of the Chester County Mushroom Laboratories, West Chester, Pa., for permission to use pictures shown in Plates 3 and 6.

First Grade or "Specials" — good quality mushrooms of the larger size. They must be tight (the veil not broken) and free from blemishes.

Second Grade or "Fancies" — medium sized mushrooms. Must be tight and free from blemishes.

Third Grade or "Buttons" — smaller mushrooms that are tight and free from blemishes.

Fourth Grade or "Spots and Opens" — off-quality or second-rate mushrooms including open, spotted, or blemished mushrooms of all sizes.

Mushrooms should be brought to the consumer as fresh as possible, preferably the same day or the day after they are picked. Deterioration in fresh mushrooms can be retarded by holding them under dry storage conditions between 36° and 40°F.

During the past 15 years the American mushroom industry has expanded rapidly until it is now one of the important food industries. In 1940 alone, over 40 million pounds of fresh mushrooms were produced in the United States. Pennsylvania produced approximately 55 percent of the total crop, while the remainder was grown in areas near Boston, Chicago, Cleveland, Kansas City, San Francisco, and along the Hudson River. The mushroom industry is also an important food industry in Canada. In addition to the fresh market, large quantities of mushrooms are canned as such or in soups. The canned pack of mushrooms in 1943 amounted to 4C0,000 cases.

Nutritive Value of Mushrooms

Until recently mushrooms were eaten almost entirely for their condimental value. The incorporation of mushrooms into gravies, sauces, soups, and other dishes added zest and flavor. However, the results of recent investigations would tend to place mushrooms in the average American diet not only on the basis of their already recognized flavor-enhancing properties but also because of certain definite food values the mushroom was found to possess.

A survey of the literature on the composition and nutritive properties of mushrooms presents a rather confused picture. This is due in part to the fact that many different types of mushrooms are reported under a common heading with little or no regard for variety. The nutritive properties and composition of different varieties of mushrooms do vary, often to a marked extent. The investigations carried out at this laboratory were concerned entirely with the commercially cultivated mushroom, *Agaricus campestris*, and not with any of the "wild" or foreign mushrooms.

Proximate Composition

The composition of fresh mushrooms is similar to that of many fresh vegetables and fruits as the following proximate analysis of *Agaricus campestris*, given by Anderson and Fellers (1), indicates:

Water	89.50 percent
Protein (N x 6.25)	3.94
Fat (ether extract)	0.19
Extract matter	4.01
Fiber	1.09
Ash	1.26

An analysis of the ash of fresh mushrooms gave the following results:

Calcium	0.0024 percent
Phosphorus	0.15
Potassium	0.50
Total iron	19.50 p.p.m.
Available iron	5.95 p.p.m.
Copper	1.35 p.p.m.

Protein

The protein present in mushrooms has long been a subject of much discussion· The controversy has ranged from the extreme of calling mushrooms the "vegetable beefsteak" to the opposite extreme when Chatfield and Adams (4) assigned a value of zero for the percentage of protein in mushrooms.

Saltet (21) employed human beings to test the digestibility of mushroom nitrogen and reported that 69 percent of the total nitrogen of *Agaricus campestris* existed in the form of protein. He concluded further that 50 percent of the total nitrogen was in the form of a digestible protein. Mendel (14) and Konig (12) indicated that the protein content of mushrooms was approximately 5 percent, and expressed the opinion that mushrooms would be a good source of protein.

Skinner, Peterson and Steenbock (23) investigated the digestibility of the protein of *Agaricus campestris* with albino rats and found it to be 71 percent, in fairly close agreement with the findings of Saltet (21). However, these data were not in agreement with those of Morner (16) who reported that only 50 percent of the total nitrogen of mushrooms was capable of being digested in vitro.

Recently Fitzpatrick, Esselen and Weir (7) have reported the results of an extensive investigation on the composition and nutritive value of mushroom (*Agaricus campestris*) protein. Several rat-feeding experiments were carried out according to the paired-feeding method of Mitchell and Beadles (15). Assigning an arbitrary value of 100 to purified casein, the relative quality of mushroom protein was 32.6 when they were fed at an 8 percent protein level. When the level of protein was increased to 15 percent, the relative quality of mushroom protein increased to 56.6 percent. The data indicated that the mushroom protein contained all of the amino acids essential for the rat. The fact that the rats on the mushroom diets did not gain as much weight as those on the control diet indicated that the essential amino acids, although present, were probably in low concentrations in the case of certain individual acids. As is discussed later the tryptophane content of mushroom protein was found to be particularly low.

Studies on the mushroom protein itself showed that total nitrogen content of *Agaricus campestris* was approximately 0.5 percent of which 63 percent was in the form of protein. Purified mushroom protein was found to have a nitrogen content of 11.79 percent.

By means of qualitative chemical tests the mushroom protein was found to contain the following essential amino acids: phenylalamine, histidine, leucine, lysine, arginine, tryptophane, and threonine. The essential amino acids which failed to give positive tests were: valine, isoleucine, and methionine. However, that these three essential amino acids were also present was borne out by the animal feeding trials.

The microbiological technique was employed in making a quantitative determination of certain of the amino acids in mushrooms. The dried mushrooms were hydrolyzed, prior to assay, in a manner similar to that described by Schweigert, McIntire, Elvehjem, and Strong (22). The microbiological method of

Hutchings and Peterson (9) was followed, using *Lactobacillus arabinosus* 17-5 as the test organism. The amino acid content of mushrooms on a fresh weight basis as determined above was found to be as follows:

Amino acid	Mg. per 100 grams fresh weight basis
l-arginine	203.17
dl-isoleucine	458.85
l-leucine	242.02
dl-methionine	144.37
l-tryptophane	5.07
dl-valine	326.02

Although the results of the animal feeding tests indicate the presence of all of the essential amino acids in mushroom protein, taken by themselves they may be open to question. However, the chemical and microbiological tests bear out the fact that these amino acids are present, even though in small amounts in some cases. Positive chemical tests were not obtained for valine, isoleucine, and methionine but their presence was demonstrated by the microbiological tests.

It was concluded that fresh mushrooms (*Agaricus campestris*) contain approximately 2.67 percent of protein. While they are not comparable with such foods as meat and fish as a source of protein, they do compare favorably with many fresh vegetables in this respect.

Carbohydrate

But little information has been found on the carbohydrate content of mushrooms (*Agaricus campestris*). Inagaki (10) found mannitol present in wild mushrooms (*Agaricus campestris*) in concentrations of 0.93 percent of the dry weight of the cap and 0.17 percent of the stipe. Nickerson and Rettew (17) isolated and identified mannitol from the same variety. They reported an average of 5.5 percent of the dry weight of the immature button stage and 9.9 percent of the dry weight of the mature open stage recovered as mannitol. Other carbohydrates and poly-alcohols such as trehalose, glucose, glycogen, sorbitol, pentoses, and cellulose have been reported present in other varieties.

McConnell and Esselen (13) have reported on the carbohydrate content of mushrooms (*Agaricus campestris*) grown in Massachusetts by a commercial grower. Good quality, large, fresh mushrooms in the closed stage were selected, sliced into quarter-inch pieces, and dried. The dried product was ground in a Wiley mill to pass through a 60-mesh screen. The A. O. A. C. (2) method for analysis of sugars in plants was followed. Qualitative tests were made for the presence of the various carbohydrates. By means of these tests many carbohydrates were found to be absent in the mushroom. Quantitative tests were then made for those carbohydrates whose presence might have accounted for the positive qualitative tests. The results are shown in table 1.

The reported mannitol content is, in general, in agreement with the amount found in this same variety by Nickerson and Rettew (17) but is much higher than that reported by Inagaki (10) for wild mushrooms. The carbohydrates present in greatest quantities were mannitol, hemicellulose, glycogen, and reducing sugars, which together accounted for 2.73 percent of the weight of the fresh mushrooms.

Table 1.—Carbohydrates and Poly-alcohols in Mushrooms (Agaricus Campestris).

Substance	Fresh Weight Basis* Percent	Moisture-free Basis Percent
Mannitol	0.95	8.56
Reducing sugars (as dextrose)	0.28	2.48
Pentoses, methyl pentoses, hexuronic acids	0.04	0.32
Glycogen	0.59	5.34
Crude hemicellulose	0.91	8.18
Total	2.77	24.88

*88.90 percent water.

Vitamins

Until quite recently little investigational work has been reported on the vitamin content of mushrooms. Orton, McCollum and Simmonds (18) found *Agaricus campestris* to be a good source of water soluble vitamin B. Hara (8) and Quackenbush, Peterson, and Steenbock (19) also reported mushrooms to be a good source of the B vitamins.

Cheldelin and Williams (5) reported the B vitamin content of fresh mushrooms purchased on the market, as gamma per gram on a fresh weight basis, to be thiamin, 12.5; riboflavin, 3.3; nicotinic acid, 69; pantothenic acid, 17; pyridoxin, 0.45; biotin, 0.16; inositol, 170; and folic acid, 0.98.

The vitamin content of fresh, commercially grown *Agaricus campestris* has been determined in this laboratory and reported by Anderson and Fellers (1), Brunell, Esselen and Griffiths (3), and Filios and Esselen (6) as shown in table 2.

It is evident that cultivated mushrooms are one of the best plant sources of several members of the vitamin B complex. They contain an appreciable amount of thiamin and are an excellent source of riboflavin and micotinic acid as well as a good source of pantothenic acid.

Table 2.—Vitamin Content of Fresh Mushrooms.

Vitamin	Mg. per 100 g. Fresh Weight Basis
Vitamin A	None*
Vitamin D	None*
Vitamin E	None
Vitamin K	++
Ascorbic Acid	8.60
Thiamin	0.12
Riboflavin	0.52
Nicotinic Acid	5.85
Pantothenic Acid	2.38
Biotin	0.018

*International units.

Plate 1.

A "break" or "flush" of cultivated mushrooms in bed of specially prepared soil in dark growing house.
It takes about six weeks from the time the beds are inoculated for the mushrooms to show up in definite "breaks".

Plate 2
Specially constructed growing houses in which cultivated mushrooms are grown scientifically under controlled temperature conditions.

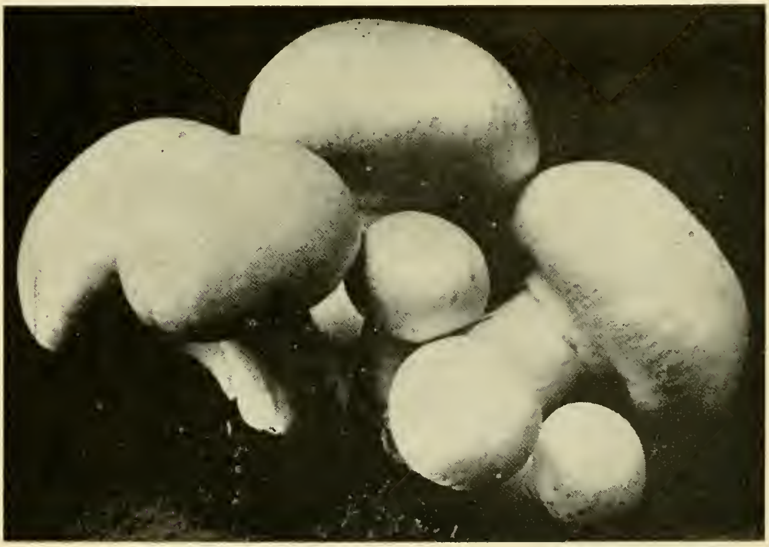

Plate 3
A cluster of cultivated mushrooms.

Plate 4.
Picking Mushrooms.
Mushrooms grow in the dark; note miner's lamp in the cap of the picker.

Plate 5.
Packing fresh mushrooms for markel.
The mushrooms are placed in the basket by hand as they are sorted.

Plate 6.
Basket of fresh mushrooms ready for market.

Plate 7.
Mushrooms are thoroughly washed before they are canned.

Plate 8.
Small mushrooms are canned whole as Buttons. Girls fill and weigh the cans before they are sealed.
Large mushrooms are canned as Sliced, and open mushrooms as Stems and Pieces.

Plale 9.
The canned mushrooms are processed or "sterilized" in large retorts at 10 or 15 pounds steam pressure.

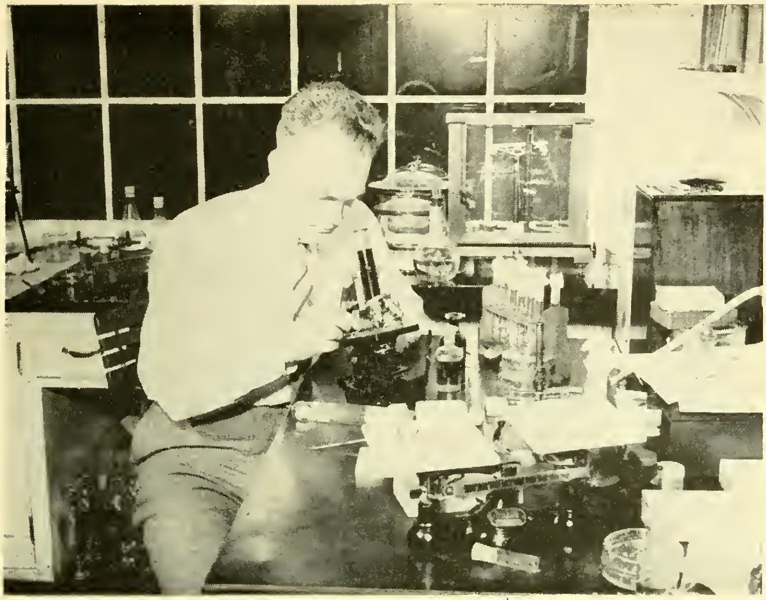

Plate 10.

Mushrooms begin their lives in the laboratory, where trained scientists select the choicest mushrooms and place sections in sterile glass tubes. These tubes, plugged with cotton, are placed in an incubator and held at constant temperature and humidity for 72 hours. During this time spores drop from the gills of the mushroom and produce a spore print within the glass tube.

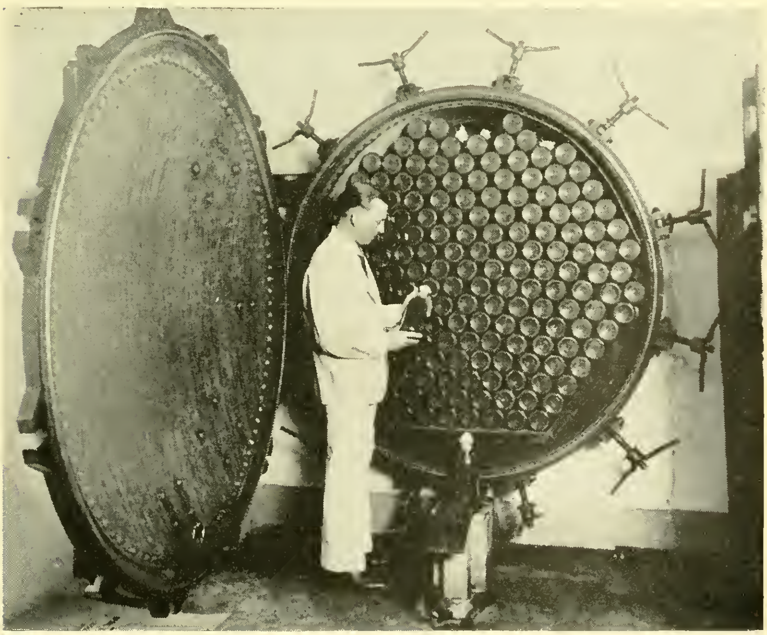

Plate 11.

Jars of nutrient medium for the pure culture of mushroom spawn are sterilized in large steam retorts.

Plate 12.

Technician making transfer of spawn from master flask to large culture bottles. The spawn culture is inoculated into growing beds where it spreads or "runs" through the beds until in two or three weeks it appears as fine white threads on the surface.

Effect of Cooking on Vitamin Content of Fresh Mushrooms

Filios and Esselen (6) found that in general the B vitamins are well retained when fresh mushrooms are cooked. Fresh mushrooms were cooked by five different methods: (1) boiled whole, (2) boiled sliced, (3) broiled whole, (4) broiled sliced, and (5) sauteed. The results are summarized in table 3. The vitamin content of the cooking liquor, as well as that of the cooked solids was determined, in order to calculate the total vitamin retention.

There was little loss of riboflavin in most cases. The broiled sliced mushrooms suffered most, retaining but 65.8 percent of the riboflavin. The nicotinic acid losses were in approximately the same range, with 77.6 to 91.3 percent retained during cooking. The percentage retention of pantothenic acid ranged from 74.6 to 100 percent. The biotin values obtained were somewhat lower, ranging from 42.2 to 62.8 percent retention. The relatively low retention of biotin is probably apparent rather than actual, owing to the difficulty in extracting biotin from the samples for assay. It was concluded that in general, riboflavin, nicotinic acid, pantothenic acid, and biotin are well retained when fresh mushrooms are cooked by various methods.

Table 3.—Effect of Cooking Methods on Retention of B Vitamins in Fresh Mushrooms.

Cooking Method	Retention, Percent			
	Riboflavin	Nicotinic Acid	Pantothenic Acid	Biotin
Boiled whole	100.0	89.6	100.0	62.8
Boiled sliced	84.5	90.3	89.4	42.2
Broiled whole	89.5	90.2	86.4	55.5
Broiled sliced	65.8	91.3	74.6	41.8
Sauteed	94.3	77.6	76.6	43.2

Effect of Canning on Vitamin Content of Mushrooms

Investigations on the stability of B vitamins in mushrooms during canning and storage and on the B vitamin content of commercially canned mushrooms have been reported by Filios and Esselen (6).

Fresh mushrooms were secured from a nearby grower and experimental packs were prepared in the laboratory to study the vitamin stability during canning and storage. The riboflavin, nicotinic acid, pantothenic acid, and biotin content of the mushrooms was determined by microbiological methods. Determinations were made on the fresh mushroom, the blanched mushroom, and the canned product immediately after canning and at intervals of 2, 6, and 12 months during storage at room temperature (70°-80°F.)

The mushrooms were washed and trimmed, blanched for seven minutes in boiling water, packed into No. 2 size (307 x 409) tin cans with a standardized fill-in weight, and brined. The cans were then sealed and processed in a retort for 25 minutes at 240°F. (116°C.). A summary of the data is presented in table 4. There was a small loss of riboflavin, nicotinic acid, panthothenic acid, and biotin during the canning process and a further loss during storage for twelve months. Despite these losses canned mushrooms are excellent sources of riboflavin, nicotinic acid, pantothenic acid, and biotin, even after storage for one year.

Table 4.—Retention of B Vitamins in Canned Mushrooms During Canning and Storage at Room Temperature.

Storage Time Months	Riboflavin		Nicotinic Acid		Pantothenic Acid		Biotin	
	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent	Mg. per 100 g	Retention Percent	Mg. per 100 g.	Retention Percent
Fresh...	0.348	...	3.65	...	1.214	...	0.0061	....
Blanched.	.342	98.4	2.78	76.2	0.99	80.0	.0068	111.5
1......	.318	91.5	2.66	73.0	0.58	46.8	.0050	82.0
2......	.297	85.3	2.96	78.4	1.06	85.5	.0051	83.6
6......	.240	69.0	2.48	68.0	0.87	70.1	.0048	78.7
12......	.225	64.7	2.11	57.8	0.75	60.5	.0048	78.7

Table 5.—The B Vitamin Content of Commercially Canned Mushrooms.

Type and Sample Number	Riboflavin Mg./100 g.*	Nicotinic Acid Mg./100 g.*	Calcium Pantothenate Mg./100 g.*	Biotin Mg./100 g.*
Buttons				
1	0.229	1.84	0.917	0.0067
4	.334	2.61	1.042	.0058
7	.352	2.69	0.827	.0070
10	.256	1.50	0.867	0.043
13	.183	2.08	1.179	.0062
16	.318	2.16	1.258	.0082
Average	.278	2.04	1.015	.0064
Sliced				
2	.263	1.96	0.914	.0041
5	.313	2.53	1.000	.0068
8	.279	1.63	0.853	.0077
11	.231	1.97	0.913	.0086
14	.191	1.56	0.877	.0071
17	.319	2.22	1.126	.0100
Average	.266	1.98	0.947	.0074
Stems and Pieces				
3	.227	1.69	0.697	.0033
6	.221	1.79	0.506	.0046
9	.213	1.00	0.450	.0076
12	.210	1.57	0.716	.0077
15	.160	0.98	0.312	.0063
18	.181	1.30	0.510	.0062
Average	.202	1.39	0.532	.0060

*Total can contents.

In order to obtain information on commercial canned mushrooms, samples were obtained from six different commercial canners. Each canner supplied samples of (1) button mushrooms, (2) sliced mushrooms, and (3) stems and pieces in 5.5 ounce cans. Three to six months after they were canned the mushrooms were analyzed for riboflavin, nicotinic acid, pantothenic acid, and biotin. For each vitamin determination a composite sample from six cans was taken. The results obtained, as shown in table 5, confirm the laboratory tests in showing that commercially canned mushrooms are excellent sources of the four vitamins under consideration.

The canned button and sliced mushrooms were a better source of the B vitamins studied than the canned mushroom stems and pieces. It is of interest that the vitamin content of commercially canned mushrooms obtained from different canners was more uniform than the vitamin content of many other kinds of canned foods as reported by Thompson, Cunningham and Snell (24) and Ives, Wagner, Elvehjem and Strong (11). This is undoubtedly attributable, at least in part, to the uniform cultural conditions employed in raising mushrooms.

Effect of Drying and Freezing on Vitamin Content of Mushrooms

In an investigation on the dehydration and freezing of mushrooms Brunell, Esselen, and Griffiths (3) obtained data on the stability of thiamin, riboflavin, and nicotinic acid during these operations. Their data are summarized in table 6.

During steam blanching and dehydration, the loss of thiamin was approximately 18 percent and that of nicotinic acid about 12 percent. It is probable that most of these losses occurred in the blanching process. There was little or no loss of riboflavin. All three of these vitamins were quite stable during storage for five months at room temperature (75°-80°F.).

With frozen mushrooms there was a slight loss of riboflavin and some loss of thiamin during blanching prior to freezing, but all of these vitamins were quite stable in the frozen product.

TABLE 6.—EFFECT OF DEHYDRATION AND FREEZING ON THE STABILITY OF THIAMIN, RIBOFLAVIN, AND NICOTINIC ACID IN MUSHROOMS.

Storage Time Months	Thiamin		Riboflavin		Nicotinic Acid	
	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent
Fresh:						
Moist basis	0.116	...	0.540	...	6.20	...
Dry basis	1.066	...	4.960	...	56.99	...
Dehydrated (dry basis):						
0	.882	82.7	4.900	98.7	50.10	87.9
1	.880	82.6	4.820	97.2	50.60	88.9
2	.875	82.1	5.000	100.8	49.20	86.3
3	.883	82.8	4.860	98.0	49.70	87.3
4	.878	82.4	4.930	99.4	....	...
5	.875	82.1	4.800	96.8	....	...
Frozen (moist basis):						
0	.100	86.2	.520	96.3	5.65	91.2
1	.100	86.2	.517	95.6	5.63	90.8
2	.097	83.7	.522	96.7	5.66	91.3
3	.096	82.7	.521	96.5	5.63	90.8

Summary and Conclusions

Recent work on the nutritive value of cultivated mushrooms (*Agaricus campestris*) provides evidence that would tend to place them in the average American diet not only on the basis of their already recognized flavor-enhancing properties but also because of certain definite food values the mushroom has been found to possess.

1. The mineral content of mushrooms provides an additional source of iron and copper.

2. Fresh mushrooms contain approximately 2.67 percent of protein and all of the essential amino acids, at least in small amounts. While not comparable with such foods as meat and fish as a source of protein, mushrooms do compare favorably with many fresh vegetables in protein content.

3. Mushrooms contain small amounts of carbohydrates and carbohydrate-like substances.

4. Mushrooms were found to be an excellent plant source of riboflavin and nicotinic acid and a good source of pantothenic acid. They also contain appreciable amounts of thiamin and biotin. These vitamins are well retained during cooking, and in canned, dehydrated, and frozen mushrooms.

5. Commercially canned mushrooms as purchased by the consumer were found to be excellent sources of certain of the B vitamins. The content of these vitamins was quite uniform in commercially canned mushrooms packaged by different canners.

6. Although mushrooms will probably always be eaten for their innate flavor and taste appeal, they do possess definite food values and are not merely a fancy source of good flavor with no nutritional merit.

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Publication of this Document Approved by Commission on Administration and Finance
5M (a) 8-46-19170

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 435 JULY 1946

Vegetative Propagation of White Pine

By William L. Doran

The difficulties experienced in propagating white pines from cuttings can be largely overcome. This is a description of methods used and results obtained.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

VEGETATIVE PROPAGATION OF WHITE PINE

By William L. Doran, Research Professor of Botany[1]

The white pine, *Pinus Strobus* L., is the most important timber tree in Massachusetts as indeed it has been since the early days of Plymouth Colony. It is also much planted for the protection of watersheds and reservoirs, is a good tree for windbreaks, and, being highly ornamental, is useful in horticulture or the improvement of the landscape. But, as is frequently observed by woodsmen and others, individual white pine trees in nature differ markedly, some being highly desirable from the viewpoint of forestry, others much less so or not at all.

The growth of white pine and consequently the type of tree is of course affected by the environment, e.g., light or the lack of it and the character of the soil. Silvicultural methods by which some of these differences may be corrected do not, however, come within the province of the work here described.

The present study is concerned with other differences which are apparently inherent in the tree, for, under the same or very similar environmental conditions, individual white pine trees of a given age may differ in rate of growth, height, spread, straightness, branching habit, general outline, type of foliage, and susceptibility to disease.

When pines possessing certain desirable characteristics are found in nature or result from tree breeding projects (25)[2], they may be worth perpetuating, reproducing in exact detail. For this, reproduction by seeds is undependable, since the progeny or some of the progeny may be quite unlike the parent tree in form or behavior. For example, trees grown from seeds of a white pine immune to blister-rust[3] were not themselves immune to that disease (16). But the white pine or some white pines are reproducible by cuttings; and, as with many other woody plants thus vegetatively propagated, members of the resulting clone, progeny of a single tree, may be expected to be identical or practically identical with each other and with their parent in form and behavior.

Some of the more abnormal forms of white pine, although useless as timber, are nevertheless useful in ornamental horticulture; and these too are reproducible in every character, not by seeds but vegetatively by cuttings.

A normal white pine may grow two to three feet in a season when young. The horticultural varieties *minima* Hornibr. and *umbraculifera* Carr. grow only about one to two inches a year — white pines botanically, but more like bushes or shrubs than trees (11, 21). Other interesting dwarf white pines for ornamental planting are the varieties *radiata* Hornibr., a shrub wider than high; var. *pumila* Beiss., three feet in height when three feet through; var. *pendula* Beiss., a roundish bush with pendulous or weeping branches (11); var. *prostrata* Masters, a decumbent or creeping form with trailing branches (1, 11, 21); and var. *nana* Knight, a short-leaved flat-topped bush (1, 11). The variety *fastigiata* has ascending branches forming a narrow pyramidal head (21). Other varieties differ from ordinary white pines in the color of the foliage; the leaves of var. *glauca* are light bluish green (21), those of var. *aurea* are yellowish, and those of var. *nivea* Booth and Knight are short and silvery-white beneath (1).

Certain conifers, e.g., yews, arbor-vitae, some of the junipers, and some cypresses (Chamaecyparis), are readily propagated by cuttings. As compared with

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[1]The writer gratefully acknowledges the interest and cooperation of Professor R. P. Holdsworth, Head of the Department of Forestry, in this work. Professor Holdsworth, with clonal differences in mind, furnished the material from which cuttings were made and he has planted rooted cuttings in the college forest for subsequent observation as to survival and growth.

[2]Numbers in parentheses refer to literature cited. See pages 15 and 16.

[3]Caused by the fungus *Cronartium ribicola* Fischer.

them, white pine in the present state of our knowledge is more difficult. But within recent years, especially since the coming into use of root-inducing substances such as indolebutyric acid, much has been learned about the propagation of white pine by cuttings and some of the principal results obtained by the writer and others are here brought together.

The material which follows is presented in the natural order in which a propagator would normally proceed, beginning with some consideration of the source of cuttings, ending with a description of the growth of the cuttings subsequent to rooting; and the methods employed are discussed in that order.

Effect of Age of Trees from which Cuttings are Taken

Cuttings of white pine used by the writer were obtained from trees twenty to thirty years old, a point to be considered, for age of the parent tree is an important factor affecting rooting.

Cuttings of white pine and many other kinds of trees, e.g., species of spruce, hemlock, apple, cherry, maple, oak, and ash, are known to root better if taken from young, seedling, trees rather than from mature, adult, trees (5).

White pine cuttings rooted readily if taken from young trees, three (26), four (3), or six years old (4), but they usually root much less well if taken from older trees. Thus in certain experiments in which cuttings from younger white pines rooted satisfactorily, cuttings from trees more than ten years old (26) or from trees twenty years old (3, 22) rooted poorly or not at all.

There is some evidence that cuttings of other species of pine are similarly affected by the age of the parent, for cuttings of slash pine (*P. Caribaea* Morelet) rooted much better if taken from younger rather than from older trees (19); and cuttings of Monterey pine (*P. radiata* Don) which rooted well were obtained from young trees (9, 12).

There is, however, considerable difference in rooting response of cuttings of white pine from different trees of the same age, and cuttings from older pines have been rooted. There was fairly good rooting of cuttings from trees fifteen years old (4, 22), from a tree thirty years old (6), and from one older tree (3); and there was good rooting of cuttings from some trees twenty to thirty years old in the work here described.

However, other things being equal, better results may be expected if the cuttings are taken from young trees, and it would probably be well to take cuttings from trees as early in the life of the tree as its desirable qualities become evident.

If the source of the cuttings is a tree which itself was grown from a cutting, such a tree is not necessarily to be considered young merely because it grew from a cutting which was recently rooted. A plant vegetatively propagated is only part of an older plant although in another clonal generation and it is not biologically young in the same sense that a seedling is. But some trees like some men may, perhaps, remain young longer than others, a possibility which is further considered below in connection with clonal differences.

Time of Year at which Cuttings are Taken

Late winter is a good time of year to take cuttings of white pine, assuming, of course, that the propagator has the needed greenhouse facilities.

There was good rooting of cuttings taken here in March (6) and, in work elsewhere, cuttings taken in February or in late or mid-winter rooted better than did those which were taken at other times of year (3). The dates named in the tables which follow, all between January 6 and March 22, in the years 1941 to

1945 inclusive, are the dates on which cuttings were taken and, within that range, there were no consistent differences in rooting which could be attributed to the time of taking the cuttings.

Cuttings of Mugho pine (*P. Mugo* Turra var. *Mughus* (Scop.) Zenari, var.) also rooted well after treatment if taken in February (28).

Spring and early summer seems to be a poor season. Cuttings of white pine taken here in April, May, June, and early July all died unrooted. But cuttings of white pine have been taken successfully in early August and rooted in an outdoor glass-covered propagating bed (22). Also, cuttings taken in late or mid-August from trees ten to fifteen years old rooted 50 to 60 percent in outdoor propagating beds shaded with lath or cloth (7).

Cuttings taken in winter usually root in three to five months (3, 4, 6) although, rooting unevenly as they often do, some require longer. Treated cuttings which were taken here on March 6, for example, began to root in sixteen weeks, most of the living rooted in twenty-five weeks, but the last few to root required thirty weeks. The problem meanwhile is to keep them alive for that length of time and that is further considered below.

Cuttings taken in summer require even longer to root (4). Summer cuttings planted outdoors and mulched with hay in the winter rooted fairly well by October of the second year, more than twelve months after they were taken (22). That is an objection to the taking of cuttings of white pines in summer, but of course the method requires no greenhouse.

Taking and Making the Cuttings

The branches from which cuttings were made were usually collected[4] in the morning and made up into cuttings the same day.

Cuttings used by the writer were made from the lower or lowest branches for it has been found (6, 22) that cuttings of white pine root less well if taken from the upper branches. This is perhaps partly an effect of light, for cuttings of Swiss stone pine (*P. Cembra* L.) rooted better if taken from branches which grew in the shade rather than from those which grew in the sun (4).

The rooting of cuttings taken from the north and south sides of three trees on March 22 was compared and the results are presented in Table 1.[5] Cuttings from the first tree rooted in slightly larger percentages if obtained from the north side. Cuttings from the other trees rooted less well than did cuttings from the first tree and only in the case of those from the second tree treated with Fermate–Hormodin No. 3 (equal parts by volume) did cuttings from the north side root much better than those from the south. On the whole, the superiority of cuttings from the north side of the trees was not proven although such small differences as did exist were more often in favor of that side.

Cuttings were made from small or medium-sized twigs which grew on lateral branches, for cuttings of this type have been found to root better than do those made from terminal shoots (3). Leaves, needles, were neither removed nor shortened, it having been found that such cuttings live longer than do those the needles of which have been cut back or removed completely (3, 22, 24).

Brachyblasts, the very short shoots or undeveloped branchlets, each of which in the case of white pine is the bearer of a cluster of five needles, have also been

[4]Branches were collected and brought into the laboratory by Mr. Daniel W. McCleary, Forest Supervisor at the College Forest on Mt. Toby.

[5]In this and the following tables, IB and NA are abbreviations for indolebutyric acid and a-naphthaleneacetic acid respectively. "IB 200 mg./l., 5 hr." indicates an immersion treatment with the bases of cuttings in a solution of 200 milligrams of indolebutyric acid in one liter of water for five hours. "IB 8 mg./gm." indicates a power-dip treatment using 8 milligrams of indolebutyric acid in one gram of talc or other dry carrier.

TABLE 1.—THE ROOTING OF CUTTINGS TAKEN FROM THE NORTH AND SOUTH SIDES OF TREES.

Treatment of Cuttings*	Percentage Rooting					
	First Tree		Second Tree		Third Tree	
	North	South	North	South	North	South
Check	22	9	0	0	10	0
IB 200 mg./l., 5 hr.	63	57	21	34	32	34
Hormodin No. 3	59	47	27	20	30	25
Fermate–Hormodin No. 3	—	—	44	26	—	—

*See Footnote 5, p. 4.

rooted (27) but the writer did no work with them since such rooted brachyblasts usually lived no more than a few months.

Cuttings were usually so made as to consist only of wood in its first year, wood which grew in the previous summer, with the basal cut at or slightly below the base of such wood. A bit of heel on the cuttings is desirable. Cuttings taken in winter and treated with indolebutyric acid (2 mg./gm. talc) rooted better if torn from the branch with a small heel of bark or older wood remaining attached to the cutting than if made without such a heel (4).

Cuttings made to include all of the wood of the last two growing seasons rooted less well or, as may be seen by reference to Table 2, were less responsive to treatments with root-inducing substances. Cuttings of the first tree were taken January 6, those of the second tree February 3. In both cases, cuttings detached at the base of the 1940 growth were compared with cuttings detached at the base of the 1939 growth. Untreated, these two types rooted equally poorly, but results with treatments were all in favor of using cuttings one year rather than two years old.

TABLE 2.—THE EFFECT OF AGE OF WOOD ON THE ROOTING OF CUTTINGS.

Treatment of Cuttings*	Percentage Rooting			
	First Tree		Second Tree	
	Wood of Last Two Years	Wood of Last Year	Wood of Last Two Last Years	Wood of Last Year
Check	13	13	0	0
IB 200 mg./l., 5 hr.	13	56	0	35
IB 150 mg./l., 7 hr.	10	42	0	27
IB 100 mg. and NA 50 mg./l., 4 hr.	15	40	—	—
NA 100 mg./l., 4 hr.	7	54	—	—
Hormodin No. 3	0	39	0	17

*See Footnote 5, p. 4.

Clonal Variations in Ability to Root

Clones, i.e., individual trees and their vegetatively propagated progeny, may differ in behavior as well as morphologically. The rooting ability of cuttings from different Norway spruces is known to differ markedly, one tree from another (3), and in recent work of the author, this was found to be true also of cuttings from different trees in the case of hemlock, *Tsuga canadensis* (L.) Carr.

Table 3.—The Rooting of Cuttings Taken on the Same Days From Trees Showing the Greatest or the Least Response to the Same Treatments.

Treatment of Cuttings*	Percentage Rooting	
	From Most Responsive Trees	From Least Responsive Trees
IB 200 mg./l., 5 hr.	57	6
Ditto	57	25
Ditto	33	13
Ditto	40	0
Ditto	73	20
Ditto	56	13
IB 200 mg./l., 5 hr., followed by Hormodin No. 3	50	9
IB 200 mg./l., 5 hr., followed by Hormodin No. 2	62	14
IB 8 mg./gm. talc	43	8
Hormodin No. 2	52	23
Fermate–Hormodin No. 3	54	16
NA 100 mg./l., 5 hr.	57	7

*See Footnote 5, p. 4

There was some earlier evidence (4, 22) that cuttings from certain white pines may root more readily than do cuttings from others, all of the same age. And, as may be seen by reference to Table 3, the results obtained by the writer support this conclusion, cuttings from some trees being much more responsive to a given treatment with a root-inducing substance than cuttings from other trees taken at the same time.

In Table 3 are listed the percentages of cuttings which rooted in a given series when taken from white pines which proved to be the most responsive or the least responsive to the same treatment with a root-inducing substance. Each line across the table represents a separate experiment involving cuttings taken on the same day in January, February, or March in four winters from two, three, or four trees, usually different trees. It is evident in several of the other tables that there were other trees the cuttings of which showed intermediate responses of varying degrees, some rooting nearly as well as the best, others nearly as poorly as the worst.

In this and all other tables, as also in the text, the percentages rooted were not recorded until all unrooted cuttings had died.

In general it appeared that cuttings from a tree which showed greatest response to one root-inducing treatment were most likely to respond to another. And cuttings from a tree which did not root fairly well after one standard root-inducing treatment were, on the whole, no more likely to root well after another and different treatment. This may mean merely that an effective treatment for such recalcitrants has yet to be found. Or it may mean instead that the failure of cuttings from some trees to root well is inherent in them because, for instance, certain trees become senescent earlier than others, or because of the presence rather than the absence of some substance in them, and is not a condition to be corrected by the application of hormone-like substances.

There were exceptions, but in the majority of cases where comparisons were possible the cuttings which rooted best came from co-dominant rather than from dominant trees. Also it was earlier observed (4) that cuttings which rooted best did not come from the most vigorously growing trees. This may sometimes be related to the factor of light; and, as has already been pointed out, cuttings from the lower branches, often more shaded, usually root better than do those from the upper.

Since there is usually little if any rooting of untreated cuttings from older trees and since cuttings from different trees differ in their response to root-inducing substances, the propagation of white pines by cuttings will have to be confined for the present to those individuals the cuttings of which do respond.

If, however, cuttings from a desirable individual fail to root at all well one year, they should be given another trial the next. Cuttings taken from the same tree sometimes rooted better one year than another. The converse may be true also, cuttings from the same tree sometimes rooting less well than in the previous year (4).

Treatments of Cuttings with Root-inducing Substances

Cuttings of several species of pine are known to respond to treatment with root-inducing substances. Treatments with solutions of indolebutyric acid improved the rooting of cuttings of slash pine (20), lace-bark pine, *P. Bungeana* Zucc. (13), and two varieties of mountain pine, *P. Mugo* Turra (13) (28). Rooting of cuttings of lace-bark pine and a variety of mountain pine was also improved by indolebutyric acid applied in powder-dip treatments (13). Treatment of cuttings of western yellow pine, *P. ponderosa* Laws., with indolebutyric acid gave fair results in one experiment, inconclusive results in another (18). Cuttings of slash pine responded to treatments with a solution containing indolebutyric, naphthaleneacetic and indoleacetic acids, vitamin B_1, mineral elements, and sugar (19). Cuttings of white pine treated with sucrose before treatment with indolebutyric acid lived longer (6), but in more recent work here they rooted in no larger percentages than did those treated with indolebutyric acid alone.

Results of earlier investigators with cuttings of white pine and root-inducing substances are not wholly consistent or in complete agreement and, considering the many factors involved, that is not surprising. It appears, however, that cuttings from young trees are more responsive to such treatments than are cuttings from older trees and that cuttings some of which root without treatment are more likely to be benefited by treatment than cuttings which root less well or not at all without treatment. Also, as has been pointed out, there is much difference in the effects of the same treatments on cuttings from different trees.

Treatments of cuttings of white pine with indoleacetic acid induce certain anatomical and histological changes (2), but the rooting of cuttings from older trees was not improved by indoleacetic acid applied in solution (26) or in talc (7) and no use was made of this material here, most of the treatments about to be described involving the use of indolebutyric acid instead.

Cuttings taken in January from white pines twenty to forty years old rooted only 6 percent without treatment, 26.6 percent after treatment with indolebutyric acid 100 mg./1., 24 hours, although this treatment was injurious to some other cuttings (3), perhaps because it was too long continued. Rooting of cuttings taken in March was much improved by indolebutyric acid 200 mg./l. applied for as short a time as five hours, and twenty hours was apparently too long at a concentration of even 100 mg./l. (6). Rooting of March cuttings from a young white pine was improved only half as much by a solution-immersion treatment with naphthaleneacetic acid as by indolebutyric acid similarly used and at the same dosage, a relatively low concentration, compared with that used by the present writer, and indolebutyric acid in a powder carrier was also beneficial (4). Hormodin No. 3 improved the rooting of cuttings from a young white pine (3). Rooting of cuttings taken in August was somewhat better after treatment with a dust containing naphthaleneacetic or indolebutyric acid preceded by treatment with the latter in solution; but the solution alone, a relatively low concentration, was of no benefit (22).

Cuttings were usually treated by the writer immediately after they were taken and just before they were inserted in the rooting medium. In one case cuttings taken from two trees on February 2 were first treated with indolebutyric acid 200 mg./l., 5 hr. or the same followed by Hormodin No. 3 nine weeks after their insertion in the rooting medium. There was no rooting of the cuttings which received this delayed first treatment although cuttings from these two trees treated earlier and immediately after they were taken rooted 20 or 13 percent following the solution immersion treatment, 37 or 13 percent following the combination treatment.

Powder-dip treatments were applied in the usual manner to the bases of cuttings which had been dipped in water immediately previously. Cuttings which were treated by the solution-immersion method were set loosely in beakers, not bound by elastic bands or otherwise.

As may be seen by reference to Table 4 and several of the other tables, rooting was often, although by no means always, improved by solution-immersion treatment with indolebutyric acid 200 mg./l., 5 hours. A longer period of immersion or immersion for four hours or less in a solution of this concentration gave no better results and more often they were inferior. And a dilution of 200 mg./l., 5 hr. usually gave better results than did a dilution of 100 mg./l. for a longer time.

Rooting of cuttings which responded to this treatment was also improved (see Tables 1, 2 and 4) by powder-dip treatment with Hormodin No. 3, but cuttings which failed to show much response to indolebutyric acid in solution were not much affected by Hormodin No. 3. Thus cuttings taken from three trees on February 1 failed to root without treatment and rooted only 8 to 22 percent after either indolebutyric acid 200 mg./l., 5 hr. or Hormodin No. 3. Hormodin No. 2 sometimes gave good results with cuttings from the responsive trees (see Table 3), but more often it was less effective than Hormodin No. 3.

Good results (see Tables 3 and 4) were obtained with some cuttings by treating them with a Hormodin dust following a solution-immersion treatment. But here again it was usually possible to distinguish between trees the cuttings of which were responsive to either or both and those which were responsive to neither.

Rooting was also improved in some cases (see Tables 2, 3, and 4) by naphthaleneacetic acid 100 mg./l., 5 hr., but rarely if ever did this treatment give any better results than indolebutyric acid 200 mg./l. similarly used. And combinations of naphthaleneacetic and indolebutyric acids in solution gave no better results than either alone. Results were not so good with naphthaleneacetic acid 50 mg./l. as with 100 mg./l.

Cuttings taken February 21 from one tree rooted 13 percent without treatment, 43 percent after treatment with indolebutyric acid 8 mg./gm. talc, and less well, only 20 percent, after treatment with indolebutyric acid 8 mg./gm. Fermate.[6]

Cuttings taken March 22 rooted not at all without treatment; 27 percent after treatment with indolebutyric acid 200 mg./l., 5 hr.; and no better, 25 percent, after treatment with 200 mg./l., 5 hr., followed by a powder-dip treatment with Fermate.

Fermate gave somewhat better results with some cuttings (see Tables 3 and 4) when combined with a Hormodin powder in the proportion of 1:1 by volume. Cuttings from one tree rooted well when treated with Fermate alone or preceded by solution-immersion treatment. But (see Tables 3 and 4) the results were no better than with indolebutyric acid 200 mg./l., 5 hr., used alone.

[6]An organic fungicide containing ferric dimethyl dithiocarbamate.

The following treatments, all for 5 hours, were ineffective or injurious: monobasic potassium phosphate 0.5 or 1.0 percent solution; potassium ferricyanide 0.1, 0.5 or 1.0 percent solution; manganous sulfate 0.5 or 1.0 percent solution.

TABLE 4.—RESPONSE OF CUTTINGS FROM DIFFERENT TREES TO CERTAIN ROOT-INDUCING TREATMENTS.*

Dates of Taking Cuttings, Tree Numbers, and Treatments**	Percentage Rooting		
	First Tree	Second Tree	Third Tree
January 6, Trees, 2, 3, 4:			
Check	9	0	9
IB 200 mg./l., 5 hr.	57	25	34
NA 50 mg./l., 5 hr.	25	25	25
January 12, Trees 6, 8, 11:			
Check	13	13	0
IB 200 mg./l., 5 hr.	13	53	56
NA 100 mg./l., 5 hr.	19	19	38
Hormodin No. 3	19	22	25
IB 200 mg./l., 5 hr., followed by Hormodin No. 3	6	50	50
February 2, Trees, 6, 8, 8:			
Check	0	8	0
IB 200 mg./l., 5 hr.	7	20	13
IB 200 mg./l., 5 hr., followed by Hormodin No. 1	20	27	7
IB 200 mg./l., 5 hr., followed by Hormodin No. 3	60	33	13
NA 100 mg./l., 5 hr., followed by Hormodin No. 2	24	0	13
NA 50 mg./l., 5 hr., followed by Hormodin No. 3	....	53	20
March 2, Trees 10, 11, 12:			
Check	0	7	0
IB 200 mg./l., 5 hr.	0	7	11
IB 200 mg./l., 5 hr., followed by Hormodin No. 2	0	62	14
IB 200 mg./l., 5 hr., followed by Hormodin No. 3	0	53	0
March 6, Trees 8, 11, 13:			
Check	0	10	0
IB 200 mg./l., 5 hr.	25	60	43
NA 100 mg./l., 5 hr.	20	67	7
IB 100 mg. and NA 50 mg./l., 5 hr.	32	15	20
Hormodin No. 3	34	45	56
IB 100 mg. and NA 50 mg./l., 5 hr., followed by Fermate–Hormodin No. 2	16	60	16
NA 100 mg./l., 5 hr., followed by Fermate-Hormodin No. 2	16	44	16

*Rooting medium was sand on March 6, old sand–sphagnum peat on the other dates.
**See Footnote 5, p. 4.

Rooting Media

The rooting medium used here was about five inches in depth, usually placed over a layer of crushed rock in a greenhouse bench for drainage. Mixtures designated below as sand–sphagnum peat or sand–sedge peat consisted of two parts sand and one part peat by volume.

It is commonly believed, and probably with good reason, that the rooting medium for cuttings of most plants should be fresh, clean, and relatively free from soil-infesting fungi. But cuttings of some species may root better in unsterilized sandy soil or in a rooting medium in which cuttings have been previously rooted than in one freshly prepared (5). There was good rooting of white pine cuttings in a sand–peat mixture that had been previously used (6) and results with used sand–peat led one earlier investigator (23) to suspect that fungi may be beneficial in the rooting medium for cuttings of white pine.

Cuttings of white pine taken from three trees on February 2 and treated with indolebutyric acid (200 mg./l., 5 hr.) rooted 7 to 27 percent in new and freshly prepared sand–sphagnum peat, 7 to 32 percent in old sand–sphagnum peat which had been similarly used the previous season. So there was here no evidence that the older material was superior. Cuttings of *Pinus pumila* Reg. taken at the same time and similarly treated rooted 43 or 44 percent in this rooting medium whether or not it had been used before.

Old sand–peat was used more often than the new, simply because it was more convenient.

Old sand–sphagnum peat unsterilized was compared with the same sterilized by steaming sixteen days before the insertion of cuttings. Untreated cuttings taken January 6 from three white pines rooted not more than 10 percent in either medium. After treatment with indolebutyric acid (200 mg./l., 5 hr.), cuttings from one tree rooted equally poorly in both media, cuttings from a second tree rooted 33 percent in both media, and cuttings from a third tree rooted 56 percent in the sterilized medium, 58 percent in the unsterilized. Similarly treated cuttings taken March 2 from one tree rooted 14 percent in either medium, while those from another tree rooted 65 percent in the unsterilized medium, 62 percent in the sterilized.

The indications are, then, that sterilizing the rooting medium, while not injurious, is of no benefit, cuttings which fail to root well in the unsteamed medium also failing to root well in the steamed. The fungus Rhizoctonia was found on the bases of some dead cuttings in both. This is not surprising, for so many weeks must elapse between the insertion of white pine cuttings and their rooting that there is ample opportunity for the contamination or reinfestation of sterilized rooting media.

Some work was also done with a rooting medium consisting of two parts sand and one part soil containing pine roots and mycorhiza from under white pine trees. This was compared with a mixture of sand and the same soil freed of fungi by earlier steaming and with freshly prepared sand–sphagnum peat. In no case did cuttings root any better in the medium containing mycorhiza than in those without them. Cuttings taken from three trees on January 6 and treated with indolebutyric acid (200 mg./l., 6 hr.) rooted from 18 to 37 percent in sand–peat, not more than 20 percent in sand–soil with mycorhiza or in sand–soil after steaming. Cuttings taken from three other trees on February 2 and treated with indolebutyric acid gave similar results, higher percentages rooting in sand–peat than in the other media.

There is here no evidence to support the view that the presence or absence of mycorhizal or other soil fungi in the rooting medium is an important factor affecting the rooting of cuttings of white pine.

It should be added that mixtures of sand and garden loam, useful as they may be with the cuttings of some kinds of plants, never gave as good results with cuttings of white pine as did sand or a sand–peat mixture. Thus, for example, cuttings taken March 31 and treated with naphthaleneacetic acid (100 mg./l., 6 hr.) rooted 43 percent in sand, 47 percent in sand–peat and only 12 percent in sandy soil.

In choosing between sand and a sand–peat mixture, one must remember that peats are not all alike, nor are sands; and different rooting media may require somewhat different attention as, for example, in the matter of watering. With this in mind, the propagator may need to do some experimenting with the materials available to him.

February cuttings of *Pinus Mugo* var. *Mughus* rooted slightly better in sand–peat than in sand (28) but, in work elsewhere (14), treated cuttings of that pine rooted well in coarse sand. And the most favorable environment for rooting cuttings of slash pine included sand as the rooting medium (19). In the work of one earlier investigator, sand gave better results than sand–peat (or peat) as a rooting medium for cuttings of white pine (3). In the work of others (7) a mixture of sand and peat gave better results than sand alone, but it is unlikely that they were using the same sand or the same peat.

Cuttings taken from three trees on January 12 and variously treated were set in sand and in sand–sphagnum peat. Out of twelve possible comparisons involving the same treatments, they rooted in higher percentages in the sand–peat in six instances and in no case did they root markedly better in the sand. The best rooting in sand–peat, 53 percent, was of cuttings which had been treated with indolebutyric acid (200 mg./l., 6 hr.) followed by Hormodin No. 3. The best rooting in sand was 29 percent. But cuttings taken another year on January 6 and treated with indolebutyric acid rooted 54 percent in sand, 34 percent in sand–sphagnum peat, the latter lacking adequate drainage and probably having at times a too high water content. That may happen also to sand if it is too fine and a coarser sand is to be preferred.

Cuttings taken from three trees on January 27 were variously treated and set in either a sand–sphagnum peat mixture or a sand–sedge peat mixture. Out of thirteen possible comparisons involving the same treatments, sand–sedge peat gave the best results seven times and never did sand–sphagnum peat give better results than did sand–sedge peat. Treated with indolebutyric acid, cuttings from one tree rooted 16 percent in the former, 41 percent in the latter. Treated with Hormodin No. 3, cuttings from another tree rooted 37 percent in sand–sedge peat, 14 percent in sand–sphagnum peat, and cuttings from still another tree rooted 34 percent in the latter, 53 percent in the former.

These results are in agreement with those of earlier investigators (7, 8) who got better rooting of cuttings of white pine in a mixture of sand and a well-decomposed peat of sedge origin than they did in a mixture of sand and a European peat moss of sphagnum origin. But sphagnum peats may differ, as may also sedge peats, and the propagator can well make some comparisons of his own.

In any case, a sand–peat mixture should not be allowed to become or to remain too wet. Water should be applied lightly, although often, and there should be some drainage material such as crushed rock below. Lacking such care, this medium may give results no better than a moderately coarse sand if as good.

Bottom heat in the bench is unnecessary for cuttings of white pine, in fact it has been found to be undesirable (26).

Atmospheric Conditions in the Propagating Room

Although it is possible for the rooting medium to contain too much water, as of course it is also possible for it to contain too little, there is small if any likelihood of the relative humidity over open benches in the greenhouse being too high. An open bench gave better results than a closed propagating case or sweat bench (3), but high relative humidity is essential if cuttings of pines are to live and root (3, 19) and this was here controlled by means of an automatic humidifying unit[7] supplemented by judicious sprinkling of walks, walls and, less frequently, the bench itself.

The propagating bench, running east and west, was shaded on the south on sunny days by white cotton cloth curtains the height of the greenhouse. If the relative humidity can be kept high, constant shading is unnecessary and probably undesirable; but if cuttings of white pine are watered from above while strong sunlight is upon them, there may be some burning of the foliage and consequent injury to the cuttings.

Ventilation was kept at a minimum and used only when necessary to keep the temperature down. The most favorable conditions for rooting cuttings of slash pine have been found to include temperatures between 75° and 90°F. (19), and in the work of the writer with white pine, air temperatures were allowed to climb from a minimum of 70°F., at night, to about 95°F. on sunny days before ventilators were opened at all.

Figure 1. Rooted Cuttings of White Pine, Taken in February and Photographed in May of the Following Year.

Subsequent Growth of Rooted Cuttings

A minimum requirement for a good white pine from the viewpoint of forestry is that its trunk be vertical. It is correspondingly important to learn how rooted cuttings of white pine behave in this respect, for not all rooted cuttings of all conifers develop into straight and well-formed trees.

Cuttings of yew grow into trees or shrubs with vertical trunks if the cuttings are made from terminal shoots but the new growth may be plagiotropic, the trunk not vertical, if the plants grew from cuttings which were made from side branches (10). Rooted cuttings of Douglas fir had not developed a well-defined

[7]Standard Model No. 31 of the Standard Engineering Works.

Figure 2. Rooted Cuttings of White Pine at the End of Their Second Growing Season in the Field.

leader in their third season (15). Rooted cuttings of Monterey pine quickly grew into straight and well-formed trees, but rooted cuttings of western yellow pine and of white pine grew more slowly and when they were five years old, one investigator was still uncertain as to whether or not they were going to develop into straight trees (17).

Cuttings of white pine which had been taken in February and were rooted by August were then transplanted to sandy soil in the greenhouse, where they re-

Figure 3. A Young White Pine Grown from a Rooted Cutting, as it Appeared on July 1, 1946.

mained until the following May. They were then transplanted to an opening in the College forest. They had made no top growth up to that time (see Figure 1) and their average growth was less than one-half inch during the first growing season after they were set outdoors. It is possible that they would have resumed growth more promptly, come out of their apparent dormancy more quickly, had they been subjected to lower temperatures than those of the greenhouse that first winter after they rooted, a factor yet to be investigated.

But in the following year, their second growing season outdoors, these rooted cuttings of white pine made good growth, an average of five inches. And as is shown in Figure 2, the new growth was in the desired or vertical direction. Their present form or habit (see Figure 3) is at least as good as that of trees of comparable age grown from seeds, and the indications are that these rooted cuttings of white pine are growing into well-formed, normal trees.

Summary

Some individual white pines are more desirable from the viewpoint of forestry than others. But certain abnormal forms, although useless as timber, are useful in ornamental horticulture.

White pines with certain individual characteristics may be worth perpetuating. Propagation by means of cuttings from such trees may be expected to produce trees identical in form and behavior with the parent tree. Many white pines can be thus propagated, although cuttings from different trees differ markedly in their ability to root.

Cuttings should be taken as early in the life of a tree as its desirable qualities become evident, for they root better if taken from young trees.

Late winter is a good time of year to take cuttings. Those taken in midsummer require longer to root.

Cuttings should be taken from wood of the last growing season and should consist of small twigs from lateral branches of lower limbs, with no needles removed.

Cuttings from some white pines are more responsive to treatments with root-inducing substances than are others. But a short immersion in a relatively concentrated solution of indolebutyric acid often improves rooting, and such treatment is recommended.

Cuttings rooted equally well in freshly prepared and in previously used sand–peat. Sterilizing the medium by steaming did not affect rooting. The presence or absence of mycorhizal or other soil fungi did not appear to be important. A sand–sedge peat, if not too wet, gave good results.

High relative humidity, as maintained by an automatic humidifying unit, is important.

Rooted cuttings of white pine are developing into normal, well-formed trees.

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MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 436 SEPTEMBER 1946

Annual Report

For the Fiscal Year Ending June 30, 1946

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

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*In charge †At East Wareham ‡At Waltham

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1945-46

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Development of Statistical Data as Controls to Livestock Production Program. (A. A. Brown, Elaine M. Roberson, and Judith E. Rosenthal.) The field work phase of this project is completed and 941 farms in the "6% sample" have been classified by major source of income. These farms fell into the following classifications:

Dairy	239	Ducks, Turkeys, Broilers	13
Poultry	104	Miscellaneous	10
Poultry with other Livestock	30	Rural Residence with Livestock	198
Tobacco, potatoes, or crops	42	Rural Residence without Livestock	235
Vegetables	47	Estates	10
Fruit	13		

In statistical tests applied to the "6% Sample", the New England Crop Reporting Service Sample, and the "10% sample" of cow numbers, the differences between means fell below the 1 percent level of significance, indicating that the samples were drawn from the same population. The same results were obtained in the comparison of chicken numbers of the New England Crop Reporting Service sample and the "6% sample." The success of these tests indicates that the "6% sample" may be used to estimate livestock numbers with a satisfactory degree of dependability.

The Effect of Public Regulation of Milk Marketing Upon the Organization of the Milksheds of Massachusetts Markets. (A. A. Brown, Elaine M. Roberson, and Judith E. Rosenthal.) The objective under this project has been to develop a satisfactory series of market data for the five principal secondary milk markets for the State. Comparable and reliable price series concerning the decade since the beginning of public control are now available for these markets. Milkshed maps have been prepared for each market. Bulletins have been published covering Springfield and Worcester.

A Study of Farm Real Estate Taxation, Methods of Taxation Reform, and the Effect of Such Measures on Farm Income. (A. A. Brown, Judith E. Rosenthal, and Elaine M. Roberson.) Statistical analysis of the tax and valuation data of the "10% sample" of dairy farms in Massachusetts has been completed. The results obtained from the compilation and analysis of data indicate excessive variation in assessment, which is fully as great among farms within a town as it is among the various taxing units. An analysis of the number of farms with more than one parcel of land, and the average number of parcels per farm show just how confused the assessment picture must be. For the entire sample, 61 percent of all the farms have more than one deed, while the average (number of farms) for the counties ranges from 39 to 94 percent. The average number of parcels per farm is 3.04. Statistically speaking, then, each farm is legally composed of three distinct units, requiring separate valuation, although from the *appraisal point of view*, good procedure might dictate either an over-all estimate or a breakdown on a different basis. The figures obtained from one farm in an eastern county present this problem of variation rather dramatically. On this farm, one parcel of land is valued at $13,000 per acre, and another at $8 per acre!

In addition to the above, results indicate the following. There is an inverse relationship between real estate tax dollars per acre and the size of the farm by county averages. (However, this correlation does not take into consideration variations in types of land, said data being unavailable.) The average real estate tax for the whole sample is $211.54 with extremes of $26 and $1128. There is a very marked positive skew to the farm size data distribution. One half of all the farms have 84 acres or less, while the range in size for the whole sample is from 7 acres to 885 acres. An inverse relation was found between value per acre and farm size by county averages. Value per acre was $24 for the whole sample with a range from $2 to $382; the range for county averages was from $16 to $41. As far as could be determined from the data available, there is no relation, inverse or otherwise, between valuation and tax rate. The modal class for house valuations was $1000 through $1499, while one half of all the farms had houses valued from $200 through $1617. The range in house valuation for the whole sample was $15,800. Cow units equal 78 percent of total livestock units, while cow valuation represents 85 percent of total livestock valuation. There is a high modal concentration in the $50 to $64 value-per-grade-cow group with the wide range in value per cow of $110. Real estate taxation and personal property taxation tend to move together; the average tax paid on personal property was 34 percent of the tax paid on real estate.

Production Efficiency on Dairy Farms in Massachusetts. (C. R. Creek.) According to farm management records, labor efficiency increased almost 20 percent in the ten years from 1934 to 1944 for the same 50 dairy farms, on the basis of productive work units per man. On these identical farms the milking herd increased from 20 to 26 cows, cropland increased by 8 acres and pasture by 15 acres, while the total labor force remained the same at 30 months of hired, family, and operator labor per farm. The most important factor in this greater efficiency of labor was the increase in labor-saving machinery on these farms. The number of farms with milking machines increased from 23 to 43 in these ten years and those with electrical milk coolers from 20 to 45. The farm work was mechanized with tractors on 40 farms in 1944 compared to 19 ten years earlier. Trucks were listed on 40 farms compared to 30 farms in 1934. The number of ensilage cutters on farms increased from 26 to 35, side delivery rakes from 6 to 21, and hay loaders from 6 to 23.

Milk production was also more efficient in 1944, with 365 more pounds of milk produced per cow on slightly less grain, hay, and silage. Milk production increased from 2.6 to 2.8 pounds for each pound of grain fed in these two years.

In the period of low prices in 1933–34 the cash farm cost of producing milk was about $1.39 per hundredweight, the price received was $2.27 per hundredweight, and net farm income was $687 per farm. In the high price period of 1943–44 the cash farm cost of production was about $2.34 per hundredweight, the price received was $4.09 without the feed subsidy, and net farm income was $2524 per farm for the same 50 farms. The margin of prices received over prices paid was greater in the period of higher costs of production. The relationship between prices was the important factor in higher returns rather than the absolute prices or costs.

Loan Performance on Low Income Farms in Massachusetts. (C. R. Creek.) Another year of high prices and generally high crop yields enabled nine of sixteen active borrowers from the Farm Security Administration in the Connecticut

Valley area to repay their crop loans in full from the 1945 production of tobacco, potatoes, and onions. Only six of 23 borrowers with livestock and livestock-crop loans paid their loans in full in the past year. Livestock loans have a longer period for repayment while crop loans are generally for one year.

Loans have been repaid on 134 of the 202 farms for which loans were made. Loans were defaulted on 5 percent of the farms and 13 percent are now classified as collection cases since these borrowers are no longer engaged in farming. Only 15 percent of the total number of farms since 1936 are now considered as active cases and less than one-half of these received supplementary loans in 1946. New loans in 1945–46 were chiefly to start potato growing and poultry farming.

Generally the cash-crop farms have shown a higher rate of repayment of loans and a lower proportion of collection and defaulted loans. The highly profitable tobacco and potato crops of the past three years have furnished income to pay off old debts and provided a surplus to finance farm operations for another season. Borrowers on livestock farms generally have met scheduled payments, but few have made advance payments on their obligations.

Methods and Costs of Improving Land on Massachusetts Farms. (C. R. Creek and J. F. Hauck.) The cost of boulder removal from crop and pasture land on Massachusetts farms varied from $40 to $100 per acre for the bulldozer charge under normal conditions. Some records have shown a cost of $175 per acre for boulder removal where a small bulldozer was used and many large boulders were pushed out. On cropland where scattered large boulders were removed the cost was about $35 per acre in one instance where 55 boulders were removed from 2.5 acres. Costs were generally less per acre where larger bulldozers were used, although the rate per hour was greater.

Costs of removing stone walls from farms ranged from 25 to 50 cents per linear foot under normal conditions, according to records obtained in 1945. Costs were highest where the stones were loaded on trucks with a gas shovel and hauled to a swamp for disposal. The cost was less where a trench was dug with a gas shovel and a bulldozer used to push the walls into the trench and cover the stones to a depth of three feet with soil. Costs were lowest where a wide and shallow trench was made with a bulldozer, the stones pushed in and spread over an area about eight feet wide and then covered with one to two feet of soil to make a dry roadway through orchards or pastures.

It is difficult to justify the removal of boulders and stone walls in order to have larger, more open fields for the use of labor-saving machinery, although many farmers contend that the cost will be repaid in seven to ten years in the lower cost of production which will result from mechanization of crop production.

A method of land improvement which has increased greatly in recent months is the blasting of drainage ditches by the Soil Conservation Districts. Although soil conditions vary between farms, the cost of dynamiting has ranged from 8 to 15 cents per linear foot for a ditch two to three feet deep and five to seven feet wide. This size of ditch with the natural slope of the land will drain many marsh and swamp areas to increase the acreage of pasture and hay land on farms. In some areas the main drainage system will be dug with a shovel or dragline through the cooperation of the Soil Conservation District and lateral ditches will be constructed by each farmer on his farm. Cooperative effort is necessary in most instances to obtain a suitable outlet for drainage ditches.

Methods and Costs of Harvesting Hay on Massachusetts Farms. (C. R. Creek.) Buck rakes mounted on a heavy car or truck chassis are an efficient means of harvesting hay when the distance from field to barn is not over one-fourth mile. The weight of load ranged from 500 to 800 pounds for these buck rakes and the hay was loaded from both the swath and windrow in various instances. Buck rakes are most satisfactory on small farms with near-by hay fields and on farms with a small labor force for hay harvesting.

On many farms the labor-saving possibilities of the pick-up baler for hay have not been developed into an efficient method of hay harvesting. On most farms the bales are dropped on the ground in the field and must be loaded on a wagon or truck by hand. At the barn the bales are unloaded by hand, lifted into the mow and carried to final storage space. This method was costly, inefficient, and fatiguing for these larger farms where field balers were used.

On one fairly large farm with a 50-cow herd and a total of 75 animal units, the job of harvesting hay was made very efficient and non-fatiguing by using other equipment with the field baler. A one-man baler was used in the field with a low-wheel, rubber-tired wagon attached to the baler so that the bales were loaded directly on the wagon from a ramp built on the baler. A small tractor was used to haul the loaded wagons to the barn where an elevator powered by an electric motor was used to unload bales into the barn. This elevator was mounted on a wagon chassis and could be moved to small doors cut in the side of the barn at 25-foot spaces so that bales were carried only a short distance in the barn mow. The haying operation was continuous on this farm since two low wagons were used. One was loaded at the rate of three bales per minute while the other was hauled to the barn, unloaded, and returned to the field in the same length of time. The crew of five men (two in the field, two at the barn, and one hauling) under normal conditions could bale, load, haul, unload, and store a load of 51 bales every 17 minutes. For a continuous operation this amounts to almost one ton of hay per man per hour with a minimum of effort.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Evaluation of Additions of Sodium Nitrate and Ammonium Sulfate when Applied to the Soil during the Late Summer Preceding the Spring when Tobacco Is Planted. (Walter S. Eisenmenger and Karol J. Kucinski.) It has been observed that tobacco grown after crops of corn, timothy, or clover frequently did not yield well, probably because of a deficiency of nitrogen at the time when certain organisms were active in decomposing fibrous tissue. Different amounts of nitrogen — 50, 100, 200, 300, and 500 pounds per acre of nitrogen in the form of sodium nitrate or ammonium sulfate — were applied to plots on which corn and grass had previously been grown, for the purpose of ascertaining to what degree this would prevent the usual bad effects of these crops on the succeeding crop of tobacco. The nitrogen was applied sufficiently early in the season to permit the warm weather to facilitate the action of decomposition agencies.

In general, the yield per acre and the quality of the tobacco increased with each increment of sodium nitrate applied to plots which had had a preceding crop of grass. These increases were larger where calcium carbonate was used as a supplement than where calcium sulfate was so used. Generally the plots on which grass was plowed under were better than the plots from which the grass was harvested as hay before plowing. No definite correlation could be established on the series of plots which had the calcium sulfate supplement and on which the hay was harvested before plowing.

No significant relationship was found in the yields or quality of tobacco grown on plots where mature corn had been plowed under in the fall. Both, however, were decidedly lower on the series of plots from which the corn had been harvested before plowing and were poorest on plots on which corn was allowed to stand over winter before plowing. Where nitrogen had been added before plowing, there was considerable increase both in yield and in quality; but the deleterious effects of corn on tobacco may not be entirely alleviated by the use of nitrogen.

The yields of tobacco on the ammonium sulfate plots were greater than on the nitrate plots, but the quality of the tobacco was inferior.

The Absorption of Chemical Elements by Food Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) The experiment was set up to compare the intake of elements when used singly and in pairs. The intake of calcium and magnesium was studied as well as the influence of the copper ion on the intake of magnesium and the movement of magnesium in the plant.

Magnesium added to the soil caused an increase of magnesium in the plants in all instances. When calcium was added to the soil, most of the plants studied contained more calcium but approximately a fourth showed no increase.

In water solutions copper ions lowered the transfer of magnesium. In the field this was not observed, probably because of the small amount of copper added (75 p.p.m.) and the buffer action of the soil. The change in the composition of seeds from plants under varied conditions of ion application was insignificant.

There seemed to be a tendency for the calcium content of plant tissue to be increased when copper was added to the soil. No explanation can be made of this unusual behavior.

The magnesium content and, to a lesser degree, the calcium content of foods and feeds can be increased by application of the salts of these elements to the soil. In the seedling stage, the transfer of magnesium from the seed and the water medium to the aerial portion of the plant was diminished by as small an amount of copper as one-half part per million.

Magnesium Requirements of Certain Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Work on this project included study of the relationship of seed plant development and the need of plants for magnesium, as well as the relation between intake of magnesium and the supply of the element in the soil. This part of the project was designed to ascertain whether plants which readily show signs of magnesium deficiency take up more or less magnesium when an ample supply is present in the soil than plants which do not show symptoms readily.

Plants vary greatly in their reaction to soils of low magnesium content, and plants of a lower order of development show the deficiency more quickly than plants of extremely high development. Thus the buttercup (Ranunculus), the mallows, geraniums, elms, anemones, buckwheat, rhubarb, cabbage, and tobacco always react to low magnesium soils; while plants like the asters, dandelions, sunflowers, ragweed, lamb's-quarters (*Chenopodium album*), pigweed (*Amaranthus retroflexus*), and the grasses do not show any symptoms of magnesium deficiency when grown on the "deficiency" plots. There are two conditions where the above does not hold. First, when plants have been changed by selection or plant breeding, there is no certainty that these species will react at all to soils of low magnesium content. Second, and less frequently, certain plants such as the portulaca and blackberry, for example, when grown in low magnesium soil show deficiency only in subnormal growth and not through chlorosis. Some plants, as the mallows and buttercups, normally take up comparatively little magnesium, and their magnesium content, compared with that of other plants, is low. There is evidence that such plants react more quickly to low mag nesium soils.

The ability to recognize the plants which are not tolerant to low magnesium content of the soil would afford a chance to correct this condition when the need arises; for it is in the *early* stages of growth that magnesium is required and applying salts of magnesium *after* the symptoms appear is generally much too late.

Long-Time Fertility Tests. (Karol J. Kucinski, Walter S. Eisenmenger.) Fifty to sixty years ago a series of test plots was established to study the effects on the soil and crops of a long-time fertilizer program. Where the plots were treated singly with either nitrogen, potash or phosphorus, the nitrogen plots showed the greatest response. Yields of hay ranged 2 to 2.5 times as great on plots receiving lime as on those not limed. Rabbits fed grass grown on limed plots made greater growth than rabbits fed grass grown on unlimed plots. Similar results were obtained where cabbage was used to feed the rabbits.

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) Although the 1945 growing season was generally unfavorable for most farm crops because of abnormal rainfall, sunflowers did remarkably well. The Mennonite and Sunrise varieties, which are considerably shorter than the Mammoth Russian, yielded less seed, but this disadvantage was counteracted by less breakage of the stalks in wind storms. The wet season was very conducive to weeds, yet the sunflowers had no difficulty in shading out all weeds growing in the plots. Yield studies indicate that sunflowers will respond to liming. Heavy fertilization of soil of good fertility tends to produce abundant vegetative growth with the possible risk of lodging, especially during wind storms.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

Physical and Chemical Properties of Wind-Blown Soils. Laboratory and field tests have been in progress for several years to determine why certain soils are subject to wind erosion while others are not. A specially constructed wind tunnel was used in the laboratory to supplement field observations.

Climatological data were studied to ascertain what elements of climate influenced dust storms as they occurred naturally in the Connecticut River Valley. It was found that rainfall has only a very small effect on retarding wind erosion; while the months of January and February, the period of greatest snowfall, usually have fewest dust storms. A direct relationship exists between known occurrence of dust storms and the monthly prevalence of winds, particularly those of over 10 miles per hour. The data show that wind velocities increase in the afternoon. This corresponds with the observation that nearly all dust storms occur in the afternoon.

In the comparison of the physical and chemical soil tests with wind tunnel studies, it was found that the more sandy the soil, the lower was the initial velocity at which it began to blow. The initial velocity was generally lower for frozen soils than for air-dried soils. For most of the soils studied, the losses were greater at low wind velocities for frozen soil than for air-dried soil; while at the higher wind velocities, the air-dried soils were more erodible. It was found that the organic matter content, the maximum water-holding capacity, the moisture equivalent, and the hygroscopic coefficient of the soil had a direct relationship to wind erosion. It was further noted that the higher the settling volume of a soil, the lower were its losses in the wind tunnel. A ripple or wave pattern appeared on the surface of sandy soils (non-agricultural) when blown in the wind tunnel, while agricultural soils showed streaks.

Soil moisture studies show that wet soil will not blow at any wind velocity. The very top thin layer of particles is relatively dry before it wind erodes, while sublayers of soil may be relatively moist. Sandy soils blow sooner after a rain because the capillary action is broken at the very surface of the sandy soil.

Dust collected showed 0.46 percent moisture, while the parent soil had a 26.0 percent moisture content.

Where the formation of aggregates in dry soils was increased by chemical treatment, their tendency to blow was decreased. Soils treated with ground limestone, burnt lime, urea, and lithium carbonate showed decreased losses with the treatments in the order mentioned; the finer the texture of the soil, the more pronounced the effect. Calcium and sodium silicates tended to bind the soil into aggregates and so reduced soil losses. Organic matter when applied in the form of raw lignin lowered the initial velocity at which the soils began to blow and also increased the rate of wind erosion. The lignin used was not comparable to soil humus or organic matter. The organic matter produced in a soil from the decomposition of yearly applications of sawdust reduced the amount of wind erosion and also raised the initial velocity at which the soil began to blow. Soil taken from under a manure pile dried into a coarse lumpy condition which was quite resistant to wind erosion.

A study of the deflocculating effects on the soil of the mono-valent elements in period one of the "Periodic Tables of Atoms" showed that, upon drying, the soils had experienced an aggregated condition which increased in the following order of the elements tried: lithium, sodium, potassium, rubidium. The pH value of the soils was greatly increased by this chemical treatment. The rate of increase of the pH values was in the reverse order to the aggregating effect.

To study the rate of wind erosion on fields of various crops and the relation of the cultural practices to dust blowing, a portable dust collector was developed. These studies show that the soil blows more on areas growing vegetables like onions and lettuce than on areas used to grow tobacco and potatoes. There was a direct relationship between pH and amount of dust collected. These observations were confirmed in the wind tunnel studies where soils from two experimental plots were tested. Soil from a plot having a yearly application of limestone had a pH of 6.9 and eroded considerably more than soil from a plot which had not received any lime and had a pH of 4.8. It is believed that the flocculating effect of continuous liming has produced a soil surface condition more susceptible to wind erosion.

Use of Snow Fencing in Controlling Wind Erosion. The results of this test, which was described in detail in the annual report of 1944–1945, were not very conclusive this year owing to the lack of dust storms during the exceptionally wet season of 1945. The anchorage of the snow fencing with iron pipes, 4½ to 5 feet long, driven 18 inches into the ground and spaced a rod apart, held the 4-foot-high lath fencing throughout the entire season. Frost action did not tend to heave the anchorage out of the ground.

Black Root Rot of Tobacco. (C. V. Kightlinger.) Strains of Havana Seed tobacco that yield well under black root rot promoting conditions often produce tobacco that is not fully acceptable to all of the tobacco trade when grown under favorable producing conditions. Therefore an attempt is being made to breed strains which will produce tobacco of acceptable type and quality in profitable amounts under both these growing conditions.

Havana K1 and Havana K2 and other new strains thus far produced are now being grown commercially to ascertain their suitability for general use in the Connecticut Valley. These strains yield well under different growing conditions; and so far, the tobacco produced seems to be receiving greater approval for type and quality by the tobacco trade than that produced by Havana 211 and other previously produced strains. It is too soon, however, to know whether these new strains will be entirely satisfactory.

Meanwhile, work is being done to effect further improvements: first, by selecting the most desirable plants within the strains already produced to improve habits of growth as well as type and quality; and second, by breeding entirely new strains.

Brown Root Rot of Tobacco. (C. V. Kightlinger.) Ordinarily, but not always, tobacco grown immediately following corn, grasses, and a few other crops develops brown root rot in some degree, in the Connecticut Valley. It is probable that more than one factor may be responsible for this irregular occurrence of the disease; but it is natural to suppose that soil fertility may be one of the most important. With this in mind, experimental work is now in progress, as follows:

1. Crops known to produce brown root rot promoting soil conditions under usual fertilizing practices are being grown with more than the usual amounts of fertilizer, to determine what effect this will have on the following crop of tobacco. Results are not yet available.
2. Different amounts of fertilizer are being used on tobacco following crops known to produce brown root rot promoting soil conditions, to determine whether fertilizer can be so used as to prevent the development of the disease following these crops. Results are not yet available.
3. Tobacco is being grown continuously on the same land, with inadequate fertilization, to ascertain whether the disease will develop under these conditions. It has been definitely determined experimentally that brown root rot will develop, in moderate degree at least, on tobacco that is grown continuously on the same land under certain inadequate fertility conditions. This result, in connection with the well-known fact that brown root rot may be overcome, in the Connecticut Valley at least, by growing tobacco continuously on brown root rot promoting land for three or four years under usual tobacco fertilizing practices, suggests that malnutrition may be important in the development of the disease. Further tests are necessary.

Control Measures for Mildew of Tobacco. (C. V. Kightlinger.) In experimental work to test the comparative effectiveness of different materials in the control of mildew of tobacco in seedbeds, Fermate and bismuth subsalicylate used in recommended concentrations gave complete control of the disease in 1946. Mildew developed in moderate severity in the untreated check. The materials were applied at weekly intervals with sprayer at 150 pounds pressure. Eight applications were made throughout the season, beginning May 3, before any cases of mildew in tobacco seedbeds had been reported.

Potato Seed Treatments. (C. V. Kightlinger and H. M. Yegian.) Seed potatoes of seven varieties grown regularly in the State (Chippewa, Katahdin, Earlaine, Sebago, Irish Cobbler, Green Mountain, and Russet Rural) were treated with cold mercuric chloride plus acid, cold formaldehyde plus acid, Semesan Bel, Sanoseed, Fermate, and Spergon, to ascertain the relative tolerance of the varieties to disinfecting treatments and the comparative effectiveness of the treatments in the control of scab and rhizoctoniose.

Mercuric chloride and formaldehyde caused little injury to tubers of the Irish Cobbler, Green Mountain, and Russet Rural varieties; moderate injury to tubers of the Katahdin, Earlaine, and Sebago varieties; and more severe injury to tubers of the Chippewa variety. These treatments caused reductions in stands of potatoes in the field ranging from slight, in the case of Irish Cobbler, Green Mountain, and Russet Rural; moderate to heavy in case of Katahdin, Earlaine, and Sebago; and severe in the case of Chippewa. Semesan Bel, Sanoseed, Fermate, and Spergon caused no noticeable injury to the tubers of any of the varieties before planting; but Semesan Bel and Sanoseed had some detrimental effects on the stands of Katahdin, Earlaine, and Sebago, and worse effects on the stands of Chippewa.

None of the seed treatments seemed to increase the vigor of plants. Careful examination of growing plants and later inspection of mature tubers after digging, showed no consistent differences in the amounts of rhizoctoniose on potatoes grown from treated and untreated seed. No scab developed in any of the plots, not even in the control grown from untreated seed.

On the basis of experimental results obtained in 1945 as well as the two previous seasons, disinfecting seed treatments are of doubtful value as control measures for rhizoctoniose of potatoes in most potato land. Although no scab developed even in the control plots, it is reasonable to believe that disinfecting seed treatments would be of doubtful value in the control of scab also.

Evaluation of New Lines of Irish Potatoes for Resistance to Scab and Rhizoctoniose. (C. V. Kightlinger and H. M. Yegian.) Newly developed lines of Irish potatoes were tested for comparative resistance to scab and rhizoctoniose in informal cooperation with the Division of Fruit and Vegetable Crops and Diseases of the United States Department of Agriculture.

Several of the new lines were apparently highly resistant to scab. A few of the lines showed no traces of scab when the Green Mountain control scabbed so badly that its tubers were utterly worthless. A few of the lines showed evidence of having considerable resistance to rhizoctoniose. Other lines bore enough small sclerotia on their tubers to interfere greatly in estimating the comparative scab resistance of the lines. There were not enough plants to spare any for examination in the growing stage to ascertain their resistance to rhizoctoniose more completely. More information about the comparative resistance of these lines to rhizoctoniose is needed.

Potato Variety Trials. (Karol J. Kucinski, Ralph W. Donaldson, Walter S. Eisenmenger.) Because the 1945 growing season was abnormally wet, the yields obtained in the potato variety test were much lower than in former years, ranging from 273 bushels per acre for Sebago to 107 bushels for 47102 Teton.

Based on yields of marketable size, the ranking of potato varieties in the Experiment Station plots during the season of 1945 was Sebago, Cayuga, 055, Red Warba, 627-103, Green Mountain, Mohawk, Chippewa, Pawnee, Katahdin, 46952, Cobbler, Houma, Russet Rural and 47102 Teton.

Corn Improvement Program. (Hrant M. Yegian.) Seventy-five varieties, mostly hybrid seed corn supplied by state experiment stations and private seed companies were tested for their general adaptability and yield. In the early maturity group, Wis. 412A and Mass. 62 produced the highest yield of shelled corn per acre (90 bushels). Wis. 643 was the highest producing full-season silage corn. The very late maturing varieties produced somewhat more silage per acre, but this consisted mostly of stalks and leaves. Therefore, the quality and feeding value of the silage would not be as high, pound for pound, as that from varieties which produce a higher proportion of ears which are in the dough or pre-dent stage before the killing frost. With somewhat earlier maturity it is possible to ensile before the usual mid-September frost or hurricanes which do great damage to silage corn. The results of the 1945 field tests are published in mimeographed form and are available upon request.

Fifty-five single crosses involving all possible combinations of eleven inbred lines in the early maturity group were tested. On the basis of this test, a few of the promising predicted double crosses were made in the greenhouse during the winter and these are being tested in the field during the 1946 season. The double cross (CC4xCC8) x (Q83xA96) promises to be an especially good, early-maturing field corn.

Among the thirty-six experimental double crosses there were two especially good mid-season hybrids. These are being tested further prior to their release to the farmers.

The results of yield tests on three rates of planting on three different dates were not very reliable. Excessive rainfall in the spring and poor drainage of the field where the test was carried on caused wide discrepancies among the replicates.

A set of fifty-five early maturing single crosses was made here last year in cooperation with the northeastern corn breeding program. These are being tested for their general adaptability in the northeastern region.

Onion Breeding. (Hrant M. Yegian.) In 1945 a number of male-sterile Early Yellow Globe and Ebenezer crosses supplied by Dr. H. A. Jones of the United States Department of Agriculture were tested. Some of this material was very promising, particularly one backcross which made a vigorous growth, was of nonbolting globe type, and had exceptionally uniform skin color and bulb shape. A number of bulbs of male-sterile lines have been planted in isolated plots and are being pollinated with selected strains of Ebenezer lines in order to determine the relative combining ability of the various strains and lines used. The resulting hybrids will be tested to ascertain their adaptability in the Connecticut Valley.

Preliminary evidence tends to show that application of borax at the rate of 30 to 50 pounds per acre on set-producing fields may have subsequent beneficial effect on the keeping quality of the stored onions. Most onion soils have a pH value of 6.0 to 6.5, which is maintained by the application of one to two tons of limestone per acre, every two or three years. Since boron starvation occurs more frequently on heavily limed soils than on acid soils, it seems advisable to apply sufficient borax to safeguard against this difficulty.

Various fungicidal chemicals, Fermate, Puratized N 5 E, Isothan Z-15, Wettable No. 604, Wettable Spergon, and Dithane D 14, were tested for the control of storage rot of onions. Preharvest spraying of plants—three applications at weekly intervals prior to pulling—dipping the bulbs from unsprayed plants, soon after they were harvested, in concentrations recommended by the manufacturers of these chemicals, did not give any control of rot in storage. The best and most weekly intervals prior to pulling—or dipping the bulbs from unsprayed plants, soon after they are harvested, in concentrations recommended by the manufacturers of these chemicals, did not give any control of rot in storage. The most practical method known for reducing losses in storage is to store only sound onions in cold storage under controlled conditions at 32°-35° F. and low humidity.

Pasture Renovation Experiments. (Wm. G. Colby.) Work was begun in 1943 in cooperation with the U. S. Department of Agriculture Regional Pasture Laboratory in State College, Pennsylvania, for the purpose of studying practical methods of renovating depleted or "runout" pasture land by tilling, fertilizing, and reseeding. Experiments were laid out on fields which differed widely in topography, character of native vegetation, degree and nature of stoniness, and soil drainage relationships. This was done intentionally; for, as the work progressed, it became increasingly obvious that different conditions may require widely varying methods of procedure to secure the most effective results. Following is a summary of some of the observations which have been made during the course of these experiments.

Degree of Stoniness. It is doubtful whether attempts should be made to renovate stony land until most of the surface stones, six inches in diameter or larger, have been removed. If many stones of this size or larger are exposed, it is extremely difficult to work up a seedbed. If a bog harrow is used, for example, the machine tends to bounce from rock to rock and in so doing loses much of its effectiveness as a tillage instrument. Repeated working of the land is necessary to secure a satisfactory seedbed. Excessive wear is caused not only on the har-

Stone Removal. In the hands of an experienced operator a large caterpillar tractor with regular bulldozer attachment is probably the most efficient and practical means of removing large stones. Rocks weighing from a few hundred pounds up to several tons can be removed in the course of a few minutes. A bulldozer was also found to be useful in leveling off uneven "hummocky" land by dragging the blade and operating the machine in reverse. This breaks down the hummocks and tends to tear them apart.

The removal of smaller stones is a more difficult problem. There seems to be no other way except to pick them up by hand, and this is a slow, arduous operation. If there is grass growing, many stones become so imbedded in the sod that the use of a bar is necessary to pry each one loose. A preliminary disking with a bog harrow after the large stones and boulders have been removed will help to dislodge many of the smaller stones and thereby facilitate their removal.

Character of Native Vegetation. The effectiveness of different tillage implements is greatly influenced by the nature and quantity of native vegetation.

1. *Moss cinquefoil association:* a bog harrow is particularly effective in destroying this type of cover. One thorough disking is usually sufficient.

2. *Grass sod:* The destruction of a grass sod can be accomplished with a bog harrow, but several diskings are usually required. So far, disking at intervals of one to two weeks during midsummer has been the most effective means of destroying bluegrass and bentgrass sods. If operations are begun in July, a satisfactory seedbed can usually be prepared for seeding in late August. If seeding is delayed until the following spring, there may be considerable recovery of the native grasses.

3. *Herbaceous woody plants (hardhack, meadow sweet, ground pine, laurel, etc.):* If the proportion of woody plants is high, a bog harrow is not particularly effective unless most of the native growths are first mowed and removed. The mowing operation, too, is most successful if carried out in midsummer. Where the land is not too stony or rough, a brush-breaker plow can be used satisfactorily, in which case mowing the native vegetation may not be necessary.

Time of Seeding. Thus far late-summer seedings have been much more successful than spring seedings. This may have been partly due to the abnormally warm weather early in the spring of 1944 and again in 1945 which was unfavorable to new seedings. Probably more important than unusual weather conditions, however, were the difficulties encountered in preparing a well-consolidated seedbed with so much undecomposed plant material present. These soils tended to dry out more quickly than regularly cultivated soil until some of this raw organic matter had broken down. It was observed that dry weather following spring seedings was more damaging than dry weather following fall seedings.

Studies on the Causes of Winter Injury to Ladino Clover. (Wm. G. Colby.) Although most stands of Ladino clover show evidences of winterkilling every spring, injury is much more severe after some winters than after others. In the summer of 1943 a field experiment was laid out with the objective of studying some of the factors associated with this trouble. Seedings were made of Ladino clover alone and in combination with orchard grass (S 143), smooth brome grass (northern strain), meadow fescue (Svalof Early), and timothy. Different cultural treatments were also included.

It was not until the spring of 1946, when Ladino clover stands generally suffered extensive winter injury, that significant differences between treatments were evident. The plots which were mulched with straw showed no injury whatsoever. The straw had been applied on November 16 at the rate of 3½ tons per acre and removed the following April just before active spring growth started. The clover in all other plots (with the exception of part of one manure plot which accidentally received a very heavy application of cow manure) was severely injured. On this one small section, the manure application was so heavy that it actually served as a good mulch. Where cow manure was applied at a lighter rate (10 tons to the acre), winter injury was severe.

The Ladino clover in all plots appeared to be vigorous and healthy at the time the manure and straw mulch applications were made in November. Since all plots were covered with snow a few days later, it seems probable that most of the injury occurred in early spring after the snow had melted. There were several days during the latter part of February and the first part of March when winds of record or near record velocity were experienced. It is suggested that much of the winter injury to Ladino clover is actually spring injury occurring after the snow melts, and is caused by the drying action of heavy spring winds on the fleshy Ladino stolons.

Trials with New Oat Varieties. (W. G. Colby.) Heavy summer thunder showers caused serious lodging in many varieties included in the oat variety test carried on in cooperation with the U. S. D. A. Division of Cereal Crops. The varieties Vicland and Tama, which had given high grain yields in previous years, lodged badly and yielded only 47 and 43 bushels per acre respectively. Clinton and a new variety, Mindo, both of which matured about the same time as Vicland, lodged only slightly and yielded 83 and 79 bushels per acre. Ajax and Bention varieties, which matured about five days later than Vicland, produced yields of 84 and 80 bushels per acre.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald.) As a result of extensive study of methods for the determination of cobalt in milk, in which Dr. Beeson of the U.S.D.A. Regional Laboratory at Cornell University collaborated, it was decided last summer that further progress could not be made with existing laboratory facilities. A room has, therefore, been remodeled and re-equipped for this and other special "trace" element work, and active work on the project is being resumed.

The Effect of Feeding Synthetic Thyroprotein to Milking Cows. (J. G. Archibald.) Results for the winter season of 1944–45 have been published.[1] The work reported was mainly a study of the effects of the hormone on milk composition. The most important effect was a considerable and rather consistent decrease in casein, and a roughly proportional increase in lactalbumin and globulin. Changes in fat content of the milk were not consistent.

Since these changes may be of considerable significance if characteristic of the action of the hormone on cows in general, it was thought advisable to repeat the work in a more intensive manner. This was done in the winter of 1945–46, with a smaller number of cows (6) but using the same individuals throughout and trebling the number of milk samples taken. This later work is in general agreement with the earlier results: the effect of the hormone on milk composition was not consistent, but the tendency for the casein of the milk to be decreased was

[1] Journal of Dairy Science, Vol. 28, No. 12, pp. 941-947, December 1945.

still apparent. Individual cows, even within a breed, varied widely in their response to the hormone stimulus. Holstein cows in general were less responsive than Ayrshires, Guernseys, or Jerseys. Live weight decreased sharply at first, but after a few weeks increased slowly, even while the hormone was still being fed. Respiration and pulse rates in general were accelerated somewhat, but individual animals showed great variations in these respects.

The Effect of Massive Doses of Irradiated Yeast on Incidence of Milk Fever in Dairy Cows. (J. G. Archibald.) This project is a part of a more comprehensive one, the other phases of which were terminated several years ago. This particular phase has been kept active but data have been slow in accumulating because of the limited number of cows (6) in the college herd suitable for the study; that is, having a previous history of milk fever.

The procedure consists in feeding one million units of vitamin D in irradiated yeast daily per cow for one month previous to calving. As indicated above the yeast was fed only to cows having had milk fever previously. In five out of the six cases, cows receiving irradiated yeast did not develop milk fever; also, when used as controls in a subsequent lactation (that is, not fed the yeast), two out of three of these cows did have milk fever again. A fourth cow, not intended as a control but refusing the grain with which the yeast was mixed, makes it three out of four cases in this latter category. Especially worthy of note is the case of one cow which responded to the yeast feeding in two successive lactations, but reverted to her original status when used later as a control.

Further cases will be studied before final conclusions are drawn; but so far as these cows are concerned, the treatment appears to have been a definite value.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Bacteriological Studies of Rural Water Supplies. (James E. Fuller.) This study was a comparative differentiation of coliform bacteria from privately owned rural water supplies at several temperatures: 37° C., as provided by the Standard Methods of Water Analysis of the American Public Health Association; 44° C., as employed by the British practice; and 46° C., as employed in the Eijkman test. To provide an intermediate temperature between A.P.H.A. Standard Methods and the British system, 40° C. was also employed in the study. The tests employed were the indole, methyl-red, Voges-Proskauer, and sodium citrate tests, as directed in the A.P.H.A. Standard Methods. The results warrant the recommendation that the methyl-red test at 44° C. be employed for effective differentiation of sewage-type (fecal) coliform bacteria from surface-wash (soil-type) coliform bacteria in the testing of raw waters from wells, springs, and streams. The study has been completed and results published.[1]

Relation of Chloramine-resistant Bacteria to Milk Supplies. (James E. Fuller.) The isolation and study of bacteria surviving chloramine treatment in a public water supply have been reported and published.[2] Since the supply in question, the others like it, serve milk-bottling plants and some dairy farms, it appeared to be desirable to determine the effect of these bacteria on milk supplies. Results indicate that all of the bacterial cultures isolated were capable of

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[1]Journal of Bacteriology, Vo. 51, No. 4, pp. 457-464, April 1946.

[2]Journal New England Water Works Association, Vol. 58, No. 2, pp. 89-100, June 1944; and Vol. 59, No. 3, pp. 244-251, September 1945.

multiplying in milk and spoiling it, even at the normal operating temperature of an electric refrigerator. All of the cultures were killed effectively by pasteurization except those that formed spores. These was as expected. This project is completed.

Study of Septic Tank Efficiency. (James E. Fuller.) In this study three septic tanks of identical size were supplied with sewage from one of the college dormitories. The rates of supply to the three tanks were so regulated that sewage was retained in them 24 hours, as usually recommended, 12 hours, and 8 hours, respectively. The object was to determine whether the shorter retention periods would result in greater operating efficiency in the tanks. Results showed that the conventional 24-hour retention was superior to the shorter periods on the basis of the following evidence: (1) the coliform index of the effluent was lower for the 24-hour period than for the shorter periods; (2) the biochemical oxygen demand results favored the 24-hour period as compared with the shorter periods; (3) at the end of three months of operation for two consecutive seasons, the thickness of scum in the normal tank was about 2 inches; while in the tanks with 12-hour and 8-hour retention periods, thicknesses of 11 and 13 inches respectively resulted, which would have plugged up the outlets of these tanks if they had been constructed with the usual outlets. An extension of the project was secured to permit a study of the permeation of coliform bacteria into the soil of the disposal field, and of the accumulation of nitrates in the soil. This work is in progress now.

Effectiveness of Commercial Surface-active Agents for Use as Household Cleansing Agents. (James E. Fuller.) Some 42 agents have been examined to determine their germicidal power. About one-third of them were found to be very effective, and several others were moderately effective. Experiments are now under way to devise a procedure for evaluating the efficiency of these agents on a sliding scale on the basis of variations of time and concentration, preparatory to investigating the effect of organic matter, acids, and alkalis on the germicidal power of the agents.

Types of Microorganisms Involved in the Spoilage of Home-canned Foods. (Ralph L. France.) This is a new projedct an work has only been begun. To date no results are available for report.

Laboratory Service, July 1, 1945, to June 30, 1946. (James E. Fuller.)

Milk samples, bacteria counts	171
Ice cream samples, bacteria counts	76
Water samples, bacteriological tests	140
Total	387

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. As of July 1, 1946, the Dutch elm disease, caused by the fungus *Ceratostomella ulmi* (Schwarz) Buisman, has been isolated from 182 trees in 28 municipalities in Massachusetts, as follows:

	1941	1942	1439	1944	1945	1946	Totals
Berkshire County							
Alford	1			2		4	7
Dalton					1		1
Egremont		3	2	3		1	9
Great Barrington		1	1	6	6	13	27
Hancock					1		1
Lanesboro						1	1
Lenox					2	1	3
Mount Washington				1			1
New Marlborough						17	17
Pittsfield				3	5	2	10
Richmond					9	8	17
Sandisfield				1			1
Sheffield		1		5	2	13	21
Stockbridge				2		12	14
West Stockbridge			1		1	11	13
Williamstown					1		1
Hampden County							
Agawam					1		1
Chicopee						2	2
East Longmeadow					1		1
Holyoke				2	1		3
Longmeadow				1	5	6	12
Southwick				2			2
Springfield				2	3	5	10
Westfield		1			1		2
West Springfield				2			2
Hampshire County							
Granby						1	1
Middlefield					1		1
South Hadley					1		1
Totals	1	6	4	32	42	97	182

Symptoms of the disease include wilting, curling, yellowing, early falling of leaves, and brown streaking of fungus-infected wood. Affected trees die suddenly or gradually. Elm bark beetles serve as carriers of the causal fungus. Adult beetles penetrate between the wood and inner bark of weakened trees and engrave breeding galleries. Later the young emerge to feed on tender small twigs and in so doing may inoculate trees if the fungus was carried from breeding galleries by beetles.

The spread of the disease during the past five years has borne out previous experimental work and observations that the incidence of disease tends to build up where conditions are most favorable for increase in population of carrier beetles. Thus far relatively few valuable elms in Massachusetts have been killed by the disease; but if the spread among weed elms is left unchecked, additional important losses may be expected.

Interest and cooperation in control of the disease throughout the State is encouraging. The timely application of appropriate disease control measures may materially check the spread of the disease.

1. Destroy all elms affected by Dutch elm disease.
2. Remove and burn promptly bark from any cut elm wood.
3. Avoid piling elm wood in the open unless it is peeled.
4. Don't transport elm wood with bark attached.
5. Spray elms to control leaf-eating insects.
6. Keep elms as healthy as possible.

Additional methods of disease control are being explored, and in cooperation with the Department of Entomology the uses of spray materials for control of carrier-insects are under investigation.

Other Tree Problems. Fifty-three diseases of twenty-seven species of trees including nine diseases of elm were identified from approximately 400 specimens and inquiries received during the year. The *Cephalosporium* wilt of elm was reported from three additional municipalities in Massachusetts. *Verticillium* sp. was isolated from several species of woody plants.

During the year, postwar planning of municipal tree programs was rapidly accelerated. The most conspicuous and obvious need is treatment of injuries and defects neglected for five years because of man-power shortages. Trees found to be in such condition as to endanger the public should be removed, pruned, or strengthened to eliminate hazards. In many communities a good start has been made on constructive tree protection programs which should help limit the spread of leaf diseases.

The occurrence of broken tree limbs this year has resulted in numerous inquiries. Wind and rain storms have caused considerable damage of this type. Also, in the course of reconverting housing and industrial activities for postwar needs, there has been considerable cartage of relatively large, partly assembled construction units throughout the State. The movement of such material is ordinarily not sufficient to cause extensive breakage of roadside trees. However, currently, extensive tree breakage is traceable to this source as well as to the increasing movement of heavy road-construction machinery along highways.

Diseases of Plants Caused by Soil-infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) It was found that, in the absence of fungicides, damping-off is much less severe if soils having a moisture content of about 30 percent of the water-holding capacity at the time of seeding are not watered for the first time until four or five days thereafter.[1]

The use of fertilizers as carriers of soil fungicides, especially for the control of damping-off, cabbage club-root, and soil-borne onion diseases, was further investigated. Organic fungicides used in this or the following project, and hereafter referred to by the trade names only, include tetramethyl-thiuram-disulfide (Arasan, Thiosan, and Tuads); 2, 3-dichloro-1, 4-naphthoquinone (Phygon); tetrachloro-parabenzoquinone (Spergon); disodium ethylene bisdithiocarbamate (Dithane D 14); ferric dimethyldithiocarbamate (Fermate); hydroxymercurichlorophenol (Semesan); and zinc salt of 2, 4-trichlorophenol (Dow Seed Protectant No. 9.)

Mercury salts, 0.2 gm. per square foot, applied to soil in the fertilizer, a 5-8-7 formula, did not control club-root of cabbage in the soils used as well as did hydrated lime. Best results on the basis of disease control and growth of plants were secured with pyridylmercurichloride or ethyl mercury phosphate used in a limed soil.

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[1]The writer read a paper on "Control of Damping-off by a Delay in First Watering after Seeding" at the December 1945 meeting of the American Phytopathological Society. An abstract will appear in an early number of Phytopathology.

Fermate, applied to the soil in and with fertilizer, successfully controlled onion smut.[2]

More recent work with onions has involved principally a study of the prevention of pink root-rot of onion, caused by Fusarium, by treatments of soil or sets with fungicides. Yields of onions, from seed, in pink root-rot infested soil were increased 48.9 percent by Thiosan, 70 pounds per acre; 36.9 percent by Fermate, 70 pounds per acre; and 23.3 percent by Fermate, 50 pounds per acre. Treatments of onion sets with Arasan, Fermate, or Spergon failed to lessen the severity of pink root-rot.

Dithane 2.5 cc., Tuads 0.6 gm., or Phygon 0.45 gm. (per square foot in all cases), applied in fertilizer to soil infested with Pythium, markedly improved the stands of onion, cabbage, tomato, and beet, and there was no chemical injury when seeds were sown immediately after soil treatment. Similarly used, Tuads also gave good results with pepper, Phygon with pea, Dithane with cress, and Dow Seed Protectant No. 9 (0.45 gm. per square foot) with cabbage, beet, and cucumber. The last named fungicide, however, was injurious to pea, onion, pepper, and tomato in some soils. The use of fertilizer as a carrier for a soil fungicide is simple and appears promising; and it should be noted that applications of 0.6 or 0.45 gm. per square foot are only about 57.6 or 43.2 pounds per acre.

Seed treatments and several standard soil treatments for the control of preemergence damping-off of *Lilium regale* were compared. The disease was best controlled by seed treatment with Thiosan, Arasan, or Semesan. Spergon or Fermate similarly used gave inferior results and so did the several soil treatments.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) The hemlock, *Tsuga canadensis* (L.) Carr., is highly variable and there are indications of increasing demand for some of the better clones, a demand which will exceed the present supply. Work on their vegetative propagation was accordingly begun. Different clones were found to respond very differently to the same treatments, rooting of cuttings from some, not from others, being improved by treatment with indolebutyric acid 200 mg./l., 8 hours, or 100 mg./l., 6 hr., with powder dips less effective. Rooting of cuttings of hemlock, taken in October and November, was not improved by supplementary treatment with the fungicide Arasan[1] applied after treatment of the cuttings with a root-inducing substance.

The effects of root-inducing substances and fungicides applied together to the cuttings of several conifers and of American holly was also investigated. Cuttings of holly rooted in larger percentages after treatment with indolebutyric acid alone (100 mg./l., 20 hours) than they did if that treatment was followed by treatment with Fermate or Spergon.

A root-inducing treatment which was applied with benefit to cuttings of holly taken in October was apparently injurious to cuttings taken in January.

As a carrier of indolebutyric acid applied as a powder-dip, Spergon caused some injury to cuttings of Norway spruce, but Fermate or Arasan caused no injury.

Rooting of cuttings of hemlock, American arbor-vitae, and Chinese juniper was improved by treatment with indolebutyric acid 4 or 8 mg./gm. Fermate.

Some work was done on vegetative propagation of the Kudzu vine, *Pueraria Thunbergiana* (Sieb. and Zucc.) Benth., interest in which, both as a forage crop

[2]The abstract of a paper by W. L. Doran and T. Sproston, Jr., on "The Control of Onion Smut by Fungicides Applied to the Soil" was published in Phytopathology 35:8:654. 1945.

[1]The active ingredients of this and the other fungicides mentioned are named in the report on the preceding project.

and for soil conservation, is increasing. One-node cuttings responded well to powder-dip treatment with indolebutyric acid, but many cuttings died after rooting if taken as late as September.

In work with the Department of Pomology on the propagation of apple dwarfing stocks, cuttings of Malling No. 4 rooted well if taken in early May and given powder-dip treatment with indolebutyric acid.

Observations on the subsequent growth of rooted cuttings of white pine were continued in the field. They appear to be developing into normal, well-formed young trees.[2]

Surface watering was compared with subirrigation as factors affecting rooting of cuttings of conifers. Cuttings of hemlock, Hinoki cypress, two species of fir, and two species of spruce taken in November rooted better in sand watered from above than in sand subirrigated.

Work on the propagation of the rose by cuttings, initiated at the request of florists who could not obtain grafting stock, was concluded and results published.[3]

Tomato Leaf Mold Caused by the Fungus, Cladosporium fulvum Cke. (E. F. Guba, Waltham.) Four tomatoes resistant to leaf mold were developed to desirable commercial type and released for commercial trial for the fall growing season of 1945. These types were designated Improved Bay State, Improved Vetomold-121, Leafmold Resistant Marglobe, and Leaf Mold Resistant Waltham Forcing. Resistance to the fungus was derived from Plant Introduction No. 112,215, a *Pimpinellifolium* type from Educador. These tomatoes are considered acceptable by the growers. The resistant Marglobe cross is particularly promising.

Four similar tomatoes which derived their resistance from Plant Introduction No. 129,882 from Peru are now completely susceptible to the disease. Other named varieties developed for resistance have also acquired complete susceptibility; namely, Globelle, Veteomold, Vetomold-121, and Bay State.

Varieties introduced to the trade as resistant, apparently have but a limited period of utility before the advantage of resistance is completely lost. Apparently, this is due to the increase in the virulence of the fungus during its culture on successive generations of resistant hosts. Loss of resistance is anticipated in the types derived from Plant Introduction 112,215, and newly released to growers for trial.

The cross of Prince Borghese, an Italian esculentum paste type, with *L. peruvianum* outcrossed to Pan America (No. 44 B 292), and of the same cross backcrossed to Prince Borghese (No. 44 B 293) by W. S. Porte, United States Department of Agriculture, are now the subject of study. *L. peruvianum* is highly resistant to *Cladosporium fulvum* (Mass. Agr. Expt. Sta. Bul. 393:7, 1942). *L. peruvianum* and the wide range of phenotypes in the above crosses are also being studied for their reaction to the rootknot nematode.

Causes and Control of Decay of Squash in Storage. (E. F. Guba, Waltham.) Six plots of squash were grown, each of the same number of plants and identical areas of land. These plots yielded 3871, 3628, 3844, 4935, 3676, and 2742 pounds of squash, respectively.

Hubbard and Butternut squash from plots sprayed five times with Bordeaux 4-4-50 combined with 1 pound calcium arsenate were practically disease-free at harvest, in contrast to the squash from plots not sprayed with fungicide, which

[2]A manuscript on "The Vegetative Propagation of White Pine" has been prepared for publication.

[3]A paper, "Propagation of the Briarcliff Rose by Cuttings" by W. L. Doran, was published in Florists' Exchange 105:11:7, 21. 1945.

showed considerable *Mycosphaerella*, *Choanephora*, and *Alternaria* rots at harvest. The squash from the sprayed plots showed the least amount of decay in storage September 25, 1945–January 2, 1946). The sprayed plots ranked fifth in yield.

There was no difference in amount of decay between long and short stemmed squash from unsprayed field plots.

Dipping Hubbard squash in wax-water-formaldehyde emulsion[1] after harvest did not control decay and did not prevent shrinkage from transpiration. The same treatment of Butternut squash reduced shrinkage considerably but had no effect on the control of decay.

Detail drawings of the fungi of squash decay and photographs of the various kinds of decay have been prepared.

Interrelation of Wettable Sulfur, Lead Arsenate, and Lime in Apple Spraying. (E. F. Guba, Waltham.) Studies were handicapped by the lack of fruit due to freezing and unseasonal temperatures during and subsequent to the blossoming period.

Several fungicides were compared for their eradicant effect on foliage scab. Fermate 1½ pounds, Puratized N 5 E 6 1/3 liquid ounces, and lime sulfur 2 gallons in 100 gallons of water gave the best results, judged by germination studies of the scab spores sampled from the scab lesions at intervals following the treatments. Of these, Puratized gave a superior eradicant effect. The foliage was freed of viable scab spores and the scab mold was removed without any leaf injury. There was no spore germination associated with the Fermate treatment although the spores appeared normal; yet the character of the scab mold on the leaves seemed not to be changed and the amount of scab appeared to increase. The eradicant action of lime sulfur appeared good, yet there was a considerable come-back in spore germination and some burning of the foliage. A second and third treatment gave more complete disinfection of the foliage. The addition of lead arsenate contributed nothing to the eradicant action of lime sulfur.

Analytical studies of sprayed foliage showed greater initial deposits of flotation paste sulfur than of dry wettable sulfur. Weathering action caused more loss of dry wettable than of paste sulfur. Paste sulfur gave the better control of scab.

On the basis of a small tabulation of apples, the period of susceptibility to fruit russet on Baldwin and Delicious apples is believed to occur in the pink, calyx, and first cover stages in tree development. Since none of this injury is caused by a combined spray of Fermate and lead arsenate, it is recommended not to use combined sulfur and lead arsenate until the period designated "second cover."

Resistance to Fusarium dianthi Prill. et Del., the Cause of a Serious Carnation Wilt Disease. (E. F. Guba, Waltham.) From a list of carnation varieties determined to be significantly resistant to *Fusarium dianthi*, the following were retained for breeding purposes and further study.

Dorothy Napier	King Cardinal
Eleanor	Maine Sunshine
Elizabeth Rowe	Miller's Yellow
Georgina	My Love
Hazel Draper	Puritan
Helen Hussey	Tom Knipe
John Briry	Woburn

[1]This wax emulsion disinfectant consisted of 2 quarts formaldehyde, 20 gallons water, and 3 gallons Ceremul wax (Socony Vacuum).

Breeding (selfing and crossing) was handicapped by the failure of some of these varieties to produce pollen and by the production of pollen of others during a limited season. Seed from selfing and crossing has been obtained. More success is anticipated in another season.

Combinations of Fermate and Arasan with hormone powders in the ratio of 10 percent fungicide and 90 percent hormone powder, as a treatment of the basal end of cuttings before they are inserted in the sand, combined disease control with better rooting. Similarly, either Fermate or Arasan combined with talc in a 10-90 ratio gave good control of branch rot and was not harmful to rooting. Comparable results were secured with concentrated Fermate and Arasan. Immersion of the cuttings for 15 minutes in a 1–1,000 solution of potassium permanganate was relatively unsatisfactory. The tests were based on the varieties Eleanor, Olivette, and King Cardinal.

Control of Seed Decay and Damping-off of Vegetable Seedlings with Seed-borne Chemicals. (E. F. Guba, Waltham.) Since the publication of Bulletin 394, "Control of Damping-off of Vegetables by Formaldehyde and Other Chemicals," in June 1942, further seed treatment trials have been made each year. As a result of these studies, Spergon (tetrachloro-parabenzoquinone) is given wider prominence, and Arasan (tetramethyl-thiuram-disulfide) is added and recommended for most vegetable seeds except crucifers. The chemical 2, 3-dichloro-1, 4-napthoquinone (Phygon) is another valuable addition. Revisions in seed treatment recommendations have been made, based on these studies.

Tobacco Frenching Induced by High Soil Temperature. (L. H. Jones.) After Havana Seed tobacco plants had become established in vigorous growth at a soil temperature of 70° F., the soil temperature was raised to 95° in one half the series, while the other half was left at 70° as a check. Frenching eventually developed in all the plants at the high temperature and the check plants remained normal.

The fact that the plant containers used in previous experiments were of galvanized iron suggested the possibility of toxicity from zinc compounds made soluble by a high moist temperature in the presence of soil constituents. To eliminate this possibility, one-gallon glazed crocks were set into the two-gallon galvanized iron containers. Lime in the form of calcium hydroxide and boron in the form of borax were added to a portion of the series. The frenching symptoms appeared in all plants at 95° F. soil temperature and were absent at 70° F. regardless of other treatment. Prior to the appearance of extreme symptoms of frenching, leaves intermediate in development between normal and truly frenched exhibited an interveinal chlorosis best described as pinhead mottling. Whenever this occurred, terminal growth decreased and the tip of the plant gradually developed a rosette of typically frenched leaves. There was considerable time lag between exposure to the high soil temperature and appearance of the pinhead mottling. Plants in the glazed containers were the first to show the symptoms, 21 days being the minimum time and this in the months of February and March. Limed soil produced the largest plants and delayed the appearance of the symptoms, the time lag being 35 days. Borax delayed the appearance of symptoms still longer, 57 days, but did not reduce their severity. The cessation of terminal growth as one of the symptoms of frenching sometimes released the inhibitory influence in the development of buds in the axils of the leaves. When growth in the axils did occur on frenching plants, it was either an elongating axillary shoot with frenched leaves. eventually producing a rosette comparable to that on the original terminal shoot, or simply a rosette of frenched leaves in the axil. The elongating shoots were nearer the tip of the plant and the suppressed shoots were nearer the base.

After the experiment had been running 80 days, all the plants were topped below the terminal growing point, and half the plants which had been at 95° F. soil temperature were exchanged with plants which had been at 70°. The shift was made in April when the daylight period is longer than in February when the experiments were started. The time lag before frenching symptoms appeared in the plants shifted to the high temperature was shortened, possibly because of better growing conditions. The minimum time before the appearance of the pinhead mottling which preceded the development of frenched leaves was reduced from 21 to 14 days. The same pattern of frenching symptoms was in evidence. Axil shoots which developed on plants shifted to 95° soil temperature had a carry-over of the normal characters of the 70° soil temperature, but eventually leaves developed with the frenching characters. Plants which had been shifted from 95° to 70° soil temperature also had a carry-over which expressed itself in some cases on the axillary shoots that developed just below the decapitated terminal. These shoots showed intense frenching on the lower leaf, but each succeeding leaf was less frenched until an apparently normal leaf was finally produced. There were instances where young leaves, decidedly frenched, began to grow again when shifted to the lower temperature and became wider with less waved margins, but they never developed into leaves of normal shape. On the other hand, no leaves of normal shape developed frenching symptoms when shifted from the low to the high soil temperature.

These results suggest that soil temperature may play a regulatory role in the frenching of tobacco by affecting absorption or translocation of nutrient elements and may even affect metabolic activity to the extent of creating growth-controlling substances either by synthesis or as by-products of a breakdown of chemical compounds within the plant.

Toxic Effect of Wood Preservatives on Plants. (L. H. Jones.) In previous work with lumber impregnated with asphalt, injury to seedling plants was traced to a small quantity of creosote which had not been removed from the resins. It has now been demonstrated that when the creosote is entirely removed there is no injury to plants from such treated wood.

It is generally understood that the greatest damage done to green leaves by creosote fumes is by the toxic action of the gas entering the leaf through the stomata. It now appears that damage may be caused also by the dissolution of the leaf, which exposes the tender cells to the dehydrating effect of dry air. Further investigation will be necessary to confirm this type of injury.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Factors Affecting the Vitamin Content of Milk and Milk Products. (Arthur D. Holmes.) The investigations that have been conducted under this project during the past year, involve consideration of several factors, but the published papers dealt with two topics: the food value of ice cream as a source of common vitamins, and the vitamin content of mare's milk.

Ice Cream As a Source of Riboflavin, Carotene, and Ascorbic Acid. (Arthur D. Holmes, John W. Kuzmeski, Carleton P. Jones, and Frank T. Canavan.) Coffee, maple, and vanilla ice creams were manufactured on the commercial scale in the Dairy Laboratory from 24.4 pounds of cream (40 percent), 56.3 pounds of whole milk, 15.0 pounds of cane sugar, 4.0 pounds of skimmed milk powder, and 0.3 pound of gelatin. The overrun was 85 percent; i.e., 9.25 pounds per gallon of the ice cream mixture weighed 5 pounds per gallon when frozen. Ten samples of each flavor of ice cream were assayed. The carotene content was 0.10 mg. per 100 gm.; the riboflavin, 0.26 mg. per 100 gm. No reduced ascorbic acid could be detected in any samples, probably owing to destruction by the large amount of air incorporated in commercial ice cream to increase its bulk. Comparison of these ice creams with numerous widely used foods, showed them to be excellent sources of carotene and riboflavin. Since the average yearly consumption of ice cream is estimated at three gallons per person, it contributes significant amounts of carotene and riboflavin to the human dietary.

The Vitamin Content of Mare's Milk. (Arthur D. Holmes, Beula V. McKey, Anne W. Wertz, Harry G. Lindquist, and Leonard R. Parkinson.) This investigation was undertaken to compare the composition of cow's milk and mare's milk—two species of animals that consume the same type of ration, but possess different types of digestive tracts. Studies have shown that the vitamin content of cow's milk is likely to be due in part to vitamins produced by bacterial synthesis in the cow's rumen, but the mare has no rumen. This, the initial paper of a proposed series, reports the results of assays of mare's milk for ascorbic and nicotinic acids, riboflavin, thiamine, bacteria, fat, size of fat globules, and total solids. Three normal, adult Percheron brood mares, in the latter stages of lactation, were used as a source of the milk. Eleven samples of fore-milk were obtained from each mare in the early morning. The average values obtained were: ascorbic acid, 12.9 mg.; nicotinic acid, 0.72 mg.; pantothenic acid (3 samples,) 2.77 mg.; riboflavin, 0.11 mg.; thiamine, 0.39 mg. per liter; bacteria, 3.70 per cc.; fat, 1.2 percent; fat globule size, 3.4 microns; and total solids, 10.20 percent. The values for ascorbic acid, nicotinic acid, riboflavin, fat, and total solids were lower than the corresponding values for milk from cows that consumed the same pasturage; but the thiamine values were higher. The greatest difference in vitamin content between mare's and cow's milk was in riboflavin. As yet, it is impossible to explain why the former has much less than one tenth as much riboflavin as the latter.

A Study of the Changes in Vitamin Content Coincident with Different Stages and Rates of Maturity of Vegetables Used for Home Consumption. (Arthur D. Holmes and Carleton P. Jones.) During the past year published results from the studies in this field have been concerned with kale and summer squashes grown under local climatic and cultural conditions, and supply information of particular value regarding the value of these vegetables for the human diet.

Influence of Supplementary Calcium and Magnesium Fertilizers Upon Nutritive Value of Kale. (Arthur D. Holmes, Leo V. Crowley, and John W. Kuzmeski.) The kale was grown on a Merrimac fine sandy loam in four experimental plots, all of which received a commercial 4-9-7 fertilizer at the rate of one ton per acre. In addition, the experimental plots received varying amounts of magnesium sulfate, ground limestone, or both, with one plot serving as a control. Twenty samples of kale were assayed for water, calcium, iron, magnesium, phosphorus, and carotene. The addition of 150 pounds of magnesium sulfate per acre definitely increased the magnesium content of the kale and may have slightly increased the calcium and phosphorus content. Limestone, applied at the rate of 1,000 pounds per acre, definitely increased the calcium and phosphorus content of the kale and may have depressed its iron content. Neither magnesium sulfate nor limestone nor both produced any pronounced effect on the water or the carotene content of the kale. As compared with other leafy vegetables kale is rich in carotene, the precursor of vitamin A. Judged by the results of this study, the use of magnesium sulfate and limestone as supplementary fertilizers enhances the food value of kale.

Ascorbic Acid, Carotene, Chlorophyll, Riboflavin, and Water Content of Summer Squashes. (Arthur D. Holmes, Albert F. Spelman, and Carleton P. Jones.) Seven varieties of this vegetable were studied. Five were *Cucurbita pepo* L. and two were *Cucurbita moschata* L. The ascorbic acid content of the raw squashes varied from 4.2 mg. for Cocozella to 16.7 mg. per 100 gm. for Early White Bush Scallop. Four varieties—Early Summer Crookneck, Early Summer Prolific Straightneck, Golden Cushaw, and Early White Bush Scallop—contained over half as much ascorbic acid as milk, decidedly over half as much as summer tomatoes, and from 50 to 100 percent more than late-winter tomatoes. The carotene content varied from 0.06 mg. for Early White Bush Scallop to 6.21 mg. per 100 gm. for Golden Cushaw. Two varieties, Butternut and Golden Cushaw, were extremely rich in carotene. The chlorophyll content varied from 0.42 mg. for Early Summer Prolific Straightneck to 12.25 mg. per 100 gm. for Zucchini Grey. The two squashes with green-colored skins, Cocozella and Zucchini, contained large amounts of chlorophyll. The raw squashes were rich sources of riboflavin. The Early White Bush Scallop contained about 33 percent, Butternut about 49 percent, Early Summer Crookneck about 79 percent, Cocozella more than 115 percent, and Golden Cushaw about 166 percent as much riboflavin as milk produced in this locality.

Vitamin Content of Field-Frozen Kale. (Arthur D. Holmes, Beula V. McKey, Katherine O. Esselen, Leo V. Crowley, and Carleton P. Jones.) It is generally agreed that the leafy green vegetables are extremely valuable components of the human diet. Unfortunately, nearly all the green vegetables are seriously damaged, if not destroyed, by freezing temperatures. Following the first killing frost, there is a considerable period during which plants that escape the frost thrive, and kale is one of these. Because of the scarcity of fresh green leafy vegetables in gardens in this area during the late fall, it seemed desirable to determine the vitamin content of field-frozen kale. Dwarf Blue-Green Scotch kale that had been subjected to freezing seven times during the previous month, was collected for assay. Eighteen samples were examined. Very mature and immature leaves were analyzed, with the following results:

	Mg. per 100 gm.	
	Very Mature Leaves	Immature Leaves
Ascorbic acid	158.6	212.2
Carotene	6.3	5.6
Nicotinic acid	1.94	2.21
Pantothenic acid	0.73	0.91

These figures supply evidence that field-frozen kale can contribute essential nutrients for the human diet, especially when the supply of fresh green leafy vegetables grown in this area is limited.

Physico-Chemical Properties of Starch. (Monroe E. Freeman.) The abnormal specific heats found previously for starch suspensions may be explained by the presence of a loosely bound shell of absorbed water on the starch grains. The quantitative data follow mathematical equations relating the composition of the sample, the heat of desorption, the amount of loosely bound water, and the maximum hydration capacity. The identical behavior of gum arabic, lemon pectin, egg albumin, and gelatin verifies this explanation. Cellulose, agar agar, and sodium bentonite systems apparently do not have this loosely bound fraction. This seems to be a general characteristic of hydrophillic colloids that has not been previously demonstrated.

The quantitative evaluation of this factor affords, for the first time, an accurate measurement of the specific heat of starch suspensions and permits the measurement of the heat of gelatinization. Preliminary experiments have indicated that this may be much lower than previously reported in the literature and may even be non-existent. Further experiments now in progress are expected to throw some light on the mechanism of starch gelatinization.

The Chemical Investigations of Hemicelluloses. (Emmett Bennett.) During the past year some of the data reported previously have been checked and certain difficulties encountered have been eliminated. The acetylation procedure generally used in this investigation would not produce the diacetate of xylan in the hemicellulose from rye straw. It was necessary to hydrate this material and to dehydrate it without exposure to air just prior to acetylation. In this way, the theoretical acetyl content could be obtained almost completely.

Results obtained so far in this investigation would seem to indicate that anhydroxylose and a hexuronic acid anhydride account for approximately 85 and 90 percent of the hemicelluloses of maize cobs and rye straw respectively. The proportions of these two constituents would correspond to a chain of anhydroxylose units approximately 30–32 units in length and terminating in a hexuronic acid group. The sugars seem to have the pyranose structure and to be connected to each other through a beta-linkage. A hexose was present to a slight extent in both hemicelluloses, while l-arabinose was detected in maize cob hemicellulose only.[1]

Studies on the Quantitative Estimation of Hemicelluloses. (Emmett Bennett.) The success of the method being tested for the quantitative determination of hemicelluloses depends upon the production of a holocellulose which contains all the hemicellulose. The percentage recovery of furfural and the color of the holocellulose were used as an index for the preparation of a holocellulose fraction which would be suitable for the quantitative extraction of hemicelluloses. A procedure suitable for the determination of this fraction in non-woody plants has been standardized. Furfural determinations on holocellulose from five different plants indicate that from 95 to 99 percent of the furfural in the original tissue can be recovered.

Nitrogenous residues seem to be the chief contaminants of holocellulose prepared from cereal grasses. In some cases 50 percent of the total nitrogen may be retained.

Preliminary extractions of hemicelluloses from holocellulose with 1.25 percent sodium hydroxide and the aid of a Waring blendor for periods of different length, yield the same results. This is believed to be indicative of a complete extraction of the more loosely bound hemicelluloses, since the residual material still bears compounds which will yield furfural.

Extracts were oxidized under definite conditions by means of a solution of hot chromic acid. The amount of material oxidized was determined colorimetrically by means of a spectrophotometer. Calibration lines were constructed from data obtained by oxidizing pure solutions of glucose and xylose under definite conditions. From such lines and the percentage transmission of an unknown solution, the percentage concentration can be determined as xylose or glucose.

The Investigation of Agricultural Waste Products. — 1. The Chemical Investigation of Lignin. (Emmett Bennett.) The results of the study of the effects of large quantities of pure lignin upon the aerobic decomposition of plant materials appear in the forthcoming volume of the Proceedings of the American Society for Horticultural Science.

[1]The results have been accepted for publication by the Journal of Agricultural Research.

The present line of investigation deals with the oxidation of lignin by nitric acid and by reagents in which the cation changes valence such as ceric sulfate. No comments are warranted at this time.

CONTROL SERVICES

Philip H. Smith in Charge

The fertilizer, feed, seed, and milk testing laws are administered as one service and the operations of each of these, with the exception of the milk testing law, are reported in annual bulletins issued for that purpose.

Under the milk testing law 5,623 pieces of Babcock glassware were tested for accuracy and 107 certificates of proficiency in testing were issued. In addition, all milk depots and milk laboratories in the State, of which there are 192, were visited at least once, as required by statute, in order to check apparatus and the general conduct of the work. It can be assumed that the greater part of the milk sold in Massachusetts is now paid for on the basis of weight and test rather than by the quart.

Under the fertilizer act the number of brands registered was about the same as for 1945; 258 in 1945 and 260 in 1946. This in spite of Federal regulations and the effort of agronomists to reduce the number of grades manufactured. The number of samples collected and analyzed has been less than for normal years but it is believed that the samples collected fully represent the grades offered in Massachusetts. Deficiencies (variations from guarantee) have not been so extensive as in previous years.

While the tonnage of feed sold in Massachusetts has been reduced because of shortages, many brands have been found that have not been previously offered for sale within the State. This has been due in large measure to the inability of many feed manufacturers to fill the requirements of their customers, who have therefore been obliged to look to smaller mills in the Middle West.

The work of the seed laboratory has continued to grow, largely on account of the realization on the part of seed dealers of the prime importance of good seed if good crops are to be expected. Through the Federal Seed Act, where seeds have entered into interstate commerce, the laboratory has been able, through cooperation of the Federal officials, to cause the prosecution of flagrant violations. This as a Federal and not as a State matter.

Considerable time has been devoted to assays and analyses not directly connected with the Control Acts but for which there appears to be a need. With increasing knowledge of the role of trace elements in plant and animal nutrition, the fertilizer and feeding stuffs laws should be made more comprehensive so as to include such elements where their presence is indicated as a part of the guarantee. Such legislation should also include vitamins where their presence is claimed.

As in the past, the Control laboratories have examined fertilizers, feeding stuffs, and other material for citizens of the State without charge wherever the work could be considered of general public value. More than the usual number of samples of feed were received which the feeders claimed to have caused the death of poultry. With few exceptions the contention could not be proved by any analysis to which the feed was subjected.

In addition to regular routine duties Control Service has been called upon to the extent of time available to assist other departments of the College and Station in conducting work in connection with research problems not originating in the department itself.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)
DDT. This insecticide was advocated as a control for gypsy moth caterpillars in the annual Cranberry Insect and Disease Control Chart in the spring of 1946, and it was used widely and freely both on bogs and on the surrounding uplands, especially in Plymouth County, with entirely satisfactory results. In spraying, complete kills were obtained with 2 pounds of the 50 percent wettable powder in 100 gallons of water, 400 gallons to an acre; and with 3 pounds in 100 gallons, 250 gallons per acre. In dusting, 50 pounds of the 5 percent dust to the acre was used. No injury to cranberry vines from the DDT appeared.

DDT was used considerably as a spray and as a dust treatment for the first brood of the black-headed fireworm in May and early June, 1946, in the amounts found effective against gypsy moth caterpillars, and the control appeared to be satisfactory in all cases. Its further use against first-brood fireworms seems advisable. It probably should not be used on second-brood fireworms or on blunt-nosed leafhoppers till more is known about its effects on bees.

Fireworm Flooding. Flooding for as short a period as 10 hours to kill the less-than-one-third-grown black-headed fireworms of the first brood was tried very successfully in 1945 and was advocated in the 1946 Cranberry Insect and Disease Control Chart. Various cranberry growers tried this treatment in the spring of 1946, some of them with excellent results. It was found that, to be entirely successful, it has to be repeated once or twice at intervals of a week to 10 days. The success of this treatment seems to be based on the following facts:

(a) It is especially important to kill the leaders of the first brood of worms, for their moths lay most of the eggs which produce the second-brood worms of this only partially two-brooded insect.

(b) A short flooding kills the smaller worms more easily and completely than the larger ones.

(c) Short floodings are less likely to harm cranberry vines than the longer ones heretofore employed.

Dusting by Airplane. Extensive tests of dusting by airplane were conducted by the A. D. Makepeace Company in the spring of 1946. Observations of the results indicated that this method of treatment is practicable on cranberry bogs when properly applied. It probably will come to be used widely in treating the gypsy moth and the black-headed fireworm.

Prevalence of Cranberry Insects in the season of 1945:

1. Gypsy moth infestation moderate, but heavy in some sections.
2. Leafhoppers (*Ophiola*) not very plentiful.
3. Fruit worm infestation lighter than for many years, in very striking contrast to the severe infestation of 1944.
4. Black-headed fireworm less troublesome than usual.
5. Practically no fire beetles (*Cryptocephalus*) found.
6. Very few spotted fireworms (*Cacoecia*) found.
7. Ladybugs normally abundant.
8. Spanworms in general not troublesome.
9. False armyworm (*Xylena*) infestation normal.
10. Black cutworm (*Euxoa*) infestation medium, mostly on bogs flowed for control of root grub (*Amphicoma*).

11. The armyworm (*Cirphis*) broke out on a good many bogs from which the winter water was let off late. They appeared in some cases where the water was let off as early as May 20. This was very unusual and may have been due to the very warm weather in March and April.

12. Cranberry girdler (*Crambus*): General infestations by this insect on the Cape Cod cranberry bogs were more severe than for many years, this evidently being due largely to lack of sanding because of labor shortages and to lack of dusting because of the shortage of Pyrethrum.

13. Spittle insect, cranberry weevil, and tipworm infestations about normal.

14. Bumblebees and honeybees less abundant than usual. Scarce on many bogs.

Weather Studies. (H. J. Franklin.) A project entitled "The Relationship of Weather to Cranberry Production through its Various Effects on Photosynthesis and Growth," established in December 1935, was brought to a close in May 1946, and the results were presented for publication as a bulletin of the Station.

Frost forecasts were continued as a special service, 212 cranberry growers subscribing to the telephone service. The forecasts by radio were cooperative between the United States Weather Bureau office at Logan Airport and the Cranberry Station at East Wareham and were distributed by stations WEEI at Boston and WOCB at West Yarmouth.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

New Sterilizing Agents for Dairy Use. (W. S. Mueller, E. Bennett, and J. E. Fuller.) The germicidal properties of the following surface-active agents have been investigated further: 9 quaternary ammonium compounds, 3 phosphonium compounds, 3 substituted phenols, 10 alkyl aryl sulfonates, 1 aryl alkyl polyether sulfonate, 1 aliphatic sulfonate, 1 aryl alkyl polyether alcohol, 2 polyoxyalkylene of fatty acids, 1 aliphatic sulfate, 1aryl alkyl polyether sulfate, 4 monoesters of polyhydroxy compounds, and 6 unknowns. Other properties which were investigated are stability, corrosiveness to metals, solubility, odor, taste, and color. Germicidal tests made within one year after the surface-active agents were obtained showed that 9 were effective sterliizing agents, 9 were moderately effective, and 24 were ineffective. The effective group included only quaternary ammonium and phosphonium compounds; while the moderately effective group included substituted phenols, alkyl aryl sulfonates, and aliphatic sulfonates. One or more of the materials of each class were represented in the ineffective group, with the exception of phosphonium compounds, substituted phenols, and aliphatic sulfonates. After 2½ years of storage only the quaternary ammonium and phosphonium compounds retained their effective germicidal properties, while all of the materials which were found to be moderately effective at first had lost most of their germicidal properties during storage. No correlation was noted between pH values, germicidal property, and stability of the products. The quaternary ammonium compounds were readily soluble, were not objectionably corrosive to metals, and were practically odorless, tasteless, and colorless, all of which are desirable properties of a dairy sterilizing agent. While the phosphonium compounds also were non-corrosive to metals and had no serious objectionable odor and taste, they did not go into solution readily and produced cloudy solutions. Results to date indicate that only the quaternary ammonium compounds show more than ordinary promise as a superior sterilizing agent for dairy use. A paper on this study has been submitted for publication.

Effect of Certain Antioxidants on the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller.) Further studies have been made on the antioxidative properties of cacao-shell and cocoa powder and certain extracts of these products, by noting their effect in butter oil, with and without added copper. Two accelerated tests, the Modified Schaal Test and the Swift Fat Stability Test, were used and the following determinations were made: Peroxide value, color (indirectly vitamin A), taste, and odor. The cacao antioxidant was more effective for butter oil in the presence of copper than in the absence of the metal, and was a potent inhibitor of the pro-oxidant effect of copper. The natural inhibitors of cacao-shell and cocoa powder were successfully extracted with suitable solvents. Drying the extracts to a powder did not significantly decrease their protective properties. The cacao inhibitor was found to be more potent than the natural inhibitors of wheat germ and of oat flour. A cacao-tannin was isolated from cacao shell and was found to be less potent as an inhibitor than pure tannic acid.

Study of Packaged Ice Cream. (J. H. Frandsen.) During the year further studies have been made in comparing the palatability of packaged and bulk ice cream under factory, drugstore, and ice cream retail store dipping conditions. Results of studies here and conferences with men in plants indicate that, under ideal conditions and with trained personnel, losses in dipping bulk ice cream may be reduced to from 20 to 30 percent. However, under ordinary conditions and with unskilled scoopers, there is a loss of from 30 to 40 percent in volume from packaging bulk ice cream as compared with the same ice cream machine-packaged directly from the freezer.

Our research work would indicate that if packaged ice cream is made from mix of the same composition as bulk ice cream, and if the overrun of the packaged ice cream is reduced 15 percent from that of bulk ice cream, the resultant ice cream should be fully as palatable and nutritious as bulk ice cream. This should overcome the prejudice now existing against packaged ice cream. The trend is towards packaged products, and packaged ice cream is in line with this trend. Machine-packaged ice cream can be kept at a lower temperature than bulk ice cream and therefore should reach the home of the cash and carry consumer in a more satisfactory condition than the warmer hand-packaged bulk ice cream.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Effects of the War and Readjustments in Massachusetts Agriculture. (David Rozman.) The major phase of the work on this project has been completed and the results presented in Bulletin 430 published under the title, "Postwar Readjustments in Massachusetts Agriculture." Of special significance among the various readjustments emphasized by the results of the study is the reconstruction of land resources in farming areas. Other important facts and recommendations brought out by the study are:

1. More than half of the commercial farming units in Massachusetts fail to meet desirable requirements of income for farm families.
2. The greatest need is for the reconstruction of substandard farming units into efficient, economic family farms capable of providing an adequate level of living under modern conditions.

3. The classification of soil and field investigations carried out in a number of towns indicate that improvement of undeveloped areas, where the cost is justified by resulting benefits, may serve to enlarge and improve land resources on existing farms, to make possible the replacement of poor land now in use, and to provide for new farming units.

4. Improvement in the condition and productivity of pasture and hay lands, the most important assets in Massachusetts agriculture, will reduce costs and improve the position of many Massachusetts farms.

5. Management of farm woodlands, which represent about 37 percent of the total area of Massachusetts farms, should be integrated with other farming operations to secure higher returns to producers.

6. The position of Massachusetts agriculture in the postwar period will be determined by the successful reduction of costs through the adoption of the most efficient methods, whether they are in the use of land resources, the employment of labor, the use of machinery, or the marketing efforts.

Additional material, prepared in connection with agricultural readjustments was presented in a manuscript dealing with the 1946 production program for Massachusetts agriculture.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and H. F. Bergman.) Storage investigations on cranberries were continued during the 1945 season. Berries were put in storage on September 7 and removed and screened on November 1. Losses under different conditions of storage were as follows:

	Percentage Loss	
	At Screenhouse Temperature	At 45 degrees
In normal atmosphere	8.4	5.6
In controlled atmosphere:		
11 percent carbon dioxide	12.3	
2.5 percent carbon dioxide	.	7.4

Berries stored in a carbon dioxide atmosphere, even at the low concentration of 2.5 percent, colored much less than those stored in normal atmosphere. Berries stored at 45 to 50 degrees color much more than those held at lower or higher temperatures, all being stored in normal atmospheres.

Storage of berries in refrigerated rooms at temperatures from 35 to 45 degrees will reduce storage losses considerably below that which occurs in the common screenhouse. Storage in controlled atmosphere holds but little promise of success.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) In the study of poultry housing, emphasis was placed on method of ventilation and arrangement of equipment to permit the housing of the maximum number of birds in a given pen. The test pen housed 150 birds, allowing 2.66 square feet per bird. This pen would normally house only 100 birds, and this number was housed in the check pen which is equal in size to the test pen. Better use of floor space was obtained in the test pen by raising feed hoppers and watering troughs off the floor. The down-draft baffle ventilator was used in this pen, opened to the extent that ventilation was increased proportionately with the increase in the number of birds as compared with the check pen. The litter was not changed during the season. At the end of the season the litter in the check pen housing 100 birds had a moisture content of 28 percent. In the test pen housing 150 birds, the moisture content of the litter was 36 percent. Egg production was equal in the two pens, but mortality was slightly higher in the crowded pen.

Electric ventilation was compared to natural ventilation through windows utilizing the down-draft baffle device. The electric fan was installed in a pen at the east end of an uninsulated house, while the check pen was the center pen in a three-pen insulated house. The electric fan was so installed as to circulate 300 cubic feet per minute, discharging through a long duct placed near the floor at the front of the house. The fan sucked in 90 cubic feet of fresh air per minute from the outside. The windows remained closed during the season. Foul air was discharged through an opening in the floor at the east end of the pen. The fan ran continuously and drew 40 watts.

The litter was not kept as dry as in former years, presumably because the pen was more crowded. The pen housed 100 birds, the same as the check pen. At the end of the season the litter contained 51 percent of moisture. Relative humidity in the pen was higher than in the check pen, but very little frost accumulated on the ceiling and temperature was kept higher than would have been possible with window ventilation. Egg production was slightly higher than in the check pen and mortality no higher.

Hay Drying. (C. I. Gunness and J. G. Archibald.) Mow drying of loose hay was continued in one of the college barns. This installation was used to take care of lots of hay which were too wet to put in the barn and which would very likely have been injured by rain if left out another day. The installation seemed very much worth while from this standpoint.

Three installations in the State have been available for study and observation. One, made in 1945 for drying baled hay, has a capacity of 50 tons and was filled three times in 1945 for three cuttings of alfalfa. Some of the bales contained up to 43 percent of moisture and in general came out very well to the satisfaction of the owner. One lot was put in in June of this year. Because of the excellent weather for haying, the bales were not put in as wet as last year, but wet enough so the hay has come out in good condition with excellent color.

Two other installations have been made in which air has been heated by being passed over steam radiators. The advantage of heating the air has been quite apparent, but a full report on this season's operations can not be made at this time.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

The early season of 1945 was characterized by very unusual weather conditions. During March there occurred a period of extremely hot weather which stimulated both plant and insect growth. European corn borer development was hastened so that pupation of overwintered larvae began much earlier than usual, and fruit bud development by the end of the month was approximately a month ahead of normal. In April, conditions reverted to ranges more normal for March, culminating in the freeze of April 23 which caused very general and severe damage to fruit buds and destroyed the crop in many orchards. May was cold and wet, conditions which were very unfavorable for activity of European corn borer moths and held the first brood of borers to such a low point that early corn suffered very slight damage whether treated or not.

The outstanding feature of June was excessive rainfall. Rain occurred on 17 days and the total rainfall for the month was 7.67 inches, a record exceeded only three times since the weather station in Amherst was established. One of the most severe hailstorms in recent years occurred on June 15, accompanied by 1.85 inches of rain. Hail knocked down some fruit and severely scarred most of that which remained on the trees. The hail also caused severe breakage of potato plants and the heavy rain washed some areas badly. The plots were flooded for more than 24 hours and neither spraying nor cultivation could be attempted for a week.

July was marked by heavy and frequent rains. The potato plots were again flooded and no spray equipment could be operated through them from July 9 to 23. Following this setback, plants in all but the higher areas began to turn yellow and died prematurely. During this period also, blight began to appear. Hot humid weather further aggravated the situation. Plants in most of the plots never recovered, and yield records could be taken from only small areas of higher elevation in the field.

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb.) Work in connection with the cooperative project with the Dow Chemical Company was continued in 1945, both at Amherst and Waltham.

Through the growing season, apple aphids were very scarce and there were practically no leafhoppers. European red mites were not only scarce but practically nonexistent throughout the college orchards and commercial orchards near by. It was not until about early September that there was any evidence of this pest. Then a sudden outbreak occurred in which a moderate to heavy infestation developed and some bronzing occurred. The attack was of comparatively short duration.

The experimental materials, Dinitro compounds D 289, D 389, C 506, and D 524, applied to apples while they were dormant, practically eliminated all aphid infestation, while on unsprayed checks the infestation averaged 720 aphids per 100 buds. None of the materials caused any direct injury to opening buds or retardation in seasonal development.

D-542 Dinitro-ortho-cresol, at both 4 and 5 percent strengths, caused an almost perfect kill of oyster shell scale on lilac.

The outstanding feature of the season's program was the successful control of the blueberry bud mite (*Erophyes vaccinii*) in commercial plantings by the use of Dn-111 in early June. Previous to these tests no spray application had been successful as a control measure. Dn-111, 20 ounces, plus Ultrawet spreader, 8 ounces, per 100 gallons reduced the number of mites per bud on the varieties Pemberton and Wareham from 54 and 59 before spraying to an average of 2.5 mites per bud for the two varieties, within 24 hours. Some injury resulted.

A second series of tests in which Dn was applied at strengths of 16 – 20 ounces per 100 gallons and at 150 pounds pressure instead of 400 pounds as in the first series, gave successful control of the mites in 24 to 48 hours and caused no serious burning. The concentration of the spray seemed to make little difference, but the reduction in pressure appeared to be an important factor in preventing injury.

In a late-season outbreak of European red mite on apples and beach plums, both Dn-111 and D-4 gave 98 to 99 percent control within 24 hours.

Studies of Different Forms of DDT. (A. I. Bourne and W. D. Whitcomb.) Materials tested were supplied by Geigy Company, Inc., and included Gesarol AK-40, Gesarol A-20 (water dispersible powders), and A-5 dust.

Orchard Tests Against Apple Pests.[1] Because of the adverse weather conditions mentioned above, several readjustments had to be made in the plans for the experiment. The set of fruit was light and scattering and much of it was severely damaged by hail. In the face of such handicaps the results of the season's work cannot be given as much weight as could be desired, but some significant differences were noted. Yield records were taken on McIntosh only.

On unsprayed checks, such fruit as survived the frost and hail damage ripened and dropped prematurely. Practically all of it was infested by curculio, codling moth, and apple maggot and blemished by scab.

DDT gave excellent control of codling moth. At a dosage of 1 pound Gesarol AK-40 (0.4 pound DDT) per 100 gallons, only 1.5 percent damage was recorded; and at a dosage of 2 pounds, no injury was found. The standard spray schedule in this block held codling moth damage to 3 percent.

DDT was not as effective against plum curculio as was the standard schedule with lead arsenate, although a combination of lead arsenate and DDT gave somewhat better control than lead arsenate alone.

No evidence of apple maggot damage appeared in any sprayed plot.

DDT on Potatoes. Reports that DDT has proved a good insecticide for potatoes would appear to be borne out in the 1945 tests. A spray contining 0.4 pound DDT (1 pound Gesarol AK-40) per 100 gallons combined with a 10–5–100 homemade Bordeaux mixture was used in the test plot. No aphid infestation developed in this plot during the season. There was a very conspicuous reduction in flea beetle damage in the DDT plot, and the highest yield of any of the plots (273 bushels per acre compared with 261 following standard 10–10–100 Bordeaux mixture with calcium arsenate). The vines in the DDT sprayed plot showed consistently more vigorous growth and remained green for a longer period than in any other plot.

The results of these tests in a season of very unfavorable weather conditions, correspond closely with those reported elsewhere. It can be expected that DDT will become an important element in the spray program for potato pests.

DDT on Onions. DDT spray at 0.4 pound DDT (2 pounds Gesarol A-20) per 100 gallons gave 89 percent control of onion thrips, as compared with 90 percent following application of a 4 percent derris powder (4 pounds per 100 gallons) and 91 percent following a fixed nicotine spray (3 pounds per 100 gallons). A 5 percent DDT dust gave 90 percent control compared with 81 percent following a 1 percent rotenone dust.

In a second series, heavy rain a few hours after application appeared to cut down the efficiency of most of the materials. DDT spray gave 82 percent control; derries 83 percent; and fixed nicotine, 80 percent. DDT dust gave 70+ percent control; rotenone dust, 61 percent. These results indicate that DDT was affected much less by rain soon after application than were the other materials.

Records of treated plots four days after treatment showed that DDT spray was giving 85 percent control, derris 38 percent, and fixed nicotine 71 percent. DDT dust showed 98 percent control; rotenone dust, 24 percent. Apparently DDT had a considerable residual effect.

In a third series, the Rohm & Haas wetting agent, Triton X-100, 6 fluid ounces to 100 gallons, was used with all spray materials and made a vast improvement in application and resultant effectiveness. DDT gave 99+ percent control, and derris 98.8 percent, in comparison with unsprayed checks. DDT dust gave 93 percent control.

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[1] Further details of these tests will be found under the project "The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts."

Rose Chafer. In two series of laboratory tests against the rose chafer, DDT spray at dosage of 0.4 and 0.8 pound DDT (Gesarol AK-40) and a 5 percent DDT dust proved very effective. Within one-half hour beetles began to show poor coordination, and became more and more inactive and helpless. After 5 to 6 hours practically all beetles were quite inactive and in about two days all died. There was practically no evidence of feeding or other normal activity after treatment.

Gypsy Moth. In three series of tests, one-half to three-fourths grown larvae soon began to show ill effects, poor coordination of muscles gradually increasing to inactivity. Within two to three days practically all had died. Full-grown larvae succumbed somewhat more slowly and in few cases attempted to form pupae. There was very little or no evidence of feeding after treatment.

A young planting of one-year-old apples, which showed an average infestation of about three half-grown larvae per tree and considerable foliage injury before treatment, was cleared of the infestation with one application. Half the block was sprayed with 0.8 pound DDT (2 pounds Gesarol AK-40) per 100 gallons, combined with a wettable sulfur fungicide. The rest of the block was sprayed with lead arsenate, 5 pounds to 100 gallons, plus wettable sulfur and excess lime. Examination five days after treatment showed no larvae on DDT rows, but one larva following arsenical spray.

Tarnished Plant Bug on Potatoes. A commercial planting of potatoes was attacked by tarnished plant bugs migrating from a recently cut field of clover and swarming over the plants of several rows of potatoes. Almost every growing tip was attacked and many were killed. One spray application of DDT, 0.5 pound per 100 gallons, cleared the field of bugs in about three days, and subsequent application to potatoes and an adjoining strip of clover stubble prevented further migration. The plants recovered and yielded an excellent harvest.

European Corn Borer. The infestation throughout the State was very light in 1945, particularly in the Connecticut Valley region. This was due in large part to adverse weather conditions during the period when moths were present. Emergence was prolonged, moth activity was seriously reduced by cold, wet weather, and egg laying was very slight and irregular.

A spray containing 2 pounds Gesarol A-20 (0.4 pound DDT) per 100 gallons, plus Ultrawet spreader, was used in four applications on sweet corn. Gesarol A-5 dust was also used in a similar schedule. Counts of tassel breakage as an index of stalk infestation, made just before harvest, showed no breakage at all in DDT plots (either sprayed or dusted) and only 9.5 percent breakage in untreated checks.

Yield records showed 2 infested ears out of a total of 265 (0.75 percent) in the plots sprayed with DDT. No infested ears were found in the dusted plots. Unsprayed checks yielded 239 ears, of which 4 (1.7 percent) were damaged by corn borer.

The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts. (A. I. Bourne, in cooperation with the Departments of Pomology and Plant Pathology.) The set of fruit was so light and uneven that the schedule of tests originally planned for this block had to be rearranged and all of the DDT series had to be relocated. Such records as were possible were taken from McIntosh plots at harvest. The crop of Baldwins, which was due to be light, was practically wiped out by the freeze and subsequent hailstorm.

Supplements to the Standard Schedule. On unsprayed trees the severe attack of all insect pests and the unusual severity of scab caused what fruit survived the early freeze and subsequent hail to drop by early August. Practically all of this was infested by scab, curculio, and codling moth.

In the plots receiving the standard schedule, there was 7.3 percent damage from curculio, 10.5 percent from codling moth, and 35 percent from scab. Only 48 percent of the fruit in this plot was free from disease or insect blemishes.

In the plot where the "emergency A" spray was interposed between the 2d and 3d cover sprays, there was 82 percent clean fruit, 3 percent showing curculio injury, 1 percent showing codling moth injury, and 13.6 percent marked by scab.

The record of apples from the plot in which the standard schedule was supplemented by the "emergency A" spray and a late application of fixed nicotine spray at mid-August showed 84.4 percent clean fruit free from all blemishes, less than 1 percent codling moth damage, and slightly less scab.

The reduction of codling moth injury following the "emergency A" spray was especially significant (from 10.5 to 1 percent), and indicated the importance of this application. The record also indicated that its timing coincided very accurately with the seasonal development of the insect.

In a separate block of McIntosh, different dosages of DDT were employed, in five applications (May 15 to July 25) following the calyx spray. The standard schedule was followed up to and including the calyx spray; and part of the block received the full standard schedule throughout the season to serve as a basis for comparison. In the standard schedule, lead arsenate was used in combination with wettable sulfur and lime. The DDT was also combined with wettable sulfur but without the addition of excess lime.

DDT (AK-40) at dosage of 1 pound and 2 pounds per 100 gallons of spray did not control curculio as well as did a combination of lead arsenate 2 pounds and DDT ½ pound, even with the addition of a fish oil sticker in the 1st cover spray. Codling moth was well checked in all DDT plots (0 to 1.5 percent injury for the higher dosages, and 2 injured apples out of 32 in the DDT plus lead arsenate plot). Scab was well controlled in all plots, indicating that the presence of DDT did not interfere with the efficiency of wettable sulfur. There was very slight evidence of damage by miscellaneous minor insect pests, and no trace of damage by apple maggot in the fruit of any of the sprayed plots.

Abbreviated Schedule. With a serious cut in the crop resulting from the killing of the blossoms by frost and subsequent cold weather, many growers were contemplating the use of an abbreviated spray schedule to give moderate protection from insect pests and particularly from apple scab of such fruit as survived, and looking forward to maintaining the trees in good condition for the following season.

One section of the orchard was given a limited post-blossom schedule or a special sulfur dust and a sulfur spray combination for scab control, a special cover spray of sulfur and lead arsenate in early June, and the first apple maggot spray on July 12.

Following the standard schedule, records showed 87 percent clean fruit, 5.8 percent injury by curculio, 2.5 percent by codling moth, 0.8 percent by scab, and 2.9 percent by miscellaneous minor pests. Following the abbreviated schedule, there was 71 percent clean apples, 2 percent damage by curculio, 5 percent by codling moth, 2 percent by scab, and 2.4 percent by minor pests. There was only a trace of apple maggot damage in the entire orchard.

Codling moth, scab, and apple maggot were well checked by a modified schedule and the foliage was maintained in good condition. Curculio damage was high following the abbreviated schedule, since no special application was made for its control. Most of this fruit could be salvaged, however, and the trees were in good vigorous condition going into the winter.

Heavy Deposit-Building Dust Against Late Codling Moth. The dusts were used in three applications covering the period from July 12 to August 9, which spanned the period of heavy hatching of eggs and appearance of late season larvae of 1st brood codling moth and of early 2nd brood larvae.

The heavy deposit-building dust proved somewhat superior to spraying, and the standard dust was approximately equal in value to spraying. Against apple scab (in a season of exceptionally heavy infection) the heavy deposit dust gave protection very comparable with the spray. The standard dust was less effective. Late summer damage by miscellaneous insect pests was uniformly low in all plots, and apple maggot injury was nil.

Insecticides for the Control of the European Corn Borer. (A. I. Bourne.) Some corn borer moths emerged before the corn had appeared above ground, the first recorded emergence being April 30. The period of emergence was prolonged over a number of weeks—considerably longer than normal—and evidently the unfavorable weather interfered to such an extent with moth activity that the first brood of borers was negligible. This was evidenced by the scarcity of egg masses and by the record of tassel breakage, counts of which were made in the experimental fields just before the crop was picked. In the check plots the percentage of infested tips was 9.5, while in the treated plots the percentage varied from 0 to 2.4, with a weighted average of 1.4 percent. The very light infestation was further shown in the yield records. The yield in *all* plots was 1532 ears, of which only 15 were found infested. In all the treated plots, 1293 ears were harvested, of which 11 (0.8 percent) were infested. Unsprayed check plots yielded 239 ears, of which 4 (1.7 percent) were infested.

Even with such a slight infestation, the percentage of marketable corn in proportion to total yield reflected the effect of the borer attack. At the first picking the yield in sprayed plots ranged from 44 to 68 ears per plot; in the check plot only 23 ears were ready to pick. In the treated plots 96 to 100 percent of the total yield was of marketable grade; in the unsprayed check, 91 percent.

Potato Spraying Experiments. (A. I. Bourne.) Flea beetles were normally abundant early in June, and the second attack occurred in late July and August.

No leafhopper infestation occurred, and there was no serious threat by aphids. A small attack appeared in July, but an application of nicotine sulfate checked it before more than a very light attack developed.

The plots were given twelve applications between June 11 (flea beetles appeared about June 8–9) and September 11, when no new growth was taking place. No evidence of injury to vines following any of the sprays was noted.

The most significant differences in flea beetle damage were between the DDT plot (attack very light) and the Dithane plots (attack very severe). In both the Bordeaux and the Dithane plots the addition of calcium arsenate materially reduced the severity of attack. This was especially noticeable in the case of Dithane, which appeared to give very little protection from flea beetle when used alone. There was no significant difference between the two strengths of Bordeaux, but there was a very appreciable reduction in all cases where calcium arsenate was used. Flea beetle damage in the DDT plot was insignificant throughout the season. As the season progressed, the increased injury by flea beetles in the Dithane plots indicated that the repellent action of sprays in near-by plots might have driven the beetles to the Dithane-sprayed plants. The sharp decline in leaf perforation following the application of calcium arsenate indicates that the arsenical is essential when Dithane is used.

The damage caused by abnormal weather conditions was so severe that yield records could be taken from only 50 feet of row across the north (higher) end of the plots. The crop throughout the entire field was much lower than normal.

The yield in the plots receiving standard 10–10–100 Bordeaux and 10–5–100 Bordeaux was approximately 195 bushels per acre in both cases. Where calcium arsenate was added to Bordeaux, the yield was approximately 35 percent greater.

The lowest yield occurred where Dithane alone was applied. When calcium arsenate was added to Dithane, the yield was about 50 bushels per acre greater and only slightly less than the yield in the standard Bordeaux plot where calcium arsenate was included and greater than in the low-calcium Bordeaux plots. Dithane appeared to have held blight in check to a degree at least comparable with Bordeaux in spite of the adverse weather conditions and the inferior appearance of the plants throughout late summer.

The highest yield in the entire field was in the plot where DDT was applied (273 bushels per acre compared with 261 bushels per acre following standard Bordeaux plus calcium arsenate). This was in line with the superior vigor and excellent appearance of the plants in this plot throughout the season.

Reports that DDT is a very good insecticide for potatoes seemed to be borne out in 1945. No aphis infestation developed in the DDT plot although a slight infestation started in other plots. There was a very conspicuous reduction in flea beetle damage and the highest yield in the whole field. The plants were more vigorous throughout the season and remained green longer than in any other part of the field. The results here correspond very closely with those reported from other regions and were so generally favorable that this material may be expected to become an important element in the spray program for potato pests.

Control of Onion Thrips. (A. I. Bourne.) A spray of a 4 percent derris (4 pounds per 100 gallons) with Ultrawet wetting agent gave 90.5 percent control of thrips, DDT (0.4 pound per 100 gallons) 89.1 percent control, and Lethane B-72 (3 pounds per 100 gallons) 48.2 percent control, as compared with 91-92 percent control following application of Black-Leaf 40 with the same wetting agent.

A 5 percent DDT dust gave 90 percent control in one test and 93 percent following a heavy application. A 1 percent rotenone dust furnished 81 percent protection, and a Lethane dust (B-71) 78 percent control in light application and 95 percent following a very heavy dusting.

The wetting agent Triton X-100 appeared to be very well suited for use on the smooth waxy surface of onion plants and improved the effectiveness of all spray materials greatly, derris spraying giving 98.9 percent control, and DDT 99.4 percent immediate control with marked residual action. Lethane B-72 gave 96 percent control but no prolonged protection.

No injury was noted following the application of any of the above materials.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) A paste containing a naphthalene base fumigant was developed for painting on steam pipes to eliminate the use of vaporizing units. Experimental fumigations on carnations with this paste at 70°–75° F. for a 6-hour exposure gave satisfactory control of the common red spider at dosages of 6/10 ounce and 8/10 ounce per 1,000 cubic feet, but were unsatisfactory at a dosage of 4/10 ounce per 1,000 cubic feet. Potted cucumber and tomato plants were slightly injured by the treatment.

Biology and Control of the Red Spider Mite on Greenhouse Crops. (W. D. Whitcomb and Wm. Garland, Waltham.) Tests of three commercial spray materials containing 5.4 percent and 3 percent rotenone in four applications at weekly intervals to greenhouse roses indicated that they will not give good commercial control of the red spider mite under these conditions. In experiments where a partially satisfactory kill was recorded, a severe infestation developed soon after spraying was discontinued.

An experimental benzene mixture killed the red spider mite well but caused excessive injury to rose foliage, while an emulsified monochlor naphthalene mixture was both injurious to rose foliage and ineffective against the mite.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) With a moderate field infestation by the cabbage maggot, untreated plants of the Early Jersey Wakefield and the Charleston Wakefield varieties were 94 and 88 percent free from injury, indicating considerable resistance compared to Golden Acre and Super Curled Savoy with only 47 and 12 percent of the plants free from injury. On Golden Acre one application of 4 percent calomel–talc dust in a small mound about the stem of the plant gave perfect protection and produced 90 percent salable heads. Corrosive sublimate solution (1 ounce in 10 gallons of water) in two applications gave 95 percent protection. DDT–talc dust containing 5 percent DDT, when applied twice at weekly intervals with a hand duster, gave 95 percent protection and was more effective than a 3 percent DDT–talc dust applied either with a duster or in a mound around the stem of each plant. A DDT solution containing 1 percent DDT applied in the same way that corrosive sublimate solution was used was quite effective but caused injury to the roots of the plant, apparently due to the action of the solvent rather than of the DDT.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In laboratory poison studies, spray suspensions containing 2 pounds or more actual DDT in 100 gallons gave reasonable control of the plum curculio. Two pounds of actual DDT in 100 gallons were approximately as effective as 4 pounds of lead arsenate. The time required to kill the beetles and the number of punctures made in sprayed apples decreased consistently as the amount of DDT in the spray was increased, and a spray containing 4 pounds of actual DDT in 100 gallons of water (0.5 percent DDT) gave almost perfect protection. Combinations of lead arsenate and DDT were generally more effective than equal amounts of either material alone. A combination of 4 pounds of lead arsenate and 2 pounds of actual DDT in 100 gallons was very effective and highly promising for practical use.

Orchard experiments were greatly limited by a general crop failure following destructive spring frosts, and the infestation of the plum curculio was very heavy.

Applications of the regular schedule on Golden Delicious apples using wettable sulfur 4 pounds, a sulfated alcohol spreader 2 ounces, with the following materials in each 100 gallons of water gave these results:

Material		Number of Apples	Percent Free from Stings
Lead arsenate DDT	4 pounds 1 pound	2063	89.63
Lead arsenate DDT	2 pounds 1 pound	1472	78.47
Lead arsenate	4 pounds	1231	60.44
Unsprayed		173	4.62

Apple Maggot Emergence. (W. D. Whitcomb, Waltham.) The emergence of apple maggot flies in orchard cages at Waltham occurred at about the normal time although the first fly was not recovered until July 1, about two weeks later than in the early season of 1944. The peak of emergence occurred on July 18.

	Orchard Cage
First Fly Emerged	July 1
25 percent of flies emerged	July 8
50 percent of flies emerged	July 15
75 percent of flies emerged	July 19
Last fly emerged	August 5
Percent of maggots which transformed	42.66

Control of the Squash Vine Borer. (W. D. Whitcomb, Waltham.) Further tests of the susceptibility of varieties of *Cucurbitaceae* indicated that all varieties of *Cucurbita moschata* are immune to attack by the squash vine borer. In 1945 no infestation was found in the Cushaw, Longfellow Pumpkin, Alagold, Large Cheese Pumpkin, Tennessee Sweet Potato, and Butternut varieties, all of which belong to the species *moschata*. The infestation in four species of *C. maxima* averaged 5.45 borers per vine, and in six species of *C. pepo* 3.47 borers per vine. Cucumber, cantaloupe, and watermelon were also immune to attack by this pest.

Biology and Control of the Celery Plant Bug. (W. D. Whitcomb and Wm. Garland, Waltham.) Unfavorable weather conditions in May and early June reduced the first generation of the celery plant bug, *Lygus campestris* L., to a minimum and the results of experimental field studies were insignificant.

The second generation was moderately abundant and caused severe injury in the form of "black heart" to all of the untreated plants of the second planting of celery. In the field where untreated celery was infested with 12 to 70 bugs per 10 plants, DDT–talc dust (containing 3 percent and 5 percent DDT) prevented reinfestation for 33 days; and sabadilla-lime dust (containing both 20 percent and 50 percent sabadilla seed) gave protection for 14 to 19 days. These treatments produced 70 to 80 percent marketable plants which were free of black heart at harvest. Dusts containing pyrethrum and rotenone killed the celery plant bugs but permitted reinfestation after 5 to 7 days.

Biology and Control of the Grape Cane Girdler. (W. D. Whitcomb and Wm. Garland, Waltham.) In laboratory insecticide experiments, none of the canes sprayed with DDT was girdled, and no eggs were laid on them. Beetles confined with DDT-sprayed canes lived about half as long as those confined with canes sprayed with lead arsenate and cryolite. The number of feeding scars was reduced proportionately. The use of freshly cut terminal grape canes in cages greatly simplified this type of insectary studies, compared with the potted grape vines which were used previously.

Sprays to Prevent Scolytid Infestation of Elm Logs. (W. B. Becker.) At Springfield, the following spray mixtures were applied once to the entire bark surface of elm logs before scolytids could attack them in the spring. The logs used in the different tests were up to 8 and 14 inches in diameter with bark up to one half and one inch thick. The percentages of prevention of scolytid infestation are based on the number of exit holes per square foot of bark in the late fall as compared with unsprayed logs. *Scolytus multistriatus* Marsham was the only or the predominant scolytid in the logs. The figures in parenthesis following each spray mixture indicate the proportion of ingredients and the amount of spray applied per square foot of bark.

	Percent Prevention
Gesarol A-20 (20% DDT wettable powder) and water	
(18 grams—3785 cc., 195 cc.)	90.3
Gesarol emulsion (20% DDT) and water	
(1-400,185 cc.)	84.0
(1-200, 179 cc.)	94.5
Kerosene alone (135 cc.)	98.8
Used crankcase oil alone (169 cc.)	94.6
No. 2 fuel oil alone	
(42 cc.)	86.1
(123 cc.)	100.0
(166 cc.)	99.2
(213 cc.)	100.0
Orthodichlorobenzene and No. 2 fuel oil	
(1-4, 113 cc.)	100.0
(1-8, 54 cc.)	96.7
(1-8, 115 cc.)	100.0
(1-8, 132 cc.)	100.0
(1-12, 105 cc.)	98.0
(1-16, 107 cc.)	99.1

At the same location other elm logs were sprayed six times at three-week intervals beginning May 31, with the following results. The proportions and amounts of spray indicated were used for each application.

	Percent Prevention
No. 2 fuel oil alone (176 cc.)	100.0
Gesarol A-20 and water (18 grams - 3785 cc., 164 cc.)	84.2
Gesarol emulsion and water	
(1-400, 164 cc.)	87.1
(1-200, 158 cc.)	90.3

Sprays to Kill Scolytids Breeding in Elm Logs. (W. B. Becker.) At Springfield, the following spray mixtures were applied on July 20 to the entire bark surface of scolytid-infested elm logs up to 6 and 10 inches in diameter with bark up to one half and three quarters inch thick in the different tests. The percentages of control are based on the number of exit holes per brood gallery in the late fall compared with those in unsprayed logs. Brood galleries of *Scolytus multistriatus* Marsham were more abundant than those of *Hylurgopinus rufipes* (Eich.) in these logs. The figures in parenthesis following each spray mixture indicate the proportion of ingredients and the amount of spray applied per square foot of bark.

	Present Control
Creosote and kerosene, strained (1-4, 189 cc.)	96.5
Orthodichlorobenzene and No. 2 fuel oil (1-8, 208 cc.)	91.7
No. 2 fuel oil alone (200 cc.)	69.8
Kerosene alone (186 cc.)	59.6
Gesarol emulsion (20% DDT) and water	
(1-400, 150 cc.)	4.6
(1-200, 133 cc.)	2.3
Gesarol A-20 (20% DDT wettable powder) and water	
(18 grams - 3785 cc., 181 cc.)	0.0

At the same location other elm logs were sprayed four times at three-week intervals beginning July 20, with the following results. The proportions and amounts of spray materials indicated were used for each application.

	Present Control
Gesarol emulsion and water	
(1–400, 182 cc.)	52.9
(1–200, 145 cc.)	2.6
Gesarol A-20 and water (18 grams – 3785 cc., 172 cc.)	0.0

Although no significant reduction in the number of exit holes resulted from these DDT sprays, dead adults were occasionally found in the exit holes on some of the infested logs which were sprayed one or more times with DDT. This phenomenon was apparently not common enough in the logs sprayed with the other materials to have been noticed. To what extent the DDT residue on the surface of the bark may have affected beetles which completely emerged, was not determined.

The Control of Elm Scolytid Infestation by Solar Heat. (W. B. Becker.) Scolytid development in elm logs, up to 16 inches in diameter with bark up to 1 inch thick, piled in partial shade and left undisturbed until late October, served as a basis with which to compare the results of the several treatments. Percentages of control are based on the number of exit holes and unemerged survivors per square foot of bark.

Merely spreading uninfested logs, up to 19 inches in diameter with bark up to 1½ inches thick, singly in a north–south position in the sun on May 25 and leaving them undisturbed until late October resulted in 63.2 percent control. The upper half of the logs in the sun was free of brood galleries, except for a few almost half way down the sides of the logs (1.9 galleries compared with 7.1 per square foot scattered over the entire upper half of the control logs). On the lower half of the logs the number of brood galleries approximately equaled those in the control logs (15.3 compared with 14.5 per square foot); however, less than half as many exit holes and unemerged survivors were found there (45.7 compared with 94.6 per square foot in the controls). Both in these logs and in the control logs piled in partial shade, brood galleries of *Scolytus multistriatus* Marsham and *Hylurgopinus rufipes* (Eich.) were almost equally abundant.

When logs up to 16 inches in diameter with bark up to 1 inch thick were similarly placed in the sun on May 25, but turned over on July 12 after the lower portion had become infested, 79.6 percent control resulted.

Other logs with diameters up to 23 inches and bark up to 1 inch thick were piled in the shade from May 25 to July 12, by which time they were well infested with scolytids. On the latter date they were spread singly in the sun in a north-south position, and on August 2 they were turned over. This resulted in 95 percent control.

When logs up to 24 inches in diameter with bark up to 1¾ inches thick were spread singly north and south in the sun on May 25, turned over every week through August 17, and then left undisturbed until late October, 99.7 percent prevention of infestation resulted. Logs up to 23 inches in diameter with bark up to 1½ inches thick, which were turned in the sun every two weeks during the same period showed 98.8 percent prevention, while other logs up to 24 inches in diameter with bark up to 1½ inches thick showed 98.7 percent prevention.

When logs up to 17 inches in diameter with bark up to 1 inch thick were spread singly north and south in the sun on May 25 and sprayed on the lower half with creosote and kerosene, strained (1 to 4 by volume), over 99.9 percent prevention resulted.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Variety Improvement and Disease Resistance. (Harold E. White, Waltham.) The Helen Tobin snapdragon, a recent introduction of the Waltham Field Station, has been grown by florists in 24 different states, north as far as Bar Harbor, Maine, and south as far as Texas and Florida, and requests for seed for trial have been received from foreign countries. Many growers reported this variety as excellent in performance and regarded it as unusual in size, color of flowers, and habit of growth, and several reported it as an excellent variety for their locality.

As with any new variety of plant material, certain characters need to be improved. Therefore, commercial winter-flowering varieties of snapdragon have been crossed with Helen Tobin to obtain a wider range of flower colors. A seedling mutation of Helen Tobin, which is of a darker pink color, gives promise of improvement over the present variety and is being selected for further trial. Seed stocks of a number of first generation hybrids of snapdragons and unnamed selfed lines are being increased so that more extensive trials can be made to determine their adaptability for commercial use.

Disease Resistance and Heredity of Carnations. (Harold E. White, Waltham.) Hybridizing of commercial varieties of carnations is being continued. To date, seed production from crosses has been very low; hence large populations from individual crosses, sufficient for a thorough study of disease resistance, have not been obtained. Selections have been made from a number of seedlings from previous crosses, but these do not offer enough variability for reliable conclusions. Cultural treatments and methods of inducing more abundant seed production from carnation plants are being investigated.

Subirrigation Methods of Watering Carnations. (Harold E. White, Waltham.) The four raised concrete V-bottom benches and two ground beds, which were constructed at the Waltham Field Station in 1945 for subirrigation studies on florists' crops, were operated with carnations. Half the benches and beds were subirrigated and the remainder were top-watered in the customary manner. The plants made excellent growth under both systems. During the early fall, plants in the subirrigated benches appeared to be somewhat more advanced in growth than the top-watered; but as the season progressed, this difference became less perceptible.

The number of blossoms cut from subirrigated and top-watered plants was not significantly different. Keeping quality, size of flowers, and length of stems were equally good. Frequency of watering was reduced 50 percent by subirrigation methods as compared to the practice of top watering.

The chief advantage of subirrigation over surface watering is the reduction in frequency of watering, which under greenhouse conditions is a considerable item of expense in growing crops. Other important features are more uniform moisture conditions, better aeration of soils, conservation of plant food elements, and less danger from air-borne fungous diseases.

Subirrigation methods of watering greenhouse crops by flooding, measured injection of given quantities, constant water level, and automatic regulation are worthy of any grower's consideration. One system may be better adapted for one grower's needs than another, but there is plenty of opportunity for modification of existing methods. Automatic regulation and constant water level methods of watering are being put into operation for observation.

Treatment of Sand with Fermate for Carnation Cuttings. (Harold E. White, Waltham.) Propagating sand for use in rooting carnation cuttings was treated with dry Fermate (ferric dimethyldithiocarbamate) at the rate of 2 pounds and 3 pounds per 100 square feet. Cuttings from 12 varieties of carnations were placed in treated and untreated sand. The increase in percentage of rooting of carnation cuttings in Fermate-treated sand over untreated sand was quite variable. Eleven lots of cuttings showed increases in percentage of cuttings rooted, from as low as 1 percent to as high as 25, and six lots showed a decrease in comparison with untreated. The difference in percentage of cuttings rooted in the 2-pound and 3-pound treatments was equally variable. Rooting response to the same treatment varied with varieties of cuttings. When cuttings of a particular variety rooted poorly with no treatment, the response was poor with the Fermate treatment.

The results obtained in these tests indicate that Fermate applied directly to the sand is of no particular value for rooting of carnation cuttings. Losses from rot diseases in the cuttings were not sufficient to determine whether such treatments are effective as a means of disease control.

Sodium Selenate as a Red Spider Control. (Harold E. White, Waltham.) In tests at Waltham, the application of sodium selenate to soils in which carnations are growing has proved to be an effective means of controlling red spider. Experiments were conducted on plants grown in pots, flats, and benches. Observations were also made on plantings of treated carnations in local greenhouse ranges. Young carnation plants in flats remained free of red spider for 5 to 6 months after one application of sodium selenate to the soil in early spring. In benches, treatments made in July kept the carnations free of red spider for 10 months, whereas untreated plants became heavily infested.

Two forms of sodium selenate were used in the tests, pure selenate ($NaSeO_2$) and a commercial product known as P-40, which is superphosphate impregnated with 2 percent of sodium selenate. The pure sodium selenate was dissolved in water at the rate of 100 grams per gallon, to make a stock solution; each quart of stock solution was diluted with 25 gallons of water; and 1 quart of diluted solution was applied to 1 square foot of soil. At this rate each square foot received ¼ gram of sodium selenate. The P-40 was applied to the soil at the rate of 3, 4, and 6 pounds per 100 square feet. At these dosages red spider was effectively controlled. Although no injury to carnations was observed from the dosage of 6 pounds, a minimum rate of 3 to 4 pounds per 100 square feet was sufficient for good control. At the rate of 3 pounds of P-40 per 100 square feet, each square foot received ¼ gram of sodium selenate.

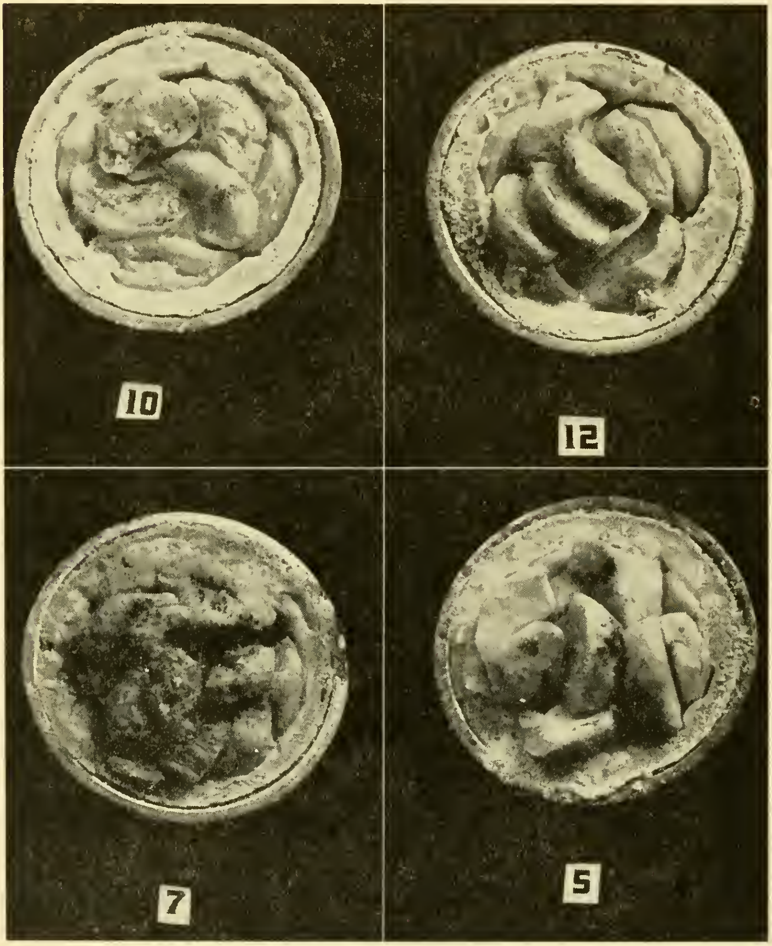
Carnation plants should be treated with sodium selenate after they are established in the soil, and at least 4 weeks must be allowed for the effect of the treatment to show. Some preliminary tests at Waltham indicated that pre-treatment of the soil with sodium selenate at the rate of ¼ gram per square foot, 6 weeks prior to planting, may be a safe procedure.

Variations in soil conditions and other factors may affect the results obtained with sodium selenate. Young, actively growing plants have been observed to respond more readily to selenate treatment than older plants. Conditions which affect movement of water into the plants are also limiting factors.

DEPARTMENT OF FOOD TECHNOLOGY

C. R. Fellers in Charge

The Use of Calcium Salts in Freezing McIntosh Apples. (W. B. Esselen, Jr., J. J. Powers, and C. R. Fellers.) In Massachusetts and throughout New England the McIntosh apple is by far the most important commercial variety. Unfortunately, this apple as grown in Massachusetts and certain other areas is usually of rather soft texture, especially after storage, and is not well adapted to freezing, canning, or bakery use. When processed by these methods the sliced apples tend to become very soft and mushy, particularly when used in pies.



UPPER: Pies Made from Fresh McIntosh Apples.
No. 10—Control
No. 12—Sliced apples treated with calcium

LOWER: Pies Made from Frozen McIntosh Apples.
No. 7—Control
No. 5—Sliced apples treated with calcium before being frozen

Experiments have been carried on during the past year with methods for increasing the firmness of sliced Massachusetts-grown McIntosh apples in order to maintain their shape during canning, freezing, and baking. The use of calcium as a firming agent is quite effective for this purpose. The amount of calcium used (such as calcium chloride) and the time of the treatment will vary depending upon such factors as the original firmness of the apples, the length of time they have been in storage, the degree of firmness desired, etc. Concentrations of from 0.03 to 1.50 percent calcium in the treating solution may be indicated depending upon the processing method and the condition of the apples These calcium treatment have been found to be just as effective with so-called. "green McIntosh" apples as with ordinary McIntosh.

Stability of Riboflavin in Processed Foods. (W. B. Esselen, Jr., A. Filios' J. Crimmins, M. W. Paparella, and M. S. Gutowska.) An investigation of the stability of riboflavin in a large number of commercially canned foods, packed in glass or metal containers is being carried on. Many different kinds of baby foods are included among the products considered. There appears to be considerable variation in the stability of riboflavin in different products, regardless of the type of container in which they are packed. The loss of riboflavin during three months' exposure to diffused daylight on a typical store shelf varied from 0.0 to 60.0 percent, depending upon the products. Such products as strained peas, liver soup, chopped spinach, vegetables and liver, red kidney beans, chopped prunes, strained and chopped beets, and chopped carrots showed only small losses; while products such as strained green beans, custard pudding, tomato juice, strained peaches, and strained tomato porridge showed greater losses. These losses tended to increase during storage for 12 months. In some cases losses, but not as great as those in samples exposed to the light, were found in both glass and tin packed products stored in the dark and at different temperatures.

To date the results show that in many glass-packed foods the loss of riboflavin during storage on a store shelf under normal conditions would be small. The results of the present investigation are in general agreement with an earlier preliminary study made with glass and tin packed asparagus, peas, corn, and green beans and show that riboflavin seems to be less stable in the more acid products.

Ascorbic Acids as Antioxidants. (C. R. Fellers, J. E. W. McConnell, J. J. Powers, W. B. Esselen, Jr., L. R. Parkinson, and G. S. Congdon.) In 1940 this department demonstrated that l-ascorbic acid (vitamin C) was an effective antioxidant in preventing surface darkening in home-canned fruits. As a result of this and later work carried on here and elsewhere, ascorbic acid is now recognized as an important antioxidant in the food industries. Today it is being used in such things as home-canned and frozen fruits, commercial frozen fruits, particularly peaches, apple juice, and certain beverages.

During the past year a study has been made of the antioxidant properties of a new ascorbic acid compound, 5, 6 diacetyl-l-ascorbic acid, which holds promise of being adapted to use where a slower-acting antioxidant is indicated. The rate of oxidation was found to be considerably slower than that of l-ascorbic acid or d-iso ascorbic acid during storage in a bottled buffered aqueous solution at pH 4.0. On an equivalent weight basis the biological vitamin C activity of 5,6 diacetyl-l-ascorbic acid was comparable with that of l-ascorbic acid as determined by guinea pig bioassay.

Further uses of ascorbic acid as antioxidants are being investigated.

There is considerable interest at present in the fortification of such juices as apple, cranberry, and grape with ascorbic acid to put them on a par with citrus juices as scources of vitamin C. In some juices such as apple, the added ascorbic acid also serves as an effective antioxidant in preventing color and flavor changes. During the past three years, a number of tests have been made to determine the stability of added ascorbic acid in glass-packed apple, cranberry, and grape juices. In all cases the ascorbic acid was well retained during processing and storage. It is recommended that ascorbic acid, if used under commercial conditions to fortify bottled fruit juices normally low in vitamin C, be added on a basis of 50 milligrams per 100 milliliters or 190 grams per 100 gallons of juice. If the ascorbic acid is added as an antioxidant only, 75 grams per 100 gallons of juice should be adequate.

Glass-Packed Citrus Juices. (W. B. Esselen, Jr., J. E. W. McConnell, C. R. Fellers, and A. S. Levine.) Experimental test packs of bottled grapefruit and orange juices, packed in a commercial plant in Florida, have been obtained in order to study the effect of added antioxidants and storage temperatures on the quality of these products. The addition of d-iso ascorbic acid or l-ascorbic acid to bottled citrus juices seemed to have a definite favorable effect on flavor retention during storage, but was not effective in preventing darkening under adverse storage conditions—tended, in fact, to accentuate it, as has been previously reported from this laboratory. Samples of the grapefruit and orange juices have been stored at temperatures of 35°, 50°–60°, 70°–80°, and 100° F. for periods up to a year. It is recommended that glass-packed citrus juices be held at temperatures of 60° F. or lower during storage. Under these conditions the original flavor of the juices is well retained. At temperatures of 70°–80°, the storage life of glass-packed citrus juices is approximately six months.

Effect of Carbon Dioxide Gas on Color Retention in Citrus Juices. (W. B. Esselen, Jr., G. S. Congdon, and J. E. W. McConnell.) Laboratory tests have shown that if grapefruit and orange juices are saturated with carbon dioxide gas prior to pasteurization and bottling, their tendency to darken during storage is decreased. In accelerated tests the storage life of these juices (based on tendency to darken) was extended from four to six times. These findings are being checked with packs of juices put up under commercial conditions.

Home Canning Research. (W. B. Esselen, Jr., G. Lycarczyk, N. Glazier, J. E. W. McConnell, A. S. Levine, C. R. Fellers.) A comparison of time and fuel consumption was made to determine the relative efficiency of the pressure canner and water bath methods of processing for acid foods. For the urban home canner the use of a pressure canner operated at 0 to 1 pound steam pressure in place of the water bath resulted in an approximate saving of 25 percent in total time required and in fuel consumption. Recommended boiling water bath process times were used in both cases.

Excessively rapid cooling at the end of processing is an important cause of loss from home canning jars; fluctuations in pressure during processing a less important cause. Jars sealed with the zinc Mason cap and the partially sealed bail-type jars showed the greatest loss of liquid. The two-piece metal lid, three-piece glass lid, and fully sealed bail-type jars exhibited a minimum loss of liquid. The number of jars being processed, the nature of the product (slow or fast heating), and the size of the pressure canner were found to have a significant effect on the come-up and cooling times of different pressure canners.

It is frequently stated that the presence of decayed vegetables in the canned product decreases the acidity so that it is more difficult to sterilize the product. Studies have been carried out with different vegetables in which various proportions of sound and decayed product were canned. It was found that the presence of decayed peas, beans, and greens, particularly, might decrease the acidity of the jar contents to a point where a longer process time would be required.

New home canning jars, as purchased, were found to be relatively free of bacteria compared with jars which had been used and then stored for use the following season. These findings point to the desirability of thoroughly washing home canning jars after they have been emptied and before they are put away, and of washing them in hot soapy water prior to use the following season.

Investigation of Processing Methods for Home Canned Fruits. (Cooperative project with the Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.) (J. E. W. McConnell, W. B. Esselen, Jr., D. Anderson, I. Powers, F. Johnson, and M. Mrowkowski.) During the summer of 1945, heat penetration and processing data were obtained for home-canned rhubarb, strawberries, cherries, raspberries, blueberries, peaches, apple sauce, tomatoes, and tomato juice. In most cases the data were obtained on the products packed in both pint and quart jars and processed in a boiling water bath and in a steam pressure canner at 1, 5, and 10 pounds steam pressure. The initial temperature is important in processing home-canned fruits because of the lethal rate of the micro-organisms concerned, the rate of heat penetration into the product, and the short process time usually employed. Processing at 1 pound steam pressure in a pressure canner was found to be similar in sterilizing value and heating rate of products to processing in a boiling water bath. Any slight differences were in favor of the pressure canner.

Home Freezing. (A. S. Levine, W. B. Esselen, Jr., K. M. Lawler, N. Glazier and C. R. Fellers.) An investigation of the suitability of different varieties of fruits and vegetables, as grown in Massachusetts, for freezing is being continued. Samples of raw material for freezing have been obtained through the cooperation of the Olericulture and Pomology Departments. A survey and study have also been made in an effort to ascertain the role and importance of home freezing in Massachusetts. This study has included a suggested freezing program based on Massachusetts products, the economic aspects of freezing certain products, home freezing costs, and a comparison of freezing and canning as methods of home food preservation.

Since relatively little meat is raised in Massachusetts it is questionable whether the freezing of meat is practical. At the present time there is considerable interest in this subject as a means of having meat on hand when the supply is short; but under ordinary conditions meat may be purchased as needed. With the large number of poultry flocks in Massachusetts, poultry may well be frozen.

It has been suggested that such foods as eggs, lard, butter, and citrus juices may be purchased when the price is low and frozen in sufficient quantities to be used throughout the year. It would appear, however, that the saving which results is completely offset by the cost of packaging and of the freezing storage and by the amount of space required in the home freezing unit.

The rental of a freezer locker is definitely less expensive than an equivalent amount of freezer capacity in the form of a home freezer, but is also less convenient. Home freezing is definitely more expensive than home canning. On a basis of equipment cost and depreciation, power, containers, and storage, the unit cost of preserving food by freezing is four to five times that of canning. With good management the freezing cost may be reduced somewhat.

Home freezing is a particularly good method of preservation for strawberries, raspberries, broccoli, greens, corn, and meats. On a basis of quality such products as tomatoes and tomato juice, green beans, carrots, beets, and peaches can be preserved equally well, if not better, by canning, as shown by comparative tests carried out during the past three years.

All things considered, home freezing in Massachusetts does not appear to be as important as it may prove to be in certain other sections of the country. It would appear that home freezing may be best used to supplement rather than to replace other methods of home food preservation.

Vitamin D Investigations. (L. R. Parkinson and C. R. Fellers.) Periodic checks were made on the vitamin D content of Vitamin D milks sold in New England. These assays showed that of the 192 samples examined, 181 contained at least 400 U.S.P. units per quart, 8 samples contained from 320–400 units, and only 3 samples were seriously deficient. Direct irradiation of milk is no longer practiced in this State. The principal means of adding vitamin D to milk is by direct addition of irradiated or activated ergosterol or purified fish oil concentrate.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Julia O. Holmes in Charge

Utilization of Iron in Foods. 1. By Human Subjects. (B. V. McKey, A. W. Wertz, D. C. Staples, and J. O. Holmes.) Four healthy women ranging in age from 24 to 37 years participated as subjects of the experiment. During the four and one half months of the study they received a basal diet which contained only 3.8 mg. of iron (about one-third of the amount recommended by the National Research Council as a daily allowance for women), but was adequate in all other respects. Beef muscle, approximately one fifth of a pound daily, was fed in addition to the basal diet from the 65th to the 115th day of the experiment; and iron sulfate, an iron salt frequently recommended by physicians as a source of iron, was fed in a quantity equivalent to the iron in the beef, from the 116th to the 130th day. During the experiment the four subjects donated approximately 1 pint of blood on the 1st, 15th, and 95th days, in an attempt to induce a mild state of anemia which would insure maximal use of the iron in the foods.

An anemia of clinical severity was not produced in any of the subjects. Following the second withdrawal of blood, the hemoglobin in only two of the subjects fell as low as 90 percent of that usually found in normal, healthy young women. Throughout the experiment the subjects were cheerful, energetic, and felt well. The absorption of iron was as follows:

	Percentage Absorption of Iron by the four subjects			
In the basal diet	0	3	14	23
In the beef alone	19	44	51	36
In the iron sulfate alone	0	26	37	19

The woman who utilized the least iron in each of the diets was one who had been severely anemic the preceding summer and had received iron medication under a physician's prescription. It is probable that she made such poor use of iron during the experiment because her body tissues were so saturated with iron that the withdrawal of blood did not reduce her iron stores enough to allow for absorption of new iron. The hemoglobin level of this subject after the second blood donation within a 15-day period approximated that found in normal, healthy non-donors of blood.

These data indicate that all four of the women made more efficient use of the iron in beef than in the iron salt. They also suggest that healthy women whose body tissues are filled with iron can donate blood in the amounts and with the frequency prescribed by the American Red Cross without serious depletion of their iron stores, provided their diet is adequate in protein, vitamins, and minerals. For continuous blood donation a level of iron higher than that used in this study would be advocated.

2. By Rats. (A. W. Wertz.) The problem of the availability of iron in foods was also studied with the use of the rat as the experimental animal. The foods studied were roast beef and boiled navy beans, both being fed in dry form. Iron sulfate was used as a standard for comparing the availability of iron in these foods. The animals received a basal ration of milk powder and were paired according to sex, weight, litter membership, and hemoglobin of the blood. The amount of iron fed in the supplement was 0.2 mg. per day; and the amount stored during the 35-day period while the rats were receiving the supplement was determined by analyzing the carcasses.

The rats receiving iron sulfate retained more iron than did their litter-mates receiving the beef or the bean supplements. When the availability of the iron sulfate was set at 100, the retention of iron approximated 60 for the cooked beef and about 90 for the dried beans. These preliminary data suggest that the iron in navy beans may be better utilized than the iron in beef. Contrary to the results obtained with human subjects, the iron sulfate appeared to be a better source of iron for the rat than did the cooked beef.

Studies Relating to the Cause of Tooth Decay. (Julia O. Holmes, L. R. Parkinson, A. W. Wertz, and B. V. McKey.) The hypothesis used in planning these studies has been (a) tooth decay is caused by the acid which is produced as a by-product of the growth of bacteria which flourish in the oral cavity, and, conversely, decay may be prevented by inhibiting the growth of these bacteria; (b) under certain dietary conditions the salivary glands secrete a substance, the anti-caries factor X, which prevents bacterial growth; (c) the factor X either is a constituent of certain foods or is manufactured in the body, possibly in the salivary glands, possibly by the bacteria in the digestive tract, from the substances contained in those foods.

During the year approximately 200 rats have been reared on the decay-producing diet consisting of coarsely ground corn, milk powder, and alfalfa meal, supplemented with various dietary factors in an attempt to find one which would prevent the rampant tooth decay consistently found in rats reared on this basal diet. These substances included beef muscle, liver, alfalfa, butter fat, yeast, a rice-bran extract, fluorine, the amino acid tryptophane, the vitamins nicotinic acid and K, a mixture of the fat-soluble vitamins, and a mixture of both the fat-soluble and the water-soluble vitamins in crystalline or concentrate form. Other groups of rats were reared on a "purified" diet consisting of casein, mineral mixture, a "complete" vitamin mixture, and either sucrose, dextrose, or cornstarch, to determine whether tooth decay can be induced in rats consuming diets which do not contain corn. A sulfa drug, succinyl sulfathiazole, was fed to groups of rats receiving (a) the corn diet in which the corn was cooked and (b) the purified diet in which the carbohydrate was starch, both of which had been found by other investigators to prevent tooth decay in the rat. The sulfa drug was given because of its "sterilizing" action in the bowel; the idea being that, if the bacteria of the bowel normally manufacture the factor X from substances in these two diets, the factor would not be made by the rats receiving the drug; hence these rats would experience more tooth decay than would be found in their litter-mates not receiving the drug.

None of the supplements fed in conjunction with the raw-corn diet caused even the slightest decrease in the rampant tooth decay observed on the basal corn diet, although some of them had been reported by other investigators as preventing tooth decay. These results led to the tentative conclusion that the corn diet may produce decay, not because of its deficiency in factor X but because it contains some deleterious substance which either unites with factor X thus making it unavailable, or makes impossible the synthesis of factor X. Unexpectedly, tooth decay was present in an advanced state in the rats receiving the cooked-corn diet, although the incidence and extent of decay were not as great as on the raw-corn diets. This led to the conclusion that corn causes decay in the rat, not because of the hardness of the particle but because of some fundamental constituent either in the corn or lacking in the corn. If corn contains a deleterious substance, it is not found in the starch fraction of the corn, since rats fed the purified diet containing cornstarch did not experience tooth decay.

The replacement of cornstarch by cane or corn sugars in the purified diets resulted in a mild degree of decay on the grinding surfaces of the teeth. This is the first report of such a finding in the albino rat fed purified diets, although it has previously been reported that the cotton rat develops tooth decay when subjected to diets containing soluble carbohydrates. The fact that the soluble carbohydrates when fed in large quantity allow tooth decay might tempt one to conclude that the sugars are the sole cause of decay. Such a conclusion must be abandoned, however, in view of the rampant decay found in rats fed corn diets, which contain only a small amount of soluble carbohydrate—the lactose in the milk powder.

The sulfa drug did not increase the incidence or extent of decay over that found in litter-mates receiving the diet without the drug. None of the rats receiving the purified diets showed decay even though they received the sulfa drug. Likewise the cooked-corn diet plus the sulfa drug was not any more conducive to decay than the diet without the drug. These findings suggest that either factor X is not manufactured by the bacteria in the bowel, or the sulfa drug in the dosage administered does not prevent the growth of the strain of bacteria responsible for its manufacture.

Although the year's work has not resulted in data which confirm or refute the hypothesis used in planning these experiments, the study will be continued.

The Role of Calcium in the Calcification of Bones. (Marie S. Gutowska and Julia O. Holmes.) In a preliminary study of the influence of environmental temperature on calcium metabolism, growing rats held at 62°F. consumed approximately twice as much food as did litter-mates held at 87°. On analyzing the carcasses of the rats, more calcium was found in those held at the cold temperature and it was concluded that the cold temperature stimulated the storage of calcium in the rat. However, since the animals in the cold environment consumed twice as much food as those in the warm, and since the percentage of calcium in the ration was identical for both groups, it is obvious that the animals in the cold environment consumed twice as much calcium. Consequently the results obtained might have been due to differences in quantity of calcium consumed rather than to differences in environmental temperature. In order to distinguish between these two variables, temperature and quantity of food eaten, a system of feeding was devised whereby the animals of two groups would receive equal quantities of calcium but would be allowed to eat as much of the calcium-free basal food as was necessary to satisfy individual needs.

In Series 1, two litter-mate groups of animals, one held at 62°F. and the other at 87°F, were fed a diet containing 0.6 percent calcium. All were allowed to eat as much as they desired. In Series 2, three litter-mate rats were fed a small portion of calcium in a fixed daily quantity separate from the ration, which was devoid of calcium. One rat was allowed to eat as much of the calcium-free food as he desired, the second was allowed only three fourths as much food as the first, and the third was allowed only half as much as the first. In Series 3, two groups were fed the same diet devoid of calcium, one being kept at 62° and the other at 87°. These animals were allowed to eat as much of the calcium-free food as they wished, but all were given an identical quantity of calcium separate from the ration. In all three series the animals were of the same age and were fed and cared for in the same way.

In Series 1, the quantity of ash stored by the animals was dependent on the quantity of food eaten; those eating the smaller amount of food had the smaller amount of ash in their bones, whereas those eating more food had the greater amount of ash. In contrast, the rats in Series 2 stored almost identical quantities of ash in their bones, irrespective of the quantity of food eaten. In Series 3, the rats reared at 62°F. had no more ash in their bones than did their litter-mates reared at 87°.

These results show the importance of controlling the intake of calcium in studies which are concerned with the growth and calcification of the skeleton.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Study of Herbaceous Perennial Material. (C. J. Gilgut, Waltham.) The perennial test garden with its extensive collection of labeled plants is the only one of its kind in New England. It is of value to nurserymen, landscape architects, students, and the gardening public, who wish to observe and study the response of various plants to our local climatic conditions. At present, it contains about 2500 plants, many of which are old garden favorites. There are also many new varieties, recently introduced into the trade, and some placed here by a number of hybridists, for comment and report as to garden value, cultural requirements, and winter hardiness.

Probably more new varieties of the so-called hardy chrysanthemum are being developed and introduced today than of any other garden flower. The collection here includes many, but not all, of the better introductions of the Korean hybrids from Bristol Nurseries, and the hybrids from the University of Minnesota, University of Chicago, University of New Hampshire, Colprit Nurseries, and the United States Department of Agriculture. Although these chrysanthemums are considered hardy, they have not been found reliably so in the test garden and it has been found necessary to resort to wintering them in cold frames to insure against loss by winterkilling.

The extensive collection of tall bearded iris suffered considerably from winter injury, which was followed by much soft rot of the older rhizomes, in spite of a mild winter and a good blanket of snow. There was more loss in the recently transplanted iris than in those established for a year or more. Mulching the first winter after transplanting might have prevented much of this loss.

Factors Influencing the Rapidity of Growth of Nursery Stock. (C. J. Gilgut, Waltham.) In a propagating medium of sand-peat in which a previous batch of cuttings had rotted badly, several materials commonly recommended for sterilizing media were tried. The dry chemicals were scattered over the sand-peat, and the formaldehyde sprinkled on with a watering pot. Each was then thoroughly worked into the medium and cuttings of *Taxus media hatfeldi* were inserted. The materials used and the effect on rooting of cuttings are shown below.

Material	Amount per Square Foot	Percentage of Cuttings Rooted In 9 Weeks	In 20 Weeks
Untreated			92
Formaldehyde	2.5 cc.	88	93
Potassium permanganate	7 grams	86	95
Fermate	28 grams	6	70
Spergon	14 grams	12	50

Rooting was quicker and better with the formaldehyde and potassium permanganate treatments than in the untreated medium. Fermate and Spergon prevented rot, but had a decidedly retarding effect on rooting. Apparently, when propagating media are to be used again, the preferred treatment is either formaldehyde or potassium permanganate.

In a comparison of the root-promoting substances, Hormodin No. 2 and Hormodin No. 3, in used sand treated with formaldehyde 2.5 cc. per square foot or with potassium permanganate 7 grams per square foot, better and quicker rooting was obtained with Hormodin No. 2. In the formaldehyde-treated sand Hormodin No. 2 gave 96 percent rooted in 10 weeks, against 80 percent for No. 3. In the sand treated with potassium permanganate, the percentage rooting in 10 weeks was 96 for Hormodin No. 2 against 86 for No. 3.

Control of Weeds in the Nursery by Chemical Sprays. (C. J. Gilgut, Waltham.) During the past season, Savasol No. 5, one of the oils which has found such a definite place in the commercial growing of carrots and parsnips, was investigated for control of weeds in the nursery. Nearly all the common weeds were quickly killed, especially when they were small. A few, notably ragweed (*Ambrosia artemesiifolia* L.), wild chamomile (*Matricaria suaveolens* (Pursh) Buchenau), and fleabane (*Erigeron canadensis* L.), all of which are in the family Compositae, were highly resistant to the oil and both young and old plants usually survived even thorough soakings.

Applications of undiluted oil were made with a 4-gallon sprayer equipped with a Skinner greenhouse irrigation nozzle, ST 50, which gives a flat fan-shaped spray. A flat spray is better than a cone-shaped for it wets the weeds better and is more easily controlled so that less oil gets on the nursery plants. The spray was directed at the weeds, and in the case of tall nursery plants the lower foliage of these plants was also wet. With the smaller nursery stock, it was necessary to wet the entire plant in order to wet the weeds.

On hemlock there was no injury to the older leaves, and slight injury to the soft, tender new needles but not enough to retard growth. Arbor vitae was likewise highly resistant, and young plants 12-15 inches tall showed only slight yellowing of foliage. Norway spruce and Colorado blue spruce, as well as white pine and Scotch pine, showed little or no injury. The most tolerant of all the evergreens tested was *Juniperus virginiana glauca*, which showed only a slight yellowing of some of the needles and no bark injury when sprayed much more heavily than is needed to kill weeds.

On *Taxus* spp. the spray injured the leaves and caused considerable defoliation as well as some bark injury, and it definitely is not safe on this group of plants. In general, on broad-leaf plants, evergreen and deciduous, there was considerable injury to the leaves, and to the bark in many cases if wet to any extent.

Although most of the narrow-leaf evergreens are highly tolerant to Savasol No. 5; as with other chemical sprays, caution should be used that too much spray does not get onto the plants. A careful operator, using a flat fan-shaped spray, can kill weeds close to the plants in a nursery row quickly and efficiently with a minimum of injury to the stock.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Asparagus Investigations. (Robert E. Young, Waltham.) Growing conditions of the two preceding years reduced the 1945 asparagus crop at the Waltham Field Station to 56 percent of the 1944 crop. A reduction of 10 to 20 percent in the stalk count taken in the fall of 1944 was due to the unfavorable weather during the growing season. Selections Nos. 1 and 4 have yielded almost twice as many spears as the commercial strain in the past; and even though the total yields were greatly reduced, this ratio was about the same in 1945. The average weight of spears was only slightly less than previously, and most of the reduction was in the number of stalks. There was no change in the percentage of the two top grades as compared with 1944.

In the spring of 1945 a new generation of roots was set. Besides several commercial varieties, these included many combinations of best male and female plants from the plantings mentioned above. To obtain information on inheritance of yield characteristics, portions of the same female plant were crossed with two or more male plants. Two low-yielding plants, one male and the other female, were also used in crosses. Nineteen different strains and varieties were planted in three replications. The plants made vigorous growth and only 19 out of 1900 died. It may be only a coincidence that 7 of these were from one of the commercial strains. Those that died were not the small ones; in fact the average weight of these crowns was greater than the average for the entire lot of plants, which was 58 grams.

In the fall a count was made of the number of stalks produced by each strain during the summer, and the average per plant varied from 5.11 to 14.41. The commercial varieties and those crosses involving one or more low-yielding parents produced the fewest stalks. Such a variation might be presumed to depend to a large extent upon the original weight of the crowns when planted, but the strain which produced the least stalks had the largest crowns. There was little or no correlation between the original weight of the crowns and the number of stalks produced. While the number of stalks an asparagus plant produces in the first year's growth is not a sure criterion of future yield, data on second-generation plants show that the production of a large number of stalks in the first year is correlated with future high yields.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding work has been conducted with broccoli, greenhouse cucumber, celery, rutabaga, New York type lettuce, tomato, carrot, and Butternut squash. While progress has been made in the development of strains of carrot, celery, New York type lettuce, rutabaga, and greenhouse cucumber better adapted for local use, it is insufficient to justify detailed discussion.

Broccoli. Lack of uniformity in time of maturity and plant type in commercial varieties of broccoli was the reason for starting a breeding project on this crop. The variation in maturity of plants is demonstrated by two commercial varieties in our spring crop. By June 15, a date in midseason when all center heads should be ready if the crop is to be profitable, 41 percent of the plants from one of these varieties had been cut and 64 percent from the other. The best of the breeding lines set in the same field at the same time had produced 98 percent center heads. Other selfed lines ran from 47 to 93 percent, depending on the number of times selfed. This self-pollination has produced the desired uniformity in type and maturity but has reduced vigor and narrowed adaptability.

In order to produce a large supply of seed of one selfed strain, R-45, the plants were allowed to cross-pollinate among themselves. This massing improved vigor while maintaining uniformity. This strain, which was grown in a large block, proved to be the most outstanding broccoli ever grown here and had produced 89 percent of the center heads by June 15. It will be tested once more to be sure of its seasonal adaptability before being released to growers.

Results of this project indicate that while some strains are adaptable for both spring and fall crops, most are satisfactory only for the season for which they are bred. If the plants are self-pollinated more than two or three times, the loss of vigor is so great as to make them commercially worthless.

Butternut Squash. In 1943, local growers asked for a better, more uniform strain of Butternut squash. Trials of commercial and growers' strains indicated considerable variation, and some strains had a large percentage of the crop that was not marketable.

There was particular objection on the part of growers to cracking, crooked or curved fruit, and too great length. The breeding program is an attempt to combine the best of these characteristics in one strain. In 1945 the crop from the commercial strains varied from 0.6 percent to 12.8 percent crooked fruit, and from 19.4 to 42.9 percent cracking. No. 1 fruit—that is, squash of the desired size and shape and not cracked—varied from 227 to 345 boxes per acre.

During 1944, some of the best strains were self-pollinated, and these were grown during 1945. Some of the selfed lines possessed most of the characters desired and seemed quite uniform. The best of them had only 11 percent cracked, 6.7 percent crooked, 0.7 percent long, 7 percent small or misshapen; and a total yield of 520 boxes per acre. The yields from these lines varied from 407 to 607 boxes per acre, but the highest yielding strains had the greatest percentage of cull fruits, so the yield per acre of No. 1 fruit (not cracked) was only 394 boxes.

There is also the problem of obtaining a squash that will keep in storage and that does not shrink or shrivel. All the selfed squashes were placed in storage and weighed at intervals. The loss in weight from October 6 to December 19 was 12 to 14 percent, and the total loss to January 3 averaged 20 percent. These figures represent shrinkage only and do not include loss by rots. Unless a means can be found to reduce the shrinkage, the Butternut squash cannot be stored economically. Careful handling from field to storage is very important in the prevention of loss in storage.

In some tests to determine the carotene content and its relation to color of flesh, it was found that a dark color of flesh was not always an indication of high carotene. One lighter-colored squash had 2.14 milligrams carotene per 100 grams, which was next to the highest carotene content found.

In some preliminary trials on spacing Butternut squash, the number of fruits per plant increased with the increase in space, as follows: 6 x 6 feet, 1.90; 8 x 8 feet, 3.04; 10 x 10 feet, 3.87; and 12 x 12 feet, 5.92. There was very little difference in the average weight of the squash. While these trials were not replicated and were on a poor part of the field, the total yields per acre did not vary much from one spacing to another. It seems, therefore, that Butternut squash can be grown at spacings of 10 to 12 feet with satisfactory results.

Trellis Tomatoes. Trials of several varieties and strains of tomatoes were conducted. During the early part of the growing season of 1945 the weather was cold and wet and not conducive to good setting of fruit on the first hand or blossom cluster. In early July counts were made to determine whether there was any variation in set among varieties and strains. One variety had set an average of only 0.5 fruit per first cluster while another had set 3.7 fruits. Some varieties the percentage of set was: Waltham Forcing, 65; Trellis No. 22, 51; percentage basis this variation was from 19 to 65 percent. For the different varieties the percentage of set was: Waltham Forcing, 65; Trellis No. 22,51; commercial Comet, 44; Stokesdale, 33; Valiant, 33; Marglobe, 41; Mass. A 13, 45. The most promising selections from the breeding work set fruit as follows: Selection 1, 36 percent; Selection 2, 36 percent; and Selection 3, 49 percent. The extreme importance of a good set of fruit on the first hand or cluster can be realized from the fact that the first fruit brought 24 cents per pound while later in the season the price went down to 4 cents.

Yield data from the selections indicate that none of the strains is superior in early yield to either Trellis No. 22 or Waltham Forcing. Selections 1 and 3 produced the greatest total yield. There was less cracking in all three selections than in Trellis No. 22 but more than in Waltham Forcing. Further testing of these selections is necessary to determine whether any are superior to those now being grown.

In the trials of new varieties grown without trellis, Red Cloud from Nebraska Agricultural Experiment Station was outstanding in the production of early fruit. It produced twice as many early No. 1 fruits as any other variety except Pennheart. Red Cloud produces fruit of size and shape more acceptable to the Boston market than Pennheart. Very few of the fruits crack or sunscald. Its disadvantages are poor color and lack of firmness compared with the trellis type tomato. Both Red Cloud and Pennheart are determinate varieties and cannot be grown on trellis. Of the trellising type tomatoes which were grown flat, Waltham Forcing produced the most early No. 1 fruits.

Weed Control in Vegetable Crops. (William H. Lachman.) The search for selective weed killers for vegetable crops has been continued. Sinox and Dow Selective Weed Killer belong to a group of chemicals known as dinitro compounds and these have been found valuable for killing weeds in peas, corn, and onions. In tests on the Experiment Station plots, these compounds were very effective in killing broad-leaved weeds but were of little value against grasses. More often than not they caused damage to the crops, depending upon the intricate combinations of weather conditions. On several occasions Sinox gave very good weed control in plantings of sweet corn with little crop damage, but in a number of other tests the corn leaves were scorched badly by the spray.

The new hormone weed killer, 2, 4-D, was also used in sweet corn but caused severe epinasty of the corn leaves. Almost all of the broad-leaved weeds were controlled satisfactorily, but the grassy weeds were unharmed.

A 2 percent solution of sulfuric acid killed many broad-leaved weeds in plantings of seedling onions but had little effect on grasses. The corrosive action of the acid on metal and clothing and its hazardous nature in general preclude the use of this method of weed control.

Frequently asparagus growers have difficulty eliminating weeds from their fields, particularly after the cutting season is over. A very potent weedicide, Dow Contact Weed Killer, was found to be especially good for this purpose. The spray should be directed down around the basal stalks of the asparagus plants for it kills the leaves or fern-like portion of the plant if these are wet by the spray.

The use of Stoddard Solvent as a weed killer in fields of carrots and parsnips was widely accepted by vegetable growers during 1945. Approximately 500 acres were treated in this manner and the growers were agreed that this was an ideal method of weed control since less labor was required, it was cheaper, and the job was done more quickly.

Stoddard Solvent is best applied when the weeds are small, since the weeds are more easily killed when young and the crop is benefited by early weed removal.

All annual weeds encountered, except ragweed, were killed by 100 gallons of the oil per acre. The carrots were relatively unharmed by the spray under most conditions, but the oil caused a scorching of the older leaves when the spraying was done while the leaves were wet.

The oil is highly volatile and does not leave any toxic residue in the soil. The oily flavor is dispersed from the carrot plant after a period of about fourteen days. Since the carrots and parsnips are not killed by this treatment they must be thinned as usual.

Young celery seedlings are not harmed by the oil, but half grown and older plants are considerably damaged. Most other crops including beets, cabbages, peppers, onions, asparagus, spinach, lettuce, turnips, and radishes are damaged or killed by Stoddard Solvent.

This oil can be used as a pre-emergence spray with susceptible crops; that is, the soil is sprayed just before the seedlings of the crop emerge from the soil. Crops of spinach, beets, and onions have been successfully weeded in this manner.

Breeding Sweet Corn, Peppers and Field Tomatoes for Massachusetts. (William H. Larchman.)

Sweet Corn. The development of inbreds or parent strains of corn has been the major objective of this project until last year. A number of the inbreds have reached a remarkable degree of uniformity in most of their plant characteristics and now many of these have been cross-pollinated in various combinations to test their relative value as parents for the production of hybrid sweet corn. One of these strains has shown itself to be a good seed parent and has been named Mass. 32. A large western seed house has increased the supply of this seed to 1500 pounds and it is now ready for use as a parent in production fields.

Mass. 32 has been found to make an excellent hybrid when crossed with Connecticut 42. The hybrid is essentially an early Golden Cross Bantam and seems to be well adapted to Massachusetts conditions. It has an ear of good size and quality and matures about one week earlier than Golden Cross Bantam.

Several other experimental hybrids looked very promising in 1945, but further testing is necessary before their merits can be established.

Peppers. The object of this work has been to develop an early, high-yielding, thick-fleshed pepper of the California Wonder Type. A number of selections from commercial varieties and some hybrids among these have been grown in an effort to achieve this goal. This project has not yet progressed to the point where results are forthcoming.

Tomatoes. There is need for a large, early, smooth fruited tomato variety with high yielding ability. Selections from commercial varieties have been intercrossed and further selections from this material have been made for several years. A number of promising strains have been developed, but they have not reached the desired degree of uniformity or excellence and none have yet been released for trial among vegetable growers.

The Culture and Nutrition of Vegetables. (William H. Lachman.)

1. Straw, sugar cane fiber, and horse manure were used as mulching materials for Rutgers tomatoes. The plants were grown unstaked and unpruned, and the treatments were replicated three times. These treatments were responsible for wide differences in yield in comparison with the control plots. The highest yield was harvested from the plots with the horse manure mulch; the lowest from those mulched with sugar cane fiber. The latter had a distinct depressing effect upon both vine growth and yield.

2. Carrot varieties and strains are planted each year to evaluate the various kinds, and these are generally tested for carotene during various stages of development and after they have been in cold storage for several months. It was plainly evident that the carrots were significantly lower in carotene in 1945 than they had been for a number of years. The only explanation that could be given was the great amount of cloudy weather and excessive rainfall during the growing season.

3. Tomato varieties with a determinate habit of growth, such as Pennheart, nearly always shed most of their leaves shortly after the ripening of the earliest fruit. The drain of food reserves from the leaves by the heavy set of fruit has been considered responsible for this condition. After various degrees of blossom removal, it was clearly evident that there was a negative correlation between the fruit load on the plant and retention of its foliage.

4. A peculiar chlorotic mottling of the leaves of greenhouse tomatoes has appeared for several years, very similar to the symptoms of magnesium deficiency; but large applications of magnesium as magnesium sulfate and high magnesium limestone failed to correct the condition. High potash supplies in the soil often aggravate magnesium deficiency in plants and the soil in question is well supplied with potash. Applications of potash are now being withheld from some of the plots in an attempt to determine whether an excess of potash is causing the trouble.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties.[1] (J. K. Shaw and W. D. Weeks.) For three successive years, spring frosts have interfered with a full crop in the large clonal rootstock orchard. As cold injury varied in severity with variety and in different parts of the orchard, it has invalidated yield records, but records of growth and bloom are still dependable. The trees are now growing vigorously. Results of an experiment like this come slowly, but the next few years should show interesting results.

An orchard of 256 trees of 16 varieties all on Malling IX was planted in 1943. There was some bloom and fruit last year and in 1946 nearly all varieties bloomed freely and set a fair to good crop in spite of spring frosts. The orchard is on higher ground than the orchard referred to above. There was little bloom on Northern Spy and Red Spy, but only four trees of the remaining 224 trees of 14 common varieties in the orchard failed to bloom. The trees have been in cultivation and are growing vigorously.

That Wealthy is very much dwarfed on Malling I while McIntosh on the same rootstock makes a typical semi-dwarf tree has been confirmed by further observations.

Lethal Incompatabilities Between Clonal Stocks and Varieties of Apples. (J. K. Shaw and W. D. Weeks.) Further studies of the lethal McIntosh strain R show that buds from the original tree of this strain failed to survive on the rootstock Spy 227. Evidently the lethal factor is present in the original tree. Failure resulted when both strain R and the non-lethal strain G were budded together on Spy 227. Evidently strain R is always lethal to Spy 227. Strain G wes budded on a tree of strain R and buds from the resulting shoot were budded on

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[1]Two papers reporting on this project will appear in Vol. 47 of the Proceedings of the American Society for Horticultural Science.

Spy 227. At the same time buds from unbudded branches of the same tree of strain R were set in other Spy 227 rootstocks. At the present writing two trees of strain R have died in typical fashion, while all the trees of strain G are normal. This suggests that the lethal factor cannot pass into strain G and that strain G cannot communicate resistance to strain R; but the final conclusion cannot be reached until more time has passed.

Some trees of Starking grow very poorly on certain clonal rootstocks; they blossom very early in life and may die or, in some cases, seem to recover and grow better. Other trees of Starking grow normally on the same rootstock. Three-year-old trees budded from such weak and vigorous trees of Starking show the same difference. Those growing from weak trees are much less vigorous and some will probably die, while buds from the vigorous trees are growing normally. There seem to be two "strains" of Starking trees. Whether the trouble is a virus is not known.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and W. D. Weeks.) The study of new varieties is a task without end. In the last report it was stated that Van Buren was the only bud sport that could be distinguished from its supposed parent variety, Duchess of Oldenberg. An examination of the original tree of Van Buren and propagation of buds from a normal branch and the sporting branch of this tree, and comparison with trees known to be Duchess of Oldenberg, has revealed that the original tree is not Duchess of Oldenberg but some other variety at present unknown. This single exception to our usual experience that red bud sports cannot be distinguished from the parent tree by nursery trees is thus removed and the general statement holds true. It is not correct to call Van Buren the Van Buren Red Duchess.

The inspection of nurseries for trueness-to-name was carried out in 1945 and is now in progress for 1946 on a somewhat enlarged scale.

A bulletin on the identification of blueberry varieties has been published.

The Nature of Winter Hardiness in the Raspberry. (J. S. Bailey, A. P. French, and R. A. Van Meter.) Canes of the six varieties, Marcy, Washington, Taylor, Milton, Latham, and Chief, were forced in the greenhouse at weekly intervals as in the fall of 1944. Again Chief and Latham were the slowest to start; Marcy and Washington started most readily; Milton and Taylor were intermediate. Milton behaved about as in 1944 but Taylor started much more readily. The rest period for all was over about a week later than in 1944.

Although the winter of 1945–46 was not severe, a large amount of cane killing occurred on all six varieties, undoubtedly caused by a very heavy infection of spur blight. Fermate sprays are being used to eliminate this source of trouble.

Comparison of Cultivation and Sod Mulch in a Bearing Orchard. (J. K. Shaw.) This project, which was started many years ago, has developed into a study of the mineral nutrition of apple trees, with special emphasis on magnesium deficiency and the value of orchard mulches. It is now planned to study the value of mineral leaf analysis in planning a fertilizer program for orchards. When unmistakable symptoms of a mineral deficiency appear, it is probable that much injury to the tree has already occurred. A knowledge of the mineral content of the leaf might suggest that certain elements were low and thus permit an earlier diagnosis of an approaching deficiency. The value of branch injections and leaf treatment as a means of diagnosis is also being studied.

The project has led to a gradually increasing appreciation of the value of potash and possibly phosphorus in the orchard; also to the belief that the so-called "complete" fertilizer is not complete. Magnesium, boron, and possibly calcium are as important as phosphorus and potassium to supplement the most important element, nitrogen. No evidence of a deficiency of other than these six elements has yet been found in Massachusetts orchards. The value to the trees of some of these elements may be indirect in that they favor the growth of grass or cover crops and thus add humus and colloidal matter to the soil to benefit the trees.

A complete fertilizer and magnesium and boron may not be needed every year, as is nitrogen, but should be applied from time to time as orchard needs require. Magnesium limestone should always be used rather than a high calcium limestone when soil acidity drops below about pH 5.50. Boron in the form of borax should be applied to orchards that have shown deficiency, every 3 or 4 years at the rate of 30 to 50 pounds per acre. Boron in excess is toxic to plants, but apple and other tree fruits are not as sensitive to boron as are many other cultivated plants.

Blueberry Culture. (J. S. Bailey.) Mummy berry infection was reduced about 50 percent in 1945 by spraying four times with Fermate.[1] This work is being continued in 1946.

DDT and cryolite as dusts were applied to control the cranberry fruit worm. Since the infestation was very light, no significant differences were observed. However, it was determined that the fluorine on berries dusted June 13 with cryolite was well below the Federal tolerance.

Several new blueberry selections were added to the Experiment Station collection during the year.

The blueberry stunt, a virus disease, was found in Massachusetts in the summer of 1945. A careful survey was made of most of the larger plantings. In most cases where the disease was found the grower promptly removed all infected or suspicious bushes. This disease has probably been in Massachusetts for a number of years, but it does not appear to be spreading.

Nutrition of the High-Bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) After five years of manuring, there is still no evidence of any toxic effect of applications of manure as heavy as 20 tons per acre.

Several years' experience indicates that blueberries can be grown in a rather heavy sod provided plenty of nitrogen is applied and the plants are not in a situation where moisture becomes the limiting factor.

Much more chlorosis than usual appeared in some of the blueberry plantings in the early summer of 1946, following the application of ammonium nitrate in place of the usual sulfate of ammonia. This chlorosis is most noticeable on the varieties Sam and Pemberton.

Control of the Peach Tree Borer. (J. S. Bailey.) Paradichlorobenzene, ethylene dichloride, and propylene dichloride were applied again in the fall of 1945 at the standard dosages. Too few borers were present to make comparisons of effectiveness possible. Again there was no sign of injury resulting from any of the treatments. A very satisfactory emulsion of propylene dichloride in water was made by using oleic acid and triethanolamine.

Magnesium Deficiency in Massachusetts Apple Orchards. (J. K. Shaw and W. D. Weeks.) The typical leaf scorch characteristic of magnesium deficiency was rather uncommon in our orchards in 1945. Yet chemical analysis of the leaves showed a tendency for the magnesium content to be lower rather than higher. Trees which had been treated with dolomitic limestone held up better than others treated with Epsom salts. A possible explanation is that magnesium

[1] The results of this experiment will appear in Volume 47 of the Proceedings of the American Society for Horticultural Science.

may have been leached from the soil by the heavy rains of May and June, 1945, and that soil moisture continued ample through July and August so that little leaf scorch appeared. The problem of correcting magnesium deficiency is difficult, particularly with mature trees. We continue to recommend the use of magnesium sulfate in three or four sprays in early summer for immediate results and dolomitic limestone for more lasting effect. An enlarged program of study of this problem is under way.

Thinning Apples with Sprays. (J. K. Shaw.) In 1946 as in 1945, spring freezes interfered with attempts to thin apples by spraying in bloom, yet some results were obtained. Dowax, 1 gallon to 100, seemed to reduce set of Macoun but had little or no effect on five other varieties, including McIntosh. A commercial preparation of naphthalene acetic acid, 20 p.p.m., was more or less effective on several varieties and thinned certain crab varieties and Stark excessively. Applied at 30 p.p.m., it reduced the set of Wealthy about one third; not enough to eliminate some hand thinning. It caused considerable dwarfing and distortion of the leaves.

Two DN powders were used, both of which thinned several varieties quite effectively and caused much less leaf burning than did Elgetol used in 1944. There were generally not effective on McIntosh. It will not usually be necessary to thin McIntosh, but the unusually heavy bloom this year seemed to offer an opportunity to study this variety. It is evidently not easily influenced by blossom-thinning sprays. Naphthalene acetic acid was partially effective and caused little leaf distortion.

Because of the abnormally cold spring, it is not safe to draw many conclusions as to the value of blossom-thinning sprays. They are being used in commercial orchards and it seems probable that they will find increasing use as we learn more about them. Evidently the variety, stage of bloom, and possibly condition of the tree must be carefully considered.

Applications of naphthalene acetic acid and 2, 4-D at heavy concentrations in August to delay blossoming the following spring and thus escape frost damage seemed to have no certain effect. Applied at the time of fruit bud formation in May, it affected the leaves in the usual way and destroyed many fruit buds of Duchess but did not noticeably affect the buds of McIntosh and Wealthy. Neither material seemed to hasten the ripening and development of yellow color in Golden Delicious and McIntosh when the apples were dipped in various concentrations of the material in water.

Chemical Control of Poison Ivy and Other Weeds. (J. S. Bailey.) Several chemicals, including ammonium sulfamate and three formulations of 2, 4-D and some oils, were tried as herbicides for poison ivy, chokecherries, and American bamboo (*Polygonum Seiboldii* De Vriese). For poison ivy and chokecherry, ammonium sulfamate was superior to anything else tried. Nothing was effective on American bamboo. Ammonium sulfamate sprayed around young peach trees to eliminate grass and weeds killed the peach trees.

DEPARTMENT OF POULTRY HUSBANDRY

F. P. Jeffrey in Charge

Broodiness in Poultry. (F. A. Hays and Ruby Sanborn.) The chief objective has been to develop a line of Rhode Island Reds entirely free from the broody instinct. This goal has not yet been attained, largely because of the problem of deferred broodiness and the difficulties of adequate progeny testing of the breeding males. A limited life span in birds also adds to the difficulties. Data indicate that females with broodiness deferred beyond the first laying year sometimes produce daughters that exhibit the broody instinct in their first year. Hens that only cluck without cessation of laying may transmit broodiness. The most recent data indicate that broody behavior often appears in the most intense winter layers.

The last complete generation was hatched in 1944 and completed their first-year record in 1945. Of the 66 pullets housed, 51 completed a full year. Only one exhibited the broody instinct, and that by a single period. These females are being tested for deferred broodiness.

Effectiveness of Selective Breeding to Reduce Mortality. (Regional Poultry Research Laboratory and Departments of Veterinary Science and Poultry Husbandry, Massachusetts Agricultural Experiment Station, cooperating.) Results of three generations of inbreeding to produce high and low mortality lines, with mortality rate the sole basis of selection, will not be completed until November 1946. The data indicate a significant difference between the two lines. One disturbing feature is that the mortality rate in the low line always exceeds the mortality rate in the control line. Complete results are not yet available.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) Particular attention has been given to methods of selecting breeders to raise the level of production. A seven-year study just completed (now in press) indicates that annual egg production is a very unsatisfactory criterion of the probable breeding value of hens in improved flocks.

Intensity of laying at all seasons of the year stands out as of highest importance in the station flock of Rhode Island Reds at the present time. Methods of measuring intensity and further evidence of its mode of inheritance are receiving special study.

At present, raising the average egg production of all daughters from the different families above 230 eggs averaging about 25 ounces to the dozen seems to depend upon higher intensity and greater freedom from winter pause.

Fertility Cycles in Males. (F. A. Hays.) Sex hormones have not proved effective in increasing natural fertility of old males in midwinter. The value of artificial light for this purpose will be studied further.

A Genetic Analysis of Rhode Island Red Color. (F. A. Hays.) This project has been concluded. General results indicate recessive genes controlling dark pigmentation.

Secondary and Adult Sex Ratio in Relation to Hatchability. (F. A. Hays.) Further data on sex ratio have been secured on high and low hatching lines. Sex has been recorded on dead embryos sufficiently advanced and upon all dead chicks up to sexual maturity. The two lines differ greatly in hatchability, and possible factors underlying this difference are being studied.

Supplementary Nutritional Factors for Distillers' By-Products. (F. P. Jeffrey, W. S. Ritchie, G. L. Woodside, and J. W. Kuzmeski.) The use of distillers' by-products in poultry breeding rations has received continued study, with special emphasis on the factor or factors in fish meal which have a supplementary value for hatchability. In a repeat trial, the use of 1.25 percent of fish meal as a supplement to the negative control gave disappointing results. The current trial shows that 2.50 percent red fish meal and 2.00 percent liver extract give equally good hatchability when supplementing the negative control.

Breeding for High and Low Incidence of Internal Defects in Hen's Eggs. (F. P. Jeffrey.) In the first generation, 769 Rhode Island Red pullets were produced from two separate lines of breeding. Breeders in line 1 were selected for freedom from blood and meat spots, blemished yolk, and fishy odor in their eggs. Breeders in line 2 were selected for a high incidence of these defects. Fertility and hatchability were excellent in both lines.

Breeding White Plymouth Rocks for Eggs and Meat. (F. P. Jeffrey.) Hatching eggs were secured from six prominent commercial breeders, and approximately 450 pullets will be housed this year. There was a wide variation among the strains, as shown by the following figures:

Hatchability of total eggs set	50 – 84 percent
Incidence of fast feathering	2 – 34 percent
Mortality to 8 weeks of age	2 – 16 percent
Pure white down	45 – 82 percent
Body weight at 8 weeks (Average of both sexes)	1.00 – 1.47 pounds

Poultry Housing Investigations. (W. C. Sanctuary and C. I. Gunness.) See report of Department of Engineering.

Methods of Feeding. (John H. Vondell.) This is the second year's study of methods of feeding layers. Three pens of 60 and 80 birds were hopper fed (free choice) laying mash, whole oats, and whole corn. Two pens were hopper fed laying mash and hand fed scratch feed to equal the amount of mash consumption. One pen was fed a complete all-mash. The test began September 28 and ran for twelve lunar months, with the following results:

	Hopper-fed	Hopper-fed and Hand-fed	All-Mash
Average egg production, percent	51.2	49.3	50.9
Mortality, percent	25.6	12.4	7.5
Feed consumption per bird, pounds	93.5	109.9	108.3
Feed cost per bird	$3.09	$3.68	$3.79
Net return per bird over feed cost	$3.39	$2.53	$2.62

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint F. G. Sperling, M. K. Clarke, and O. M. Olesiuk.)

1. *Pullorum Disease Eradication.*[1] During the 1945-46 season, 1,259,623 samples, representing 630 chicken and turkey flocks, were tested. Compared with the previous season, 284,582 more samples and 101 more flocks were tested; but the average percentage of reactors was the same, 0.12. Progress in eradication of the disease is definitely evidenced by the fact that 95.3 percent of all birds tested are in 100 percent tested, non-reacting flocks. The average percentage of reactors was lower in flocks tested annually than in flocks tested for the first time or intermittently.

A detailed report of the 1945-46 testing season has been published in Control Series Bulletin 128.

The testing results for turkeys are not so encouraging. A total of 21,473 birds, representing 103 flocks, was tested. Approximately 25 percent of the tested birds are in infected flocks. This situation may be improved through more persistent education regarding pullorum disease eradication and prevention.

During the past year natural pullorum infection was identified in pheasants for the first time in Massachusetts. The history of the flock showed that the infected birds were part of a group of pheasants imported from a Midwestern State by a Massachusetts State Game Farm. This observation suggests that pheasants may be a potential hazard to pullorum-free flocks.

2. *Diagnostic Service.* During the calendar year of 1945, 4224 specimens were received in 939 consignments, of which 509 were delivered in person. This is the largest number of consignments and specimens ever examined in a single year. The specimens were classified as follows: 3340 chickens; 715 turkeys; 75 ducks; 24 rabbits; 11 bovine semen; 9 each of canine feces, pheasants, and pigeons; 5 fish; 4 guinea pigs; 3 each of canaries, swabs from horses, and swine; 2 each of swine organs and bovine organs; and 1 each of bovine fetus, canine, deer, fox, goat feces, junco, rat, robin, and sheep.

Coccidiosis, tumors, pullorum disease, infectious bronchitis, and fowl paralysis were the conditions encountered most frequently. On the basis of gross examination, the tumors were classified as follows:

Lymphocytoma	31	Carcinoma	4	Fibroma	1
Myelocytoma	14	Embryonal nephroma	4	Hematoma	1
Leukosis	8	Leiomyoma	2	Melanoma	1
Hemangioma	6	Myxoma	2	Neurogenic sarcoma	1
		Unidentified	2		

Avian tuberculosis was identified in three flocks. Fowl typhoid reappeared in serious proportions and 14 cases were called to the attention of the laboratory, 12 of which represented new known foci of infection and were located principally in two new areas. Fowl cholera was identified in 25 instances including 12 new premises. Fowl cholera was found also in turkeys, ducks, and a robin. The infection in the robin was believed to have originated from a flock of chickens on range where an acute outbreak of the disease was in progress. Newcastle disease was found in chickens in November, and 10 cases were identified before the end of the year. The recognition of this disease calls into question the diagnoses of infectious bronchitis made earlier in the year without the benefit of embryo inoculations.

An unusually large number of cases of poisoning in chickens was noted and confirmed by the Feed Control Service Laboratory when necessary. These included 1 arsenic; 9 coal tar, creosote oil, and derivatives; 4 salt; 1 cocoa bean; 1 kerosene; 1 naphthalene; and 2 phosphorus. Attempts to confirm the diagnosis of cocoa bean posioning by feeding a small quantity of beans and shells to three birds were unsuccessful, but other observations indicated that the beans were the source of injury.

The 715 turkeys were received in 154 consignments and represent nearly twice the number of the previous year and ten times that of ten years ago. Pullorum disease, enterohepatitis, rickets, and paratyphoid were the diseases encountered most frequently. Coccidiosis, ulcerative enteritis, and perosis were each recognized in eight instances. Fowl typhoid was found in six poults and in one bird five months of age.

3. *Flock Mortality Studies.* Necropsies were made on 256 birds (111 females, 144 males, 1 unidentified) from the flock hatched in the spring of 1944 and maintained at the College for genetic studies. In the females, tumors, reproductive disorders, kidney disorders, and fowl paralysis accounted for more than three-fourths of the mortaility. On the basis of gross examination, the tumors were classified as follows:

Lymphocytoma	11	Leukosis	2	Papilloma	1
Myelocytoma	4	Carcinoma	2	Unidentified	1
Leiomyoma	3	Hemangioma	2		

In males, cannibalism, bacterial and mycotic diseases, kidney disorders, and fowl paralysis were the conditions most frequently encountered, accounting for 60 percent of the deaths.

4. *Infectious Bronchitis.* During 1945, 228 flocks were enrolled in the infectious bronchitis control program, which was carried on in much the same manner as in 1944. Several flocks enrolled in 1944 did not continue the program in 1945 for reasons not reported by the owners.

The bronchitis problem was greatly complicated by the identification of the Newcastle disease in Massachusetts in November 1945. Since the symptoms and lesions of the two diseases are so similar, an accurate diagnosis is not likely without resorting to refined and tedious laboratory tests. A survey is in progress to determine the distribution and incidence of these two diseases. Investigations into the transmission of the virus have recently shown that the virus of Newcastle disease can be isolated from fresh eggs laid by flocks which are in the terminal stages of the disease. The potential and practical significance of this finding is being investigated. When more personnel becomes available, methods of control will also be studied.

5. *Farm Department Brucellosis Control and Eradication.* The laboratory tested 388 bovine and 22 porcine blood samples by the standard tube agglutination method during the 1945 calendar year.

Mastitis Testing Laboratory. The progress in the development of an adequate mastitis testing laboratory has been consistent with delays experienced in all activities where new personnel and equipment are necessary.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon, In Charge

The members of the research staff of the Waltham Field State are assigned to this branch by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to reports of these Departments for results of investigations conducted at this Station.

PUBLICATIONS

Bulletins

428 Annual Report for the Fiscal Year Ending June 30, 1945. 71 pp. October 1945.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in field- or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

429 Annual Molt in Rhode Island Reds. By F. A. Hays and Ruby Sanborn. 24 pp. illus. December 1945.

The primary objective of this study was to determine the value of molting behavior as a guide in selecting breeding stock. Attention is given to both males and females in exhibition-bred and production-bred Rhode Island Reds.

430 Postwar Readjustments in Massachusetts Agriculture. By David Rozman. 35 pp. illus. March 1946.

Among the various postwar readjustments leading to greater efficiency and lower costs, primary consideration should be given to the reconstruction of farm units to take full advantage of land resources.

431 Identification of Blueberry Varieties by Plant Characters. By John S. Bailey and Arthur P. French. 20 pp. illus. May 1946.

This bulletin describes some of the vegetative characteristics which are useful in identifying plants of blueberry varieties in the nursery. Familiarity with these characteristics should aid in the prevention of variety mixtures.

432 Black Root Rot Resistant Strains of Havana Seed Tobacco for the Connecticut Valley. By C. V. Kightlinger. 20 pp. illus. May 1946.

This bulletin reports attempts to develop a strain of Havana Seed tobacco satisfactorily resistant to black root rot, yet capable of producing high yields of good quality.

433 Weather and Water in Cranberry Production. By Henry J. Franklin and Neil E. Stevens. 51 pp. illus. June 1946.

This is a supplement to Bulletin 402, and together they are intended to cover our present understanding of cranberry weather and water relations.

434 Mushrooms—For Food and Flavor. By William B. Esselen, Jr., and Carl R. Fellers. 20 pp. illus. June 1946.

Laboratory studies prove that mushrooms, besides serving as a flavor or garnish for other foods, are a nutritious food in themselves.

435 Vegetative Propagation of White Pine. By William L. Doran. 16 pp. illus. July 1946.

The difficulties experienced in propagating white pines from cuttings can be largely overcome. This is a description of methods used and results obtained.

Control Bulletins

124 Twenty-fifth Annual Report of Pullorum Disease Eradication in Massachusetts. By the Poultry Disease Control Laboratory. 12 pp. July 1945.

125 Inspection of Commercial Feedstuffs. By Feed Control Service Staff. 32 pp. July 1945.

126 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 28 pp. September 1945.

127 Seed Inspection. By F. A. McLaughlin. 40 pp. December 1945.

Meteorological Bulletins

679-690, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

NUMBERED CONTRIBUTIONS

521 Composition and nutritive value of mushroom protein. By William H. Fitzpatrick, William B. Esselen, Jr., and Edith Weir. Jour. Amer. Diet. Assoc. 22 (4):318-323. 1946.

523 A note on the presence of pyruvic acid in Ebenezer onions. By Emmett Bennett. Plant Physiol. 20 (3):461-463. 1945.

538 Studies in the chemistry of grass silage. By J. G. Archibald. Jour. Agr. Res. 72 (8):277-287. 1946.

545 Influence of supplementary calcium and magnesium fertilizers upon nutritive value of kale. By Arthur D. Holmes, Leo V. Crowley and John W. Kuzmeski. Food Res. 10 (5):401-407. 1945.

548 The ascorbic acid, carotene, chlorophyll, riboflavin, and water content of summer squashes. By Arthur D. Holmes, Albert F. Spelman and Carleton P. Jones. Food Res. 10 (6):489-496. 1945.

550 Immunization against a lymphoid tumor of the chicken. I. Attenuation by freezing. By Carl Olson, Jr., Cornell Vet. 35 (3):221-230. 1945.

551 Immunization against a lymphoid tumor of the chicken. II. Use of centrifuged material. By Carl Olson, Jr. Cornell Vet. 35 (4):308-313. 1945.

552 Immunization against a lymphoid tumor of the chicken. III. Attenuation by heat, drying and chemicals. By Carl Olson, Jr. Cornell Vet. 36 (1): 41-47. 1946.

556 Isolating gene E′ for early sexual maturity. By F. A. Hays. Amer. Nat. 79:372-377. 1945.

558 Further data on correcting magnesium deficiency in apple orchards. By Lawrence Southwick and C. Tyson Smith. Amer. Soc. Hort. Sci. Proc. 46:6-12. 1945.

561 Frost injury to trees. By Malcolm A. McKenzie. Trees 6 (3):10. 1945.

562 Venting times for community cannery-type retorts. By William H. Fitzpatrick, John E. McConnell and William B. Esselen, Jr. The Canner 101 (1):16-18; 101 (2):12-13. 1945.

564 Some notes on the mechanics of applying selective herbicides to vegetable crops. By William H. Lachman. Amer. Soc. Hort Sci. Proc. 46:323-328. 1945.

565 Ice cream as a source of riboflavin, carotene and ascorbic acid. By Arthur D. Holmes, John W. Kuzmeski, Carleton P. Jones and Frank T. Canavan. New England Jour. Med. 234:47-49. 1946.

566 Study of false presumptive tests from water treated with chlorine-ammonia. By James E. Fuller and Chas. K. Ewing. New England Waterworks Assoc. Jour. 59 (3):244-251. 1945.

568 Variation in bacteria, fat, ascorbic acid, and riboflavin content of commercial goat's milk. By Arthur D. Holmes, Harry G. Lindquist and Elliott K. Greenwood. Jour. Dairy Sci. 28 (11):853-858. 1945.

569 Some effects of thyroprotein on the composition of milk. By J. G. Archibald. Jour. Dairy Sci. 28 (12):941-947. 1945.

570 Utilization of Shrimp Waste. By Francis P. Griffiths. Nat'l Chemurgic Digest, August, 1945.

572 Propagation of the Briarcliff rose by cuttings. By William L. Doran. Florists' Exch. 105 (11): 17 and 21. 1945.

574 Vitamin content of field-frozen kale. By Arthur D. Holmes, Beula V. McKey, Katherine O. Esselen, Leo V. Crowley, and Carleton P. Jones. Amer. Jour. Dis. Children 70 :298-300. 1945.

575 Influence of incubation temperatures on differential tests of coliform bacteria. By James E. Fuller. Jour. Bact. 51 (4):457-464. 1946.

576 The vitamin content of mare's milk. By Arthur D. Holmes, Beula V. McKey, Anne W. Wertz, Harry G. Lindquist and Leonard R. Parkinson. Jour. Dairy Sci. 29 (3):163-171. 1946.

581 The control of the blueberry bud mite. By John S. Bailey and Arthur I. Bourne. Jour. Econ. Ent. 39 (1):89. 1946.

584 The application of chemistry to animal husbandry. By J. G. Archibald. Jour. Chem. Ed. 23:49-51. 1946.

587 The use of calcium salts in freezing McIntosh apples. By John J. Powers and William B. Esselen, Jr. Fruit Prod. Jour. and Amer. Food Mfr. 25 (7):200-202, 217. 1946.

591 Goat's milk as a source of bone building minerals for infant feeding. By Arthur D. Holmes, John W. Kuzmeski, Harry G. Lindquist and Henry B. Rodman. Amer. Jour. Dis. Children 71:647-653. 1946.

UNNUMBERED CONTRIBUTIONS

Minerals for dairy goats. By J. G. Archibald and S. A. Asdell. Better Goatkeeping 1 (2). September 1945.

The current feed situation. By J. G. Archibald. New England Homestead, January 12, 1946.

Soil fertility and animal health. By J. G. Archibald. Amer. Fert. 104 (7). April 1946.

Dutch elm disease in Massachusetts during 1945. By Malcolm A. McKenzie. New England Div. Amer. Phytopath. Soc. at New Haven, Conn., December 5, 1945. Abstracted for Phytopathology.

Role of riboflavin in poultry nutrition. By Arthur D. Holmes. Northeastern Poultryman, December 1945, p. 37.

Milk in the human dietary. By Arthur D. Holmes. Amer. Cookery, February 1946, p. 28.

Tansy causes off-flavor. By H. G. Lindquist. New England Homestead 118 (17):12. September 8, 1945.

Higher quality milk. By H. G. Lindquist. New England Goat News 8 (4):1, 3, 5-6; 8 (5): 3-4. April and May 1946.

Milk products in bread enrichment. By J. H. Frandsen. Natl. Butter and Cheese Jour. 36 (10):66, 1945. Certified Milk 20 (234):7, 18, 1945; Hoard's Dairyman 90 (19):541, 1945; Amer. Milk Rev. 7 (9):336, 1945.

Pests outside the four walls. By A. I. Bourne. Pests 13 (3):6-12. 1945.

DDT saves colonial coach at Amherst. By A. I. Bourne. Pests 13 (4):31. 1945.

Supply outlook for fungicides and insecticides in 1946. A. I. Bourne and O. C. Boyd. Fruit Notes, November 1945; Commercial Vegetable Grower, December 1945.

Leaf-feeding sawfly larvae burrowing in structural wood. W. B. Becker and H. L. Sweetman. Jour. Econ. Ent. 39 (3):408. 1946.

DDT, its uses in horticulture. By W. D. Whitcomb. Mass. Hort. Soc. Flower Show Program. March 1946. pp. 37-41.

MIMEOGRAPHED CIRCULARS

FM 19 Returns from poultry farming in Massachusetts in 1944. By Charles R. Creek. 17 pp. October 1945.

High costs and high returns on 50 dairy farms in Massachusetts. By Charles R. Creek. 5 pp. June 1946.

Standards for Massachusetts dairy farms (4 pp.); Standards for Massachusetts poultry farms (2 pp.); Standards for Massachusetts market garden farms (4 pp.); Standards for Massachusetts fruit farms (3 pp.). By Charles R. Creek. Revised August 1945.

Dutch elm disease. By Malcolm A. McKenzie. Five progress reports.

Progress reports issued under the National Cooperative Project, Conservation of Nutritional Value of Foods:
Effect of containers and other factors on the ascorbic acid content of processed tomato juice. By W. B. Esselen, Jr., and R. A. Woodward. 3 pp. 1945.

Extension Publications

The following Extension Leaflets and Circulars were prepared wholly or in part by members of the Experiment Station staff:

Improving land the modern way. By Charles R. Creek and Joseph F. Hauck. Special Circular 122. 1945.

Cost figures on boulder removal. Farm Economic Facts, March 1946.

High costs—high returns. By C. R. Creek. Farm Economic Facts, June 1946.

Minerals for dairy cattle. By J. G. Archibald. Leaflet 236. 1945.

Winter injury to trees. By Malcolm A. McKenzie, Special Circular 117, revised.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 437

OCTOBER 1946
Revised NOVEMBER 1948

Home Freezing in Massachusetts

By William B. Esselen, Jr., Katherine M. Lawler,
and Carl R. Fellers

Home freezing of foods is arousing much interest. In Massachusetts freezing seems best suited as a supplement to other methods of home food preservation. Questions frequently asked by prospective home freezer owners are answered.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

HOME FREEZING IN MASSACHUSETTS

By William B. Esselen, Jr., Associate Research Professor of Food Technology, Katherine M. Lawler,[1] and Carl R. Fellers, Head of the Department of Food Technology

In recent years freezing has become an important method of home food preservation in many parts of the country. Today many persons are concerned with the question of whether or not to buy a home freezer, how to use it, and its value as a replacement for home canning.

Several types of freezing facilities are available. The home freezing unit may consist of a unit built for freezing and holding food at a temperature of approximately 0°F. or one with a freezing unit operated at —20°F. and a holding compartment at 0°F. In addition some of the new types of home refrigerators are being built with a special compartment for frozen foods. The community locker plant may serve for many families either as a food bank where raw materials may be taken, processed, and stored until needed for use or where food prepared at home may be taken to be frozen and stored. The building of new locker plants and the increased production of home freezing units encourages and provides for an expanded development in this method of home food preservation. It is well known that this equipment is expensive and that the expense of operation varies with (1) the amount and kinds of food being processed, (2) the care and technique of handling both food and freezer, (3) initial investment, and (4) power consumption and rate.

Home and locker freezing have had their initial and greatest development largely in certain rural areas of the country, especially where farmers raise considerable quantities of their own meats. During the past few years many questions have been raised by people in Massachusetts as to the place of home and locker freezing for a more urban population such as is found in this State. This bulletin attempts to answer some of these questions as they apply to this area and to present the results of research carried on here on freezing and canning. Factors to be considered by the individual before he embarks on a home freezing program are indicated and information is presented to assist in successful home freezing.

Facilities for Home Freezing

Home Freezing Cabinets

A good home freezing unit should provide high quality foods after a storage period of several months. The food must be prepared, packaged, frozen rapidly, and held in storage at a temperature of 0°F. or below. There are two general types of home freezing cabinets—the chest type and the front opening type. The size of the unit selected should be determined by the size of the family, the amount of food to be frozen, and whether the home unit will be used for freezing and storing or in combination with a locker plant. Six cubic feet per person is the recommended storage space for a year's supply of frozen foods. This will allow storage of from 150 to 250 pounds of meats, fruits, and/or vegetables. However, if only a few selected foods are to be preserved by freezing or if freezing is to be used as a supplement to home canning, the space required will be less.

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Construction details should be carefully considered from the standpoint of durability, operating efficiency, and convenience in use. The finish should be easy to clean and rust resistant. Food should be easily accessible and shelves, if present, should be spaced for efficient use.

A thermometer should be provided so that the temperature within the cabinet can be checked during operation. Top lids should be of a size and weight that can be lifted comfortably, and the installation of an alarm device to prevent loss of food due to mechanical failure or power shut-off is suggested by Masterman (11).

According to Crowther (3), construction details supplied by the manufacturer should provide information on the types of material used, the kind and thickness of the insulation, the sealing of the unit, and the refrigeration equipment. Guarantees, provisions for servicing, and adequate instructions for the care and use of the cabinet are all important.

Locker Freezers

Frozen food locker plants and the facilities they offer are becoming increasingly popular among homemakers who wish to freeze foods. The first so-called lockers used for the cold storage of food were located in California about 1913, according to Tressler and Evers (15). They were nothing more than locked boxes, furnished by farmers, which were stacked in a cold room. Later, lockers were constructed as drawers and arranged in tiers to slide in and out. The service was limited to farmers who raised and processed their own products, since cold storage was the only service provided.

When services were offered for preparing and freezing meats, vegetables, and fruits, the demand for lockers increased. Locker plants have become very popular in the Middle West and West and are increasing in popularity in the eastern part of the country and New England. A recent survey (Warner, 20) showed that there were 29 locker plants in Massachusetts and 185 in the six New England States. On a nation-wide basis, 5,300,000 locker boxes handled 1,750,000,000 pounds of products, or an average of 330 pounds each.

Locker plants are of five general types:

1. Plants which offer preparation and freezing storage for meat and poultry.
2. Plants which offer preparation and freezing storage for meats, vegetables, and fruits.
3. Plants employed in a refrigerating enterprise such as a refrigerated warehouse or creamery which rent lockers as a side line.
4. Plants employed in a refrigerating enterprise which rent lockers and offer food preparation and freezing services.
5. Plants which rent lockers in combination with a retail business such as a grocery store or meat market.

The most common size locker has a capacity of about 6 cubic feet and is about 18 inches high, 20 inches wide, and 30 inches long.

Locker-plant patrons have the inconvenience of transporting food back and forth to the locker. There may also be an additional cost for transportation if special trips to the locker are necessary. The home freezing unit is much more convenient than the locker but there is the added expense of depreciation, repairs, and electrical energy.

In the use of lockers the average rent of approximately $18 to $20 yearly, plus preparation, packaging, freezing, and insurance, is the only expense. The latter items vary with different locker plants and their method of operation. Many people have found that a combination of both a locker and a small home freezing cabinet is quite satisfactory. Some of the new home refrigerators contain storage space for holding frozen foods and this facility in combination with a locker may be adequate in some instances. In this case a week's supply of frozen foods may be brought home from the locker plant at one time and stored in the home refrigerator frozen food storage compartment.

Some owners of home freezing cabinets take advantage of the services offered by locker plants for the wholesale purchase, preparation, and freezing of some foods such as meats. For instance, if a whole or half an animal is to be frozen at once, the capacity of a home cabinet may be inadequate to handle the load. Under such conditions the meat may be cut, packaged, and frozen at the locker plant, and when frozen it can be placed in the home cabinet.

Freezing Space Required

The number of cubic feet of storage space required for frozen food will depend upon the total quantity of food needed for good nutrition, the amounts of food that may be best processed by freezing, the proportion of their yearly food requirements that a family desires to freeze, and the extent to which other methods of preservation, such as canning and common storage, are employed.

In owning a home freezer or renting frozen-locker space, the practical side must be considered and a freezing program mapped out. It is recommended that a definite freezing budget for foods be outlined on paper. Such a plan will serve as an aid in planning the home garden and in the purchase of foods for freezing. Tressler, Evers, and Long (16), have suggested a four-point program which can be used as the structural basis for any size freezer and any size family:

1. Freeze those foods at hand.
2. Freeze what you use.
3. Need what you freeze.
4. Confine "Specials" to left-over space.

A typical vegetable budget for one person for one year as prepared by Foley and Cole (6), and modified to include freezing is shown in Table 1. A freezing budget to furnish a fruit, vegetable, and meat supply for a family of four to six, and utilizing 12 cubic feet of freezer space, as suggested by Tressler, Evers, and Long (16), is presented in Table 2.

Filinger (5), has indicated that the proper size of a freezing cabinet to store an adequate supply of food for the family is difficult to determine. He showed that an average family of five would require 3,135 pounds of foods, that can be preserved by freezing, a year. He assumed that about half of this could be obtained and used fresh and that only about 1,500 pounds would be frozen. In his opinion a home unit would permit a rapid turnover of food and, with careful management, a 12-cubic-foot cabinet would accommodate 1,500 pounds of food in a year. If the food in a home or locker freezer can be turned over rapidly the operation will be much more economical per pound of food stored. Table 3 shows a schedule of changes in a food freezer as suggested by the above author.

For practical purposes, in calculating the capacity of home freezers and lockers, it may be assumed that one cubic foot of freezer space will accommodate from 35 to 40 pounds of meat or 25 to 35 pint packages of fruit or vegetables. These figures may vary because of variation in sizes of meat cuts, irregular packages, the type of package used, etc.

Table 1.—Vegetable Budget for One Person for One Year.*

Prepared by May E. Foley and William R. Cole
Extension Service, University of Massachusetts

Number of Servings PRODUCT	Amount to Be Used FRESH	Amount to Store and Can or Freeze for Out-of-Season Months	
		CANNED or FROZEN	STORED
Choose One Daily			
Asparagus	2 pounds	3 pints or 3 pounds	
Broccoli	2 pounds	3 pounds	
**Cabbage	8 pounds		15 pounds
Celery	2 pounds		5 pounds
***Greens	8 pounds	8 pints or 8 pounds	
Lettuce or other salad greens	15 pounds		
Peas	1 peck	3 pints or 3 pounds	
Snap Beans	15 pounds	15 pints or 15 pounds	
Choose One Daily			
Beets	10 pounds	5 pints or 5 pounds	10 pounds
Carrots	15 pounds	7 pints or 7 pounds	20 pounds
Corn	30 ears	4 pints or 4 pounds	
Onions	12 pounds		25 pounds
Squash	10 pounds		20 pounds
Kohlrabi, Parsnips, Rutabagas, Turnips	10 pounds Total of last four		25 pounds
One and One-half Daily			
****Potatoes	30 pounds		150 pounds
Three Times a Week at least			
Tomatoes	25 pounds	30 pints	
If no storage is provided, add to canned or frozen vegetables			
Greens	8 pints	Carrots	20 pints
String Beans	8 pints	Beets	12 pints
Tomatoes	12 pints	Corn	12 pints

*Multiply by number in family to obtain family budget.

**Some of the cabbage may be made into sauerkraut.

***Greens include spinach, New Zealand spinach, Swiss chard, kale, beet tops, and wild greens.

****This will be very liberal in some cases.

Estimate allows for four servings per pint of canned vegetables.

The canning budget should also include at least 25 pints or pounds of canned or frozen fruit and not more than 8 pints of jam, jelly, and pickles for each member of the family. Sweet pickled peaches and pears may be counted as canned fruit. The fruit should be of kinds that are home grown, gathered wild, or bought at reasonable prices.

TABLE 2.—FREEZING BUDGET FOR FRUIT, VEGETABLE, AND MEAT SUPPLY

Family of four to six, 12 cubic feet freezer space.
(From Tressler, Evers and Long, 16)

Month	Produce	Prepared*
January	Beef (2 quarters)	200 pounds
March	Pork (1 hog)	100 pounds**
May	Veal (1 calf)	100 pounds
May-June	Asparagus	15 pints
June	Strawberries	30 pints
	Chickens (12 broilers)	16 pounds
June-July	Peas	30 pints
	Rhubarb	10 pints
June-October	Spinach, other greens	30 pints
July	Raspberries, other berries	30 pints
	Chickens (24 fryers)	48 pounds
	Beef (1 quarter)	100 pounds
July-August	Green beans	30 pints
July-September	Cauliflower, or mixed vegetables	15 pints
July-October	Broccoli, or Carrots	15 pints
August-September	Sweet corn	45 pints
	Peaches	25 pints
	Assorted fruit juices	10 pints
	Lima and shell beans	10 pints
September	Lamb (1 carcass)	50 pounds
October	Pumpkin or Squash	10 pints
November	Pork (1 hog)	100 pounds**

* A carcass dresses out to about 50 percent of its original weight by the time it is trimmed, boned, etc., and ready for the freezer.

** A portion of this meat would be cured for use as hams, bacon, etc.

Explanation: The fruits and vegetables in this budget are to be used as soon as fresh produce is no longer available from garden or local markets, to be replenished if need be before the next producing season with commercially prepared frozen fruits and vegetables purchased in dozen lots. The meat supply should be drawn on continuously to supply all the meat needs. As the freezer empties, surplus space may be utilized with fish, leftovers, baked goods, cooked foods, ice cream, etc.

TABLE 3.—SCHEDULE OF CHANGES OF FOOD IN A HOME CABINET.

Capacity—12 cubic feet (equal to two standard lockers).
(From Filinger, 5)

Month	Food Put In*	Food Taken Out*	Food Remaining*
Jan.		20 fruit; 20 vegetables; 30 beef; 25 pork; 10 veal; 5 lamb; 4 fryers; 2 roasters; 5 game birds; 5 butter	25 fruit; 50 vegetables; 40 pork; 45 veal; 8 fryers; 8 roasters; 20 butter
Feb.	325 beef	10 fruit; 20 vegetables; 25 pork; 15 veal; 4 fryers; 4 roasters; 5 butter	15 fruit; 30 vegetables; 325 beef; 15 pork; 30 veal; 4 fryers; 4 roasters; 15 butter
March	130 pork	10 fruit; 15 vegetables; 30 beef; 15 pork; 15 veal; 4 fryers; 4 roasters; 10 butter	5 fruit; 15 vegetables; 295 beef; 130 pork; 15 veal; 5 butter
April		5 fruit; 15 vegetables; 30 beef; 20 pork; 15 veal; 5 butter	265 beef; 110 pork
May	60 vegetables	40 beef; 20 pork	60 vegetables; 225 beef; 90 pork
June	80 fruit; 35 lamb; 50 butter	40 beef; 25 pork	80 fruit; 60 vegetables; 185 beef; 65 pork; 35 lamb; 50 butter
July	50 fruit (raspberries, etc.)	30 beef; 25 pork	130 fruit; 60 vegetables; 155 beef; 40 pork; 35 lamb; 50 butter
Aug.	20 fruit (peaches); 60 vegetables (corn, beans etc.); 12 fryers; 25 fish	30 beef; 20 pork; 10 lamb; 5 butter	150 fruit; 120 vegetables; 125 beef; 20 pork; 25 lamb; 12 fryers; 25 fish, 45 butter
Sept.	40 vegetables (beans, etc.); 90 veal	20 fruit; 20 beef; 20 pork; 10 lamb; 15 fish; 5 butter	130 fruit; 160 vegetables; 105 beef; 15 lamb; 90 veal; 10 fish; 12 fryers; 40 butter
Oct.	130 pork; 6 roasters**	35 fruit; 30 vegetables; 25 beef; 20 pork; 15 veal; 10 fish; 5 butter	95 fruit; 130 vegetables; 80 beef; 110 pork; 75 veal; 15 lamb; 12 fryers; 6 roasters; 35 butter
Nov.	6 roasters; 10 game birds	30 fruit; 30 vegetables; 20 beef; 20 pork; 10 veal; 5 lamb; 5 butter	65 fruit; 100 vegetables; 60 beef; 90 pork; 65 veal; 10 lamb; 12 fryers; 12 roasters; 10 game birds; 30 butter
Dec.		20 fruit; 30 vegetables; 30 beef; 25 pork; 10 veal; 5 lamb; 2 roasters; 5 game birds; 5 butter	45 fruit; 70 vegetables; 30 beef; 65 pork; 55 veal; 5 lamb; 10 roasters; 12 fryers; 5 game birds; 25 butter

* Figures represent pints of fruits and vegetables; pounds of meats and butter; and number of fryers, roasters, and game birds.

** Turkey, chicken, duck, etc.

Is Home Freezing Expensive?

During the past five years we have received many queries as to the expense involved in home freezing. If one is concerned with the economic aspects of home food preservation in terms of the dollars-and-cents cost, it is obvious that home freezing is more expensive than other methods of preservation, such as canning or common storage.

In figuring the cost of home freezing in a home freezing cabinet, Crowther (3) has suggested that in addition to the electricity required for the operation of the unit, repairs (2 percent of initial cost), depreciation (10 percent of initial cost), and interest on the investment (at 5 percent) should be considered. The packaging cost should also be included.

In laboratory tests with a typical home freezing cabinet of 12.5 cubic feet capacity, electricity consumption amounted to an average of 3 kilowatt hours per day. If it is assumed that such a freezer was purchased for $300 and filled once, twice or three times a year with 450 pounds of food in packages of an average size of 2 pounds, the freezing cost may be broken down as follows:

10 percent depreciation on $300 home unit	$30.00
2 percent allowance for repairs	6.00
5 percent interest on investment	15.00
Cost of electricity (at 2.5c per kilowatt hour)	27.00
225 packages at .04 per package	9.00
Total cost for freezing and storing 450 pounds food	$ 87.00

Unit cost per pound of food	
If freezer is filled once	.193
If freezer is filled twice	.107
If freezer is filled three times	.078

The above figures do not include the cost of the food itself or its preparation. However, the cost per pound may be reduced by efficient management and by replacing the foods that are used from the freezer with others as indicated previously. In refilling the freezer with foods, the cost for freezing would be based on 4 to 6 kilowatts of electricity for each 100 pounds of food.

If foods are frozen in a commercial food locker, the cost includes such items as locker rental, packages, processing (in some instances), freezing, and insurance. Service charges for preparation and packaging and transportation charges to and from lockers are other expenses to be considered.

The cost of home freezing on the above basis may amount to from four to five times as much as that for home canning. According to Benson (2) and Fellers, Chenoweth and Cole (4), the cost for home canning, considering costs other than that of the raw material, will amount to four to five cents per pound of food. On the other hand it should be pointed out that home freezing offers a means of preserving and conserving certain products grown in the home garden which are not well adapted for canning, such as eggplant, broccoli, and brussels sprouts; as well as eggs and some types of fish.

However, as suggested above, the cost of freezing and storing foods at home may be considerably reduced if a well-planned freezing program is set up and the freezing cabinet used to maximum capacity. If a program such as that indicated in tables 2 and 3 is followed, it should be possible to reduce the above costs by approximately 50 percent or more. The use of large-size freezers, if justified by the needs of the family, will also reduce the unit cost of freezing if good use is made of it. Crowther (3) and Stout (13) have indicated that freezing costs may be further reduced if a good home-built freezer is used. In comparing lockers, small and large home freezing cabinets, and home-built freezers, Stout (13) reported that the cost per pound for storage amounted to from 4 to 13 cents. On a basis of economy, he pointed out that with freezer storage at 10 to 13 cents per pound only high-priced items such as meats, poultry, and luxury foods in the fruit and vegetable line should be stored.

Atherton, Briwa, Foss and Dorsey (1) indicated that, on a basis of a 24-cubic-foot capacity freezer costing $400, the cost of freezing and storing food would range from 10 1/2 to 6 1/4 cents per pound, depending upon whether the freezer was filled once or twice during the year. In this case the cost of the freezer was written off in fifteen years. Essentially similar data on the cost of owning and operating a home freezing unit have been indicated by Wiant, Griswold, Barrows and Blakeslee (21).

The above discussion is presented as a guide to persons who are considering home freezing in their food preservation program and who, by necessity or otherwise, are concerned with its economic aspects. On the other hand, there are groups of people who are not concerned with the expense of a new appliance, either because they can readily afford it or because it will pay for itself in the personal satisfaction derived from it. The above discussion would naturally not be of particular interest to persons in the latter group.

Freezer Operation

One of the hazards in home freezing is overloading the freezer. In this case the food may actually spoil before it is cooled to below 32°F. and frozen. For this reason information should be provided on the maximum quantity of food which should be frozen in a particular cabinet at one time.

Power and mechanical failures must also be considered in the operation of the freezer. The time it takes the frozen food to thaw depends on the size of the freezer, the amount of food stored, the amount of insulation, and the temperature of the room in which the freezer is located. In experimental tests Tressler, Evers, and Long (16) reported that food in a well-filled 4-cubic-foot cabinet showed no appreciable thawing until about 72 hours after the current was shut off. Larger cabinets would hold products over a comparatively longer period. In case of a power or mechanical failure dry ice may be placed in the cabinet to prevent the thawing of the frozen products. Except for this, the cabinet should not be opened during the shut-off period. If the freezer must be shut off for a prolonged period for repairs, the food should be transferred, if possible, to some other freezing facility such as a locker plant.

According to Masterman and Lee (12), the cost of operating a home freezing unit depends on the capacity of the cabinet, its construction, the refrigeration unit, the surrounding or ambient temperature, the amount and initial temperature of the food frozen, the efficiency of the refrigeration machine, the length of time and the frequency of opening the cabinet, and the temperature which is maintained in it.

Crowther (3), states that new, well-built cabinets with five inches of insulation may use on an average the following amounts of electricity per month:

Size of Cabinet (Cubic Feet)	Average Kilowatt Hours per month
2	40
4-8	60
10-16	100
18-25	125

He also suggests that 2 percent of the initial cost of the cabinet be allowed for annual repairs, including the replacement of sealing gaskets, refinish of cabinet, or repairs to the refrigerating system. Assuming full depreciation in ten years, he indicated that a reasonable annual allowance for depreciation is 10 percent of the purchase price. Some other authorities have assumed full depreciation in fifteen years.

Freezing Rate

In the opinion of most laymen commercial frozen foods are frozen very rapidly. However, even though we speak of them as quick frozen foods, in most cases the freezing time may extend up to several hours, at least. The question is often asked, whether home freezing cabinets can be used for freezing as well as for storage of frozen food. Home freezers do not ordinarily have the capacity to freeze food as quickly as is done in usual commercial practice. Throughout the history of freezing there has been considerable difference of opinion as to the relative merits of "slow" and "fast" freezing. More recently experimental work has demonstrated that in most cases there is but little practical difference between "slow" and "fast" frozen foods if the freezing is completed within 24 hours. Lee and Gortner (10), in studies with peas and snap beans, found no significant difference in quality and nutritive value which could be attributed to the rate of freezing. Their results confirm the results obtained in practice by many home-freezer owners in showing that one need not hesitate to use these facilities for freezing products at home. The authors also stress the importance of speed in handling and cooling foods for freezing and the danger of overloading a home freezing cabinet with unfrozen food.

Gortner, Erdman and Masterman (7) have summarized the available information on freezing rate as follows:

> To summarize the best information now at our disposal, it would seem that too much emphasis has been placed in the mind of the public on "quick-freezing" and not enough on "quick to the freezer" and "quick cooling," without which high-quality food is sure to be affected adversely. Without "quick freezing" (a loosely used and much abused term) high quality can still be achieved. With all foodstuffs adaptable to freezing, a rapid freezing rate will prove satisfactory. With most if not all of these foodstuffs, a moderate rate of freezing will prove satisfactory. With a few foodstuffs, particularly when a large cut surface is exposed, a slow freezing rate may prove something less than satisfactory.
>
> In appearance, odor, flavor, and nutritive value, the home-frozen product can usually vie with the quick-frozen food in commerce as being a quality item.

Temperature in Freezing Cabinet Should Not Fluctuate

If the temperature in the freezing cabinet fluctuates, it can cause a deterioration of the product, particularly if there are some air spaces in the package. When the temperature rises, moisture is pulled out of the food. When the temperature drops, this moisture freezes out of the air in the package and is deposited as ice crystals on the surface of the food or the inner surface of the package.

In a recent publication, Gortner, Fenton, Volz and Gleim (8) have reported the results of a study on the effect of fluctuating storage temperatures on quality of frozen foods. They stored frozen pork, strawberries, green beans, and peas for twelve months at 0°F., at 10°F., and in a freezer alternately fluctuating between 0° and 20°F. in a repeating 6-day cycle. The food stored at temperatures fluctuating between 0° and 20° underwent quality changes similar to those occurring in food stored at 10°. The foods stored under the above conditions were definitely inferior in quality to those stored at 0°. It was suggested that exposure of frozen foods to temperatures above 0° rather than merely temperature fluctuation may be a major factor influencing deterioration of food quality. These results further emphasize the importance of maintaining storage temperatures in home and locker freezers at 0°F. or below.

What About Power Failure or Freezer Breakdown?

It is important that all home freezing cabinets be equipped with some sort of an alarm or warning system that will indicate when the temperature inside of the cabinet gets too high owing to power failure or mechanical breakdown. Although such failures may be uncommon, the individual may lose considerable quantities of food if adequate precautions are not taken. It has been reported that food in a loaded freezing cabinet will remain frozen for from two to five days depending upon the size of the cabinet, size of load, etc. (U.S.D.A., 19; Tressler, Evers and Long, 16).

In order to obtain further information on temperature changes that take place in a home freezer when the power is shut off, some experimental tests were made using a 12.5-cubic-foot cabinet. The side walls and bottom of the cabinet contained five inches of moisture-proof, low-density, insulation. The two covers on top contained three inches of the above insulation. The hinged covers made a tight seal on rubber gaskets and were held tightly closed by means of an adjustable latch. Each of the two compartments of the cabinet had separate covers and each was divided in half on the inside providing four sections, one of which was a freezing section.

Temperature changes inside the freezing cabinet during the tests were followed by means of twelve iron-constantan thermocouples connected to a Leeds and Northrup "Micromax" automatic recording potentiometer with stations for twelve thermocouples. All four sections of the freezer cabinet were filled with packages of frozen apples. Thermocouples were placed in the centers of six packages of fruit which were placed in various parts of the cabinet. Other thermocouples were placed in the bottom and top in each of the two compartments. After the freezer had been operated 24 hours to reach equilibrium, it was shut off and the temperatures at the different points were recorded continuously for eight days. At the end of this time the food was removed from the freezer. All of it had thawed completely, but there was no evidence of bacteriological spoilage. The products were in good condition as evidenced by their color and flavor.

The data are presented in figure 1. These show the average rise in temperature at the bottom and top of the freezer and in the packages of food. The temperature in the cabinet rose rapidly up to 30°F. during the first two days but there was a rise of only two degrees from the third to the sixth day and a rise to 40°F. by the end of the eighth day. The temperature in the packages of food lagged behind that of the cabinet.

The results of a similar experiment to determine the effect of a power shut-off when the freezer was one-half full of frozen food are summarized in figure 2. This test was set up in the same manner as described above with the exception that only two sections of the freezer were filled with frozen food. At the end of five days the food was removed from the freezer. It was completely thawed but showed no evidence of spoilage. With the freezing cabinet only one-half full the rise in temperature was much more rapid than when the unit was completely filled.

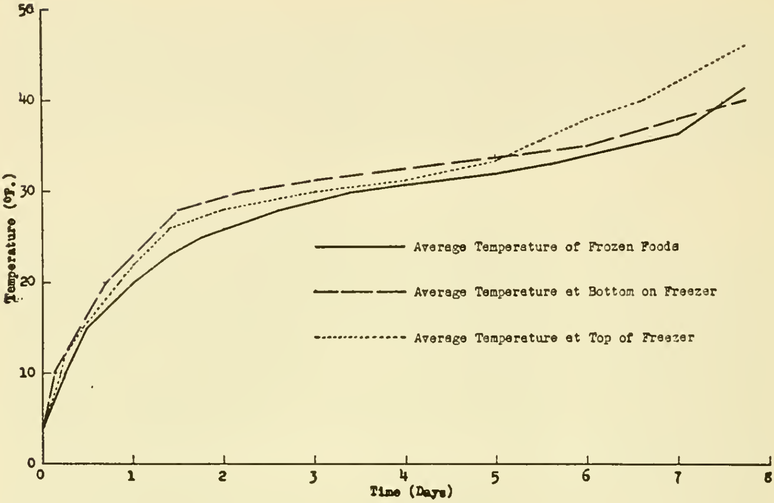


Figure 1. Time for Frozen Food in Freezer to Thaw after Current Shut-off. (Full freezer load, 300 pounds frozen apples.)

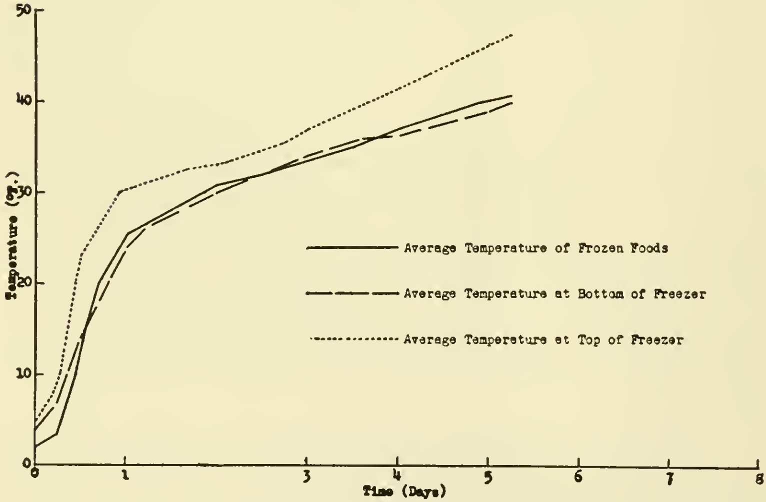


Figure 2. Time for Frozen Food in Freezer to Thaw after Current Shut-off. (Half a freezer load, 150 pounds frozen apples.)

Since food showed no signs of spoilage at the end of eight days when the freezing unit was completely filled, and none at five days when it was half full, and since during this time the temperature was within the range used for the refrigeration of foods, it would appear that the average power shut-off would not be too serious with this type of home freezing cabinet. As a general rule, a power or mechanical failure could be remedied within a safe length of time.

Varieties of Fruits and Vegetables for Freezing

In general most vegetables which are commonly cooked may be satisfactorily frozen. These include asparagus, beans (green, lima, wax, shell, and soy beans), beets, broccoli, brussels sprouts, carrots, cauliflower, corn (on the cob, whole kernel, or cream style), eggplant, greens, kohlrabi, mushrooms, parsley, peas, peppers, pumpkin, rhubarb, spinach, squash, and succotash. Vegetables which are eaten raw are not usually satisfactory if frozen as they lose their crispness during the freezing process.

Most fruits are suitable for freezing if they are carefully prepared, especially those of pronounced flavor. Different fruits require different methods of preparation, such as blanching or mixing with sugar or a sirup, to prevent undesirable changes in color and flavor. The following fruits are among those suitable for freezing: apples, apricots, blackberries, blueberries, citrus juices and sections, cherries, cranberries, currants, gooseberries, peaches, pineapples, plums, raspberries, and strawberries.

In commercial freezing, considerable attention is paid to the variety of fruits and vegetables used. Variety is of importance from the standpoint of quality such as color, flavor, texture, etc. It has been stated that in home freezing a satisfactory product can be obtained as long as the variety used is one that is of good quality when eaten fresh. However, in many instances a home frozen product of better quality can be obtained if some care is exercised in selecting and growing the varieties known to be most suitable for freezing.

During the past five years, tests have been carried on here to investigate the suitability of Massachusetts-grown fruits and vegetables for home freezing. Most of the raw material was grown on the University Farm at Amherst by the Olericulture and Pomology Departments. In all cases the fruits and vegetables were prepared and frozen in one-pound packages according to methods recommended by the United States Department of Agriculture (19), and Tressler and Du Bois (14). After storage for approximately six and ten months the frozen products were prepared for serving and judged for quality on a basis of flavor, texture, and color by a tasting panel composed of members of the Food Technology Department staff and others. In some cases considerable difference was noticed in the quality of different varieties of a particular fruit or vegetable. The results of these tests have been compiled with variety recommendations of Tressler and Du Bois (14) for New York State, and Hepler (9) for New Hampshire, in tables 4 and 5 to serve as a guide for home freezers. The quality of different fruits and vegetables for freezing is also influenced by such factors as climate, growing conditions, freshness, and maturity; but if the suggested varieties are used they should provide frozen foods of a good quality. Varieties not listed in tables 4 and 5 either have not been tested to date or sufficient information is not available for them.

Most of the vegetables were frozen as both dry and brine packs. In general the dry-packed vegetables were of better quality and easier to handle than the brine-packed products. Well-blanched (scalded) vegetables showed little or no quality loss during storage for 6 to 10 months.

Frozen corn on the cob tended to develop a "cob flavor" and was not as sweet as the frozen whole kernel corn. The latter type of frozen corn had more nearly the flavor of fresh corn and was a more satisfactory product.

Tomatoes were not satisfactory when frozen. Those which were frozen whole were found to break down markedly when thawed. When cut tomatoes were frozen, the degree of breakdown was greater, the smaller the pieces. Treatment with calcium chloride, such as is sometimes used to firm commercially canned

TABLE 4.—SUITABILITY OF DIFFERENT VARIETIES OF FRUITS FOR HOME FREEZING IN MASSACHUSETTS.

Fruit and Variety	Quality
Apples	
*Baldwin	Excellent
*Cortland	Very good
Delicious	Good
*Gravenstein	Good
Greening	Excellent
Jonathan	Very good
*McIntosh	Fair
Northern Spy	Excellent
Rome Beauty	Very good
Stark	Very good
Winesap	Very good
Blueberries	
Cabot	Very good
Concord	Very good
*Jersey	Very good
Pemberton	Very good
Pioneer	Very good
Rancocas	Very good
*Rubel	Very good
Scammell	Very good
Stanley	Very good
Wareham	Very good
Wild (high-bush)	Very good
Cherries (sour).	
English Morello	Very good
*Montmorency	Very good
Cherries (sweet)	
Bing	Good
Early Honey Heart	Good
Emperor Francis	Good
Nelson	Good
Paul Rose	Fair
Royal Duke	Good
*Schmidt	Good
Vernon	Good
*Windsor	Good
Cranberries	
Early Black	Excellent
Howes	Excellent
Currants	
Cherry	Very good
Diploma	Very good
Fay's Profile	Very good
Perfection	Excellent
Red Cross	Good
Red Lake	Very good
Viking	Very good
*Wilder	Very good
Peaches (yellow)	
Ambergem	Good
Colora	Good
Eclipse	Very good
*Elberta	Very good
Fertile Hale	Good
Fisher	Fair
Goldeneast	Good
Golden Globe	Very good
*Golden Jubilee	Fair
*Halehaven	Very good
Ideal	Very good
J. H. Hale	Very good
Kalhaven	Good
Marigold	Good
Massasoit	Very good
Michigold	Good
Mikado	Good
Oriole	Good
Pacemaker	Very good
Primrose	Very good
Red Haven	Good
Rochester	Fair
Summercrest	Good
Sunbeam	Good
Sungold	Very good
Sunhigh	Very good
Triogem	Fair
Valiant	Good
Vaughan	Fair
Vedette	Very good
Veteran	Very good
Viceroy	Very good
Peaches (white)	
Belle of Georgia	Good
Champion	Good
Culbertson's Champion	Good
Delicious	Good
Duke of York	Good
Greensboro	Fair
Polly	Fair
Radiance	Fair
Redrose	Fair
White Hale	Very good
Pears	
Anjou	Fair
*Bartlett	Good
Cayuga	Poor
*Clapp Favorite	Poor
Clyde	Fair
Ewart	Fair

Table 4.—Suitability of Different Varieties of Fruits for Home Freezing in Massachusetts.—Continued

Fruit and Variety	Quality
Pears (continued)	
Kieffer	Good
Lawrence	Fair
Louise	Fair
Ovid	Fair
Phelps	Fair
Poultney	Fair
*Seckel	Poor
Sheldon	Poor
Vermont Beauty	Fair
Willard	Fair
Plums	
*Albion	Very good
Bavay	Good
Bradshaw	Good
Burbank	Very good
California Blue	Fair
Elephant Heart	Very good
*Formosa	Very good
Grand Duke	Good
Gueii	Fair
Lombard	Good
Milton	Fair
Monarch	Very good
Monitor	Good
Pacific	Fair
President	Very good
Primlew	Fair
Red Wing	Very good
Reine Claude	Good
*Shropshire Damson	Fair
Sky Blue	Good
Underwood	Good
Wickson	Good
Yakima	Fair
Yellow Egg	Good
Prunes	
German Prune	Very good
Imperial Epineuse	Very good
Italian Prune	Very good
Stanley	Very good
Raspberries (black)	
Bristol	Very good
Cumberland	Fair
Dundee	Fair
Evans	Fair
Raspberries (purple)	
Marion	Good
Ruddy	Good
Sodus	Excellent
Raspberries (red)	
Cayuga	Good
*Chief	Very good
Cuthbert	Excellent
Indian Summer	Very good
June	Fair
*Latham	Very good
Lloyd George	Very good
Marcy	Fair
Milton	Good
Newburgh	Fair.
Ohta	Good
Ranere	Good
Sunrise	Good
Tahoma	Good
Taylor	Good
Viking	Very good
Washington	Good
Strawberries	
Aberdeen	Fair
Big Late	Fair
Blakemore	Good
*Catskill	Very good
Chesapeake	Good
Crimson Glow	Very good
Clermont	Good
Culver	Very good
Dorsett	Very good
Fairfax	Very good
Fairpeake	Very good
Gem (everbearing)	Good
*Howard 17 (Premier)	Good
Howard Supreme	Fair
Mastodon (everbearing)	Good
Midland	Very good
Pathfinder	Good
Red Heart	Very good
Redstar	Good
Robinson	Good
Senator Dunlap	Very good
Shelton	Good
Sparkle	Very good
Starbright	Good
Temple	Good
William Belt	Good

*Recommended for planting in Massachusetts.

Table 5.—Suitability of Different Varieties of Vegetables for Home Freezing in Massachusetts.

Vegetable and Variety	Quality
Asparagus	
Martha Washington	Very good
Mary Washington	Very good
Beans (green)	
Black Valentine	Very good
Blue Lake	Very good
Bountiful	Good
Kentucky Wonder	Very good
Keystone	Good
Logan	Good
Plentiful	Good
Refugee	Very good
Streamliner	Good
Stringless Green Pod	Very good
Tendergreen	Very good
Beans (wax)	
Black Wax	Good
Golden Wax Improved	Good
Golden Wax Top Notch	Good
Pencil Pod	Good
Sure Crop Wax	Good
Beans (lima)	
Ford Hook	Very good
Beets	
Crosby Egyptian	Fair
Detroit Dark Red	Very good
Broccoli	
Italian Green Sprouting	Very good
Brussels Sprouts	
Long Island Improved	Good
Carrots	
Chantenay	Very good
Danvers Half Long	Very good
Hutchinson	Good
Imperator	Very good
Nantes	Very good
Oxheart	Good
Corn	
Early Golden	Very good
Golden Cross Bantam	Very good
Norcross	Very good
North Star	Very good
Seneca Dawn	Very good
Seneca 60	Good
Span Cross	Very good
Sugar and Gold	Good
Greens	
Beet	Good
Turnip	Good
Mushrooms	
Cultivated	Very good
Peas	
Lincoln	Very good
Telephone	Good
Thomas Laxton	Very good
Worlds Record	Good
Peppers (green)	
California Wonder	Good
Charter Oak	Good
Harris Early Grand	Good
Harris Wonder	Good
King of the North	Good
Waltham Beauty	Good
Rhubarb	
Canada Red	Very good
McDonald	Very good
Ruby	Very good
Spinach	
King of Denmark	Very good
Long Standing Bloomsdale	Very good
Squash	
Butternut	Very good
Golden Delicious	Very good
Hubbard	Very good
Summer Squash	
Crookneck	Poor

whole tomatoes, was tried but was not effective in preventing the frozen tomatoes from collapsing when thawed. Other tests were carried out in which tomatoes were boiled or stewed and then frozen. They showed a greater degree of separation and breakdown than canned ones, and were also tough and stringy. Both the frozen raw and frozen heated tomatoes tended to develop a noticeable off-flavor.

Although green beans tend to be more acceptable than wax beans for freezing in most cases, this method appears to have no great advantage over canning. Considerable variation has been encountered in the quality of frozen green beans.

Instances have been noted where green beans were frozen according to recommended procedures and yet the resulting product had a poor flavor. Stout (13) also has indicated that erratic results may be obtained in freezing green beans. He was unable to correlate seasonal growing conditions or maturity with the quality of the finished product. It is generally accepted that the maturity of green beans is of particular importance when they are to be frozen. Only young tender beans should be used.

With strawberries, a superior product was obtained if the berries were sliced and mixed with dry sugar prior to freezing. This method gave a better-flavored product than when whole berries were mixed with dry sugar or packed in sirup.

Quality of Canned and Frozen Fruits and Vegetables

The question is frequently asked whether canning or freezing yields the better product from the standpoint of eating quality. A comparison was made of the general eating quality of a number of varieties of fruits and vegetables as influenced by these two methods of preservation. Portions of the same lots of raw material were preserved by both home-canning and home-freezing methods, following procedures recommended by the United States Department of Agriculture (18, 19). The frozen fruits were packed with sugar in a ratio of four to one. The canned fruits were processed in a boiling water bath and the vegetables in a pressure canner.

The canned products were stored at room temperature and the frozen products at 0°F. After being stored for from six to eight months the products were prepared as for serving on the table and judged for quality by a tasting panel comprised of 10 to 15 members of the laboratory staff. The flavor, texture, and color of each sample were scored in evaluating its general quality and acceptance. The following score was used in making the quality tests:

	Flavor	Texture	Color	Total
Excellent	21-25	13-15	9-10	41-50
Very good	16-20	10-12	7-8	31-40
Good	11-15	7-9	5-6	21-30
Fair	6-10	4-6	3-4	11-20
Poor	1-5	1-3	1-2	1-10

The results of these tests are summarized in table 6.

On a basis of flavor, texture, and color the quality of some frozen products was generally superior to the same ones canned, as in the case of raspberries, strawberries, broccoli, carrots, cauliflower, corn, and greens. With other products there was little or no difference in the acceptability and it was largely a matter of personal taste which was preferred, the canned or the frozen. Variety also plays a role in the quality of the finished product whether it be canned or frozen. It is also generally recognized that frozen meat is more nearly like the fresh product than is canned meat.

From the standpoint of their importance in home food preservation in this area, such foods as the small fruits (strawberries, raspberries, etc.), broccoli, carrots, corn, and greens are more palatable for many people when frozen than when home canned. On the other hand such foods as peaches, asparagus, green beans, and beets are generally acceptable either canned or frozen. Canning rather than freezing is recommended for tomatoes and tomato juice.

Table 6.—Effect of Method of Preservation on Quality of Fruits and Vegetables.

Fruits			Vegetables		
Variety	Canned	Frozen	Variety	Canned	Frozen
Peaches			**Asparagus**		
Ambergem	Very good	Good	Martha Washington	Very good	Very good
Champion	Good	Good			
Delicious	Good	Good	**Beets**		
Goldeneast	Good	Good	Crosby Egyptian	Fair	Fair
Golden Globe	Good	Very good	Detroit Dark Red	Very good	Very good
Golden Glow	Good	Good			
Halehaven	Good	Very good	**Broccoli**		
Ideal	Very good	Very good	Italian Green Sprouting	Fair	Very good
New Jersey 66	Fair	Poor			
New Jersey 116	Good	Good	**Carrots**		
Radiance	Fair	Fair	Chantenay	Good	Very good
Red Rose	Good	Fair	Danvers Half Long	Good	Very good
Summercrest	Good	Good	Hutchinson	Good	Good
Valiant	Very good	Very good	Imperator	Good	Very good
Vedette	Good	Very good	Nantes	Good	Very good
			Oxheart	Good	Good
Raspberries					
Chief	Fair	Good	**Corn**		
			Golden Cross Bantam		
Strawberries			Young	Fair	Very good
Catskill	Poor	Very good	Optimum maturity	Good	Very good
Fairfax	Poor	Very good			
Howard 17	Poor	Good	**Green Beans**		
			Black Valentine	Very good	Very good
			Bountiful	Good	Good
			Green Stringless Valentine	Very good	Very good
			Stringless Green Pod	Very good	Very good
			Spinach		
			Long Standing Bloomsdale	Fair	Very good
			Summer Squash		
			Crookneck	Fair	Poor
			Tomatoes		
			Marglobe	Very good	Fair
			Rutgers	Very good	Fair

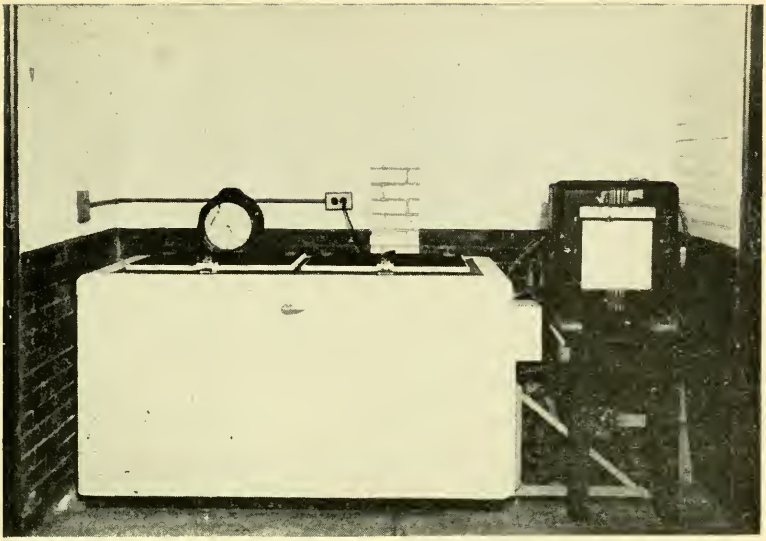


Plate I. Home Freezing Cabinet and Temperature Recording Apparatus Used in Experimental Work.

Plate II. Removing Foods from Home Freezer.

Home canning jars and cans as well as packages especially designed for frozen foods are suitable for home freezing.

Plate III. Typical Containers for Frozen Foods.
(1) Laminated paper bag; (2) stockinet overwrap for meat and poultry; (3) home canning jar; (4) home freezing jar; (5) tin can; (6) waxed cardboard carton with slip-on lid; (7) waxed cardboard tub with set-in lid; (8) cardboard carton with inner cellophane envelope which is heat sealed.

Plate IV. Packaged Meat.
(1) Laminated freezer paper; (2) cellophane; (3) aluminum foil.

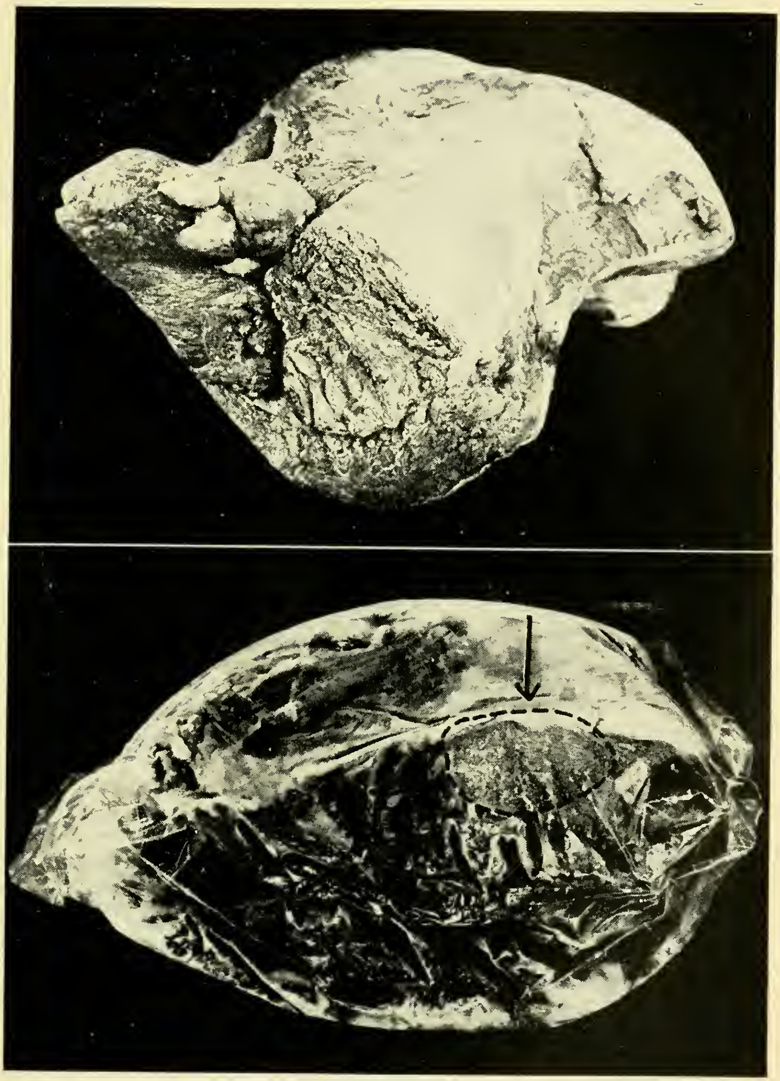
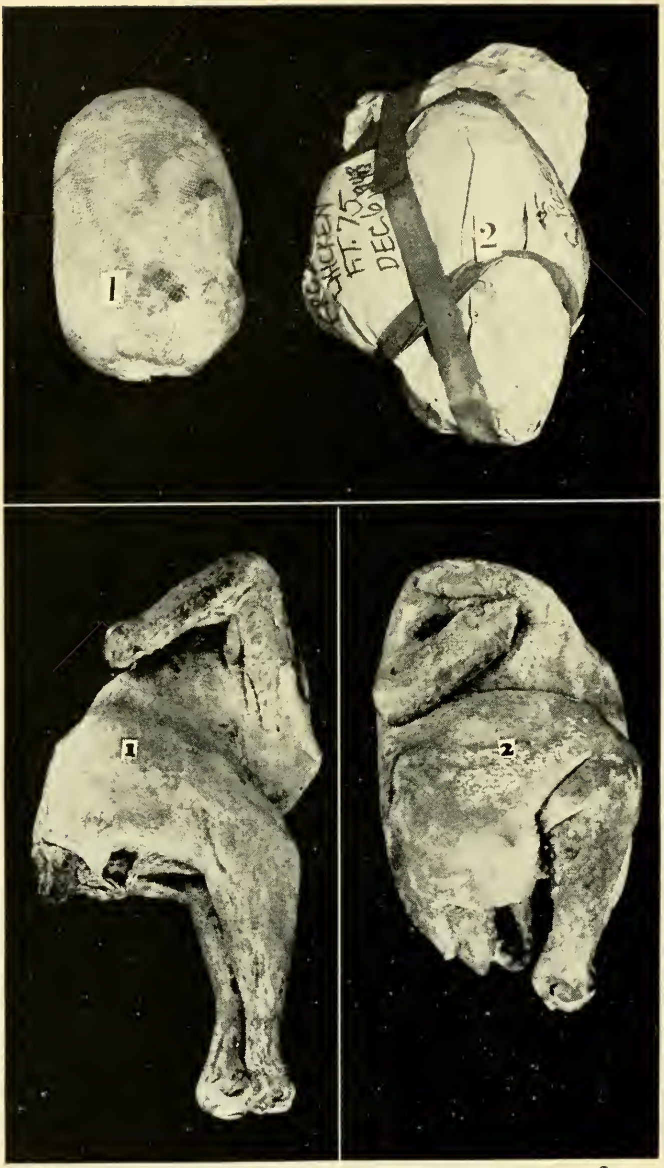


Plate V.
Upper: Frozen Beef Showing Extreme Freezer Burn or Drying Due to Inadequate Packaging.
Lower: Frozen Beef Wrapped in Cellophane. Marked freezer burn occurred, during six months storage, where film was broken.



Plave VI.

Upper: Packaged Chickens. (1) Cellophane with stockinet overwrap; (2) freezer paper with freezer locker tape.

Lower: Frozen Chickens. (1) Chicken shows severe freezer burn due to improper packaging; (2) Control chicken, properly packaged.

Meats, Poultry, and Eggs

At present there is considerable interest in the freezing of meats and poultry, undoubtedly stimulated by the meat shortage during the past few years. Since relatively little meat is raised in Massachusetts, meat freezing would have to be confined largely to those products which might be bought in large amounts such as a side of beef, etc. When the cost of preparation, packaging, and storage is considered, it is questionable whether it would be practical to purchase meat in large quantities for home freezing in normal times. On farms where home-grown meat is processed, the home freezing of meats would have a definite place in the freezing program. This accounts for much of the popularity of home freezers and locker storages in the Middle West and West.

With the large number of backyard poultry flocks in Massachusetts, poultry may well be considered in the home freezing program. Poultry may be frozen in several ways, such as (1) drawn, (2) not drawn, (3) stuffed, or (4) cut up in pieces. Tests were carried out to compare the quality of poultry frozen in the above ways, and in all cases the finished cooked product was very good. Since poultry that is not drawn before being frozen requires a longer time to thaw out, it is recommended that poultry be drawn before rather than after freezing. Chickens which were stuffed before being frozen were very good, but here again the thawing and cooking time is prolonged.

Freezing may provide a satisfactory method for storing surplus eggs for many people. Eggs should not be frozen whole in the shell because freezing causes them to expand and crack the shell. Frozen eggs are quite satisfactory for use in the preparation of scrambled eggs or omelets. They may also be used in cooking when they are mixed with other ingredients. The ultimate use of the frozen eggs should be anticipated at the time of freezing in order that the most convenient methods of preparation and packaging may be used.

Seasonal Freezing

It has been suggested that the seasonal freezing of products such as butter, lard, eggs, and citrus juices might play an important part in the home freezing program. The price of these products varies between the seasons of high and low production. It seemed possible therefore, that freezing such products during the seasons of high production and low prices might result in decided savings and that these savings might offset in part the general overhead and operating cost of the freezer.

Freezing and storage tests were conducted with butter, lard, eggs (frozen in different ways), and citrus juices—products which are adapted to home freezing. Butter for freezing is best when unsalted. Home-frozen eggs are somewhat limited in use, since they must be removed from the shell before being frozen. Also, the white and yolk must be mixed together or, if they are frozen separately, salt, sugar, honey, or a corn syrup must be added to the yolk to prevent gumminess. This further limits their use.

It was found that, although a considerable economy could be realized through the purchase of such foods when their price was low, the resultant saving was completely offset by the cost of packaging and of the freezing storage and by the amount of space required in the unit. The additional labor involved is also a factor which must be considered.

Containers

Because of the humidity and temperature conditions in a home freezing cabinet the selection of adequate containers and wrapping for home frozen foods is of utmost importance. The air in a home freezer is dry because most of its moisture is frozen out and deposited on the walls and freezing coils in the form of ice or frost. The dry air can take up moisture from improperly packaged foods and leave them with a dry and spotted surface called "freezer burn." The degree of "freezer burn" and loss of quality increases with the length of storage time. To prevent such a deterioration of frozen foods during storage, it is essential that the package or wrapping be air-tight and moisture-vapor-proof. An ideal container is moisture-proof and can be sealed so that no liquid, vapor, or air can get into or out of the packaged product.

An excessive accumulation of frost on the inside of the freezing cabinet may be an indication that some or all of the food is improperly packaged and is losing moisture. The accumulation of frost inside the cabinet is also caused by freezing the moisture out of air that enters when the cabinet is opened. This condition is accentuated when the cabinets are opened frequently in warm, humid weather.

Water-proofness is not the same as moisture-vapor-proofness. Ordinary waxed or oiled paper is water-proof, but not moisture-vapor-proof.

A satisfactory package for home or locker frozen foods should have the following characteristics and properties:

1. Must be moisture-vapor-proof.
2. Must be leak-proof.
3. Must protect food from absorbing and giving off flavor and odor, and should not impart a flavor or odor to the food.
4. Should not absorb grease, oil, or water.
5. Must be durable.

A partial list of sources of supply for packages and sealing materials is presented in Appendix 2. In addition to the various types of fiber containers available for packaging home frozen foods, home canning jars and tin cans are also very satisfactory. If home canning containers are used, it is particularly important that an adequate headspace (10 percent of the capacity of the container) be left to allow for expansion of the product when it freezes. For home freezing there is one objection to round or odd-shaped packages: they occupy greater space in relation to their capacity than do square or rectangular packages.

For heat-sealing many of the different types of paper or fiber containers, an ordinary electric curling iron or a household flatiron is quite satisfactory.

In the course of home freezing and other investigations in this laboratory during the past five years, over 10,000 jars of fruits, fruit juices, vegetables, meats, fish, and poultry have been frozen under typical home-freezing conditions. Home canning type jars were used in most cases. Glass containers are satisfactory for home freezing as they provide a moisture-vapor-proof container which can be re-used many times. No trouble from undue breakage has been encountered. The objection to glass jars is that inherent in all cylindrical containers—they take up more space in the freezer than do square-sided containers. This disadvantage would probably be offset by the advantages in many cases.

Instructions for Home Freezing

Detailed instructions for home freezing and the use of home-frozen foods are provided in several excellent and readily available publications as indicated in Appendix I. It is of the utmost importance that instructions be followed carefully if high quality home frozen foods are to be obtained. Attention must be given to the selection of raw materials, preparation, blanching, selection of packages and packaging, freezing, storing, thawing, and cooking. The general procedures recommended by the United States Department of Agriculture (19) and others for home freezing fruits and vegetables are presented in tables 7 and 8, and the approximate yield of frozen fruits and vegetables from fresh produce is indicated in table 9. Procedures for freezing meat, poultry, and fish are given in table 10, and the approximate amount of trimmed meat cuts from the several animals is given in table 11. Table 12 gives directions for freezing eggs.

Use of Ascorbic Acid to Prevent Browning of Peaches

The use of small amounts of ascorbic acid either alone or in combination with citric acid has proved very effective in preventing discoloration and flavor changes in some frozen fruits, especially peaches, after they have thawed. If powdered ascorbic acid, as indicated in table 7, is not available, ascorbic acid or vitamin C tablets may be obtained from drug stores or other sources of supply for vitamin preparations. Ascorbic acid may be obtained in 50 or 100 milligram tablets. It should be added to peaches at the rate of 150 to 200 milligrams per pint. The tablets may be crushed and mixed with the appropriate amount of sugar or they may be dissolved in a small amount of sirup or fruit juice and mixed with the prepared fruit.

There are also several commercial products on the market consisting of a mixture of ascorbic and citric acids, which are quite satisfactory. They should be used according to the directions of the manufacturer.

TABLE 7.—FRUITS FOR FREEZING—PREPARING AND PACKING.

Fruit / How to Prepare	How to Pack
Apples	
Peel, core, and cut into sections of uniform thickness (about 12 sections for medium-sized, more for larger apples to insure sufficient scalding). Scald apples in steam or boiling water 1½ to 2 minutes to prevent darkening. Or if sirup is used for packing, you can slice apples directly into it.	Pack in 1 part sugar to 3 or 4 parts fruit, by weight (1 cup sugar to 5 cups fruit); or in sirup to cover (3 to 4 cups sugar to 4 cups water).
Apricots	
Sort for ripeness. Wash, halve, pit, and cut into sections. To keep from darkening, dip for 1 to 2 minutes in a solution of ¼ teaspoon citric acid dissolved in 1 quart water, or use ascorbic acid.	With Citric Acid. Pack in 1 part sugar to 3 or 4 parts fruit, by weight (1 cup sugar to 4½ to 6 cups fruit); or in sirup to cover (3 to 4 cups sugar to 4 cups water). With Ascorbic Acid. Put directly into sugar sirup to which has been added 1¼ teaspoon ascorbic acid to each 1 to 1½ cups sirup.
Berries (except Blueberries and Strawberries)	
Pick over, wash, drain well. Do not wash raspberries unless necessary.	Pack without sugar; or pack in 1 part sugar to 4 parts fruit, by weight (1 cup sugar to 6 cups fruit); or in sirup to cover (3 cups sugar to 4 cups water).
Blueberries	
Pick over, wash, drain well.	Pack in 1 part sugar to 4 parts fruit, by weight (1 cup sugar to 6 cups fruit); or in sirup to cover (3 cups sugar to 4 cups water); or pack without sugar.
Cherries, sour	
Wash, drain, and pit.	Pack in 1 part sugar to 3 or 4 parts fruit, by weight (1 cup sugar to 4 to 5 cups fruit).
Cherries, sweet	
Wash and drain. Pit or not, as desired	Pitted Cherries. Pack in 1 part sugar to 4 parts fruit, by weight (1 cup sugar to 5 cups fruit). Whole Cherries. Pack in sirup to cover (3 cups sugar to 4 cups water, with ¼ teaspoon ascorbic acid added to each 1 to 1½ cups sirup).

TABLE 7.—FRUITS FOR FREEZING—Continued.

Fruit / How to Prepare	How to Pack
Cranberries	
Pick over and wash.	Pack without sugar; or pack in 1 part sugar to 3 or 4 parts berries, by weight (1 cup sugar to 6 to 8 cups berries); or pack in sirup to cover (4 cups sugar to 4 cups water).
Peaches (freestone) or Nectarines	
Sort, pit, peel (skins may be loosened by scalding whole peaches 15 to 30 seconds in boiling water). Cut in sections. To keep from darkening, dip sections for 1 to 2 minutes in a solution of ¼ teaspoon citric acid dissolved in 1 quart water, or use ascorbic acid.	With Citric Acid. Pack in 1 part sugar to 3 or 4 parts fruit, by weight (1 cup sugar to 4½ to 6 cups fruit); or in sirup to cover (3 cups sugar to 4 cups water). With Ascorbic Acid. Put peaches directly into sugar sirup to which has been added ¼ teaspoon ascorbic acid for each 1 to 1½ cups sirup.
Plums and Prunes	
Sort, wash, halve, and pit.	Pack in 1 part sugar to 3 to 5 parts fruit by weight (1 cup sugar to 4½ to 10 cups fruit); or in sirup to cover (3 to 5 cups sugar to 4 cups water, with ¼ teaspoon ascorbic acid added to each 1 to 1½ cups sirup).
Rhubarb	
Wash, trim, and cut stalks into 1-inch pieces.	Pack without sugar; or pack in 1 part sugar to 4 or 5 parts rhubarb, by weight (1 cup sugar to 5 to 6 cups fruit); or in sirup to cover (3 cups sugar to 4 cups water).
Strawberries	
Cap and sort, wash, and drain well. Leave berries whole or slice.	Pack in 1 part sugar to 3 or 4 parts fruit, by weight (1 cup sugar to 5 to 8 cups fruit). Pack tightly so juice covers berries.

Head Space:

In carton or bag, leave ½ inch head space if packed without liquid. Leave 1 inch head space if packed with sirup, or for purees or crushed fruits. In glass jars or tin cans leave 1½ inches head space.

Packing Fruit in Dry Sugar:

When packing fruits in dry sugar, be sure to mix thoroughly until all sugar is dissolved and sufficient sirup is formed to cover the fruit when packed. If necessary press fruit down in package until sirup covers the fruit.

Table 8.—Vegetables for Freezing — Preparing and Packing.

Vegetable How to Prepare	Time to Scald in Boiling Water
Asparagus Wash well and cut into desired lengths. Sort into 3 groups, according to thickness of stalk. Scald, chill, and pack.	2 to 4 minutes according to size of stalk
Beans, Lima Shell, wash, and sort according to size. Scald and chill. Sort out any beans that have turned white; these may be cooked or canned. Pack.	2 to 3 minutes according to size
Beans, Snap Wash well, cut off stem and tips. Leave whole, slice, or cut into pieces. Scald, chill, pack.	2 to 3 minutes
Broccoli Cut off large leaves and tough stalks. Wash well and soak, heads down in salted water (4 teaspoons salt to 1 gallon cold water), for about ½ hour. Split lengthwise so heads are not more than 1½ inches across. Scald, chill, and pack.	4 minutes, or 5 minutes in steam
Cauliflower Select white, compact heads, and break them into pieces about 1 inch across. Wash, scald, chill, and pack.	3 minutes
Corn on the Cob Husk, remove silk, and trim off bad spots. Wash and sort according to thickness of ear. Scald, chill, and pack.	slender ears, 7 minutes; medium, 9 minutes; large, thick ears, 11 minutes
Corn, Whole Kernel Husk, remove silk, and trim off bad spots. Wash, scald, chill, cut kernels off cob, pack.	5 to 7 minutes
Greens Wash well, remove imperfect leaves and large, tough stems. Scald, chill, and pack.	1 to 2 minutes
Peas Shell, sort out immature and tough peas, wash, scald, chill, and pack.	1 minute
Peppers, Green and Pimento Wash. Remove seeds and slice or cut as desired. Scald and chill. Pack in brine of 1 teaspoon salt to 1 cup cold water.	2 minutes
Soybeans Boil in pods for 5 minutes. Chill. Squeeze beans out of pods. Wash, drain, and pack.	No additional scalding required

Head Space:

In carton or bag, when packed without liquid, leave ½ inch head space for vegetables that pack tightly, such as peas and corn. No head space is needed for vegetables that pack loosely, such as broccoli and cauliflower.

For vegetables packed with brine or for vegetable purees, leave 1 inch head space. In glass jars or tin cans leave 1½ inches head space.

Vegetables not given in table:

The table gives recommendations for those vegetables most commonly frozen. Other vegetables, such as beets, brussels sprouts, cabbage, carrots, mushrooms, okra, and sweet potatoes have been frozen successfully and directions have been developed by some of the state agricultural experiment stations.

Whole tomatoes, lettuce, celery, cucumbers, and onions have not been frozen satisfactorily.

TABLE 9.—APPROXIMATE YIELD OF FROZEN FRUITS AND VEGETABLES FROM FRESH.

Product	Fresh (as purchased)	Pint Packages (frozen)	Servings per Pint
	Fruits		
Apples	1 bu. (48 lb.)	32 to 40	–
	1¼ to 1½ lb.	1	
Berries	24-qt. crate	30 to 36	4
	3 qt.	4	
Cherries, as picked	3 lb.	4	4
Cherries, pitted, pie	3 lb.	3	–
Cranberries	5 lb.	10	–
Peaches	1 bu. (48 lb.)	36 to 48	4
	1 to 1¼ lb.	1	
Plums	10 lb.	8 to 10	3 to 4
Rhubarb	1 lb.	1	4
Strawberries	10 qt.	8 to 10	4
	Vegetables		
Asparagus	1 crate, 24 one-lb. bunches	15 to 22	4
Beans, green or wax	1 bu. (30 lb.)	30 to 40	3 to 4
	¾ to 1 lb.	1	
Beans, lima, in pods	1 bu. (32 lb.)	12 to 16	4 to 5
	2 to 2½ lb.	1	
Beets, without tops	1 bu. (52 lb.)	32 to 40	4
Broccoli	6 good heads	4 to 6	3
Brussels Sprouts	4 qt.	5 to 6	3 to 4
Carrots, without tops	1 bu. (50 lb.)	32 to 40	4
Cauliflower	3 medium heads	5	3
Corn, sweet	100 ears	22 to 24	4
Greens	1 bu. (18 lb.)	12 to 18	3
Peas, green, in pods	1 bu. (30 lb.)	12 to 15	4
Squash and Pumpkin	3 lb.	2	3 to 4

TABLE 10.—MEATS, POULTRY, AND FISH FOR FREEZING—PREPARING AND PACKAGING.

Product	How to Prepare	How to Package
Beef	Chill and age at 34° to 36°F. for 5 to 7 days if well-finished animal. With little covering of fat, chill only. After chilling and aging, trim off surplus. Cut into compact pieces suitable for family use. Separate steaks from roasts; pot roasts from stew meat and from meat that should be ground. Pieces should be at least 1 inch thick. Remove surplus fat and bone. Boning of meat makes wrapping easier and saves from 5 to 35% of storage space needed. Less tender cuts may be canned.	Wrap in moisture-vapor-proof package material or seal in cellophane or other airtight package to prevent drying. Use stockinet or outer wrap over cellophane or pliofilm wrapped meats. When two or more steaks, meat patties, or other pieces of meat are wrapped together, put 2 pieces of waterproof paper between the pieces of meat. Wrap and pack tightly in order to eliminate air from within the package.
Veal	Same as for beef, except age only 1 or 2 days.	Same as for beef.
Lamb	Same as for beef.	Same as for beef.
Pork	Cut, package, and freeze as soon as thoroughly chilled. Hams, shoulders, and bacon are usually cured. Use trimmed lean meat for sausage.	Same as for beef.
Ground Meat including Sausage	Pack unsalted in rolls or patties. Salts accelerate oxidation and development of rancidity.	Same as for beef. Cartons or wrappings may be used.
Cured and Smoked Meats	Chill after curing. Bacon may be sliced before freezing. Hams, shoulders, and bacon slabs may be frozen whole or cut into thick slices or roasts.	Same as for beef.
Poultry	In preparing to pick chickens, avoid overscalding the skin. Scald for 20 to 30 seconds in water about 128° to 140°F. Chill completely. Ice water may be used or a refrigerator over night.	Tight wrap and seal. Paper should come in close contact with the pieces or carcass to prevent freezer burn and excessive drying.

TABLE 10.—MEATS, POULTRY AND FISH FOR FREEZING—Continued.

Product	How to Prepare	How to Package
Roasters	Completely dressed. Remove excess fat. Tie wings and legs close to body. Giblets may be wrapped separately in freezer paper and placed in body cavity.	With cellophane and pliofilm, a piece of stockinet will hold wrap closer to pieces and carcass. Poultry cut into pieces can be wrapped more firmly and requires less space in locker. May be frozen and glazed before wrapping to help prevent drying.
Fryers and Fowl—	Unjoint or cut up.	
Broilers—split.		
Wild Game—Birds and Rabbits	Same as for poultry.	Same as for poultry.
Wild Game—Animals	Same as for beef.	Same as for beef.
Fish	Chill promptly, pack in ice if necessary. Clean, dress, remove head, and wash. Trim fins and tail if fish is to be frozen whole. Cut large fish into steaks or boneless fillets.	Wrap in moisture-vapor-proof freezing paper or wrapping as for meat. May be glazed. The glaze should be renewed when necessary—every 1 to 3 months.

Table 11.—Meat and Poultry Yield. Approximate amounts of trimmed meat cuts with surplus fat and bone removed.

(United States Department of Agriculture, 17.)

Beef:			Pounds
Live weight			750
Whole carcass			420
Trimmed cuts:	Percent of live weight	Percent of carcass weight	Pounds
Steaks and oven roasts	23	40	172
Pot roasts	11	20	83
Stew and ground meat	11	20	83
Total	45	80	338
Forequarters			218 lb.
		Percent of forequarters	Pounds
Steaks and oven roasts		25	55
Pot roasts		32	70
Stew and ground meat		27	59
Total		84	184
Hindquarters			202 lb.
		Percent of hindquarters	Pounds
Steaks and oven roasts		58	117
Stew, ground meat and pot roasts		18	37
Total		76	154
Pork:			Pounds
Live weight			225
Whole carcass			176
Trimmed cuts:	Percent of live weight	Percent of carcass weight	Pounds
Fresh hams, shoulders, bacon, jowls	40	50	90
Loins, ribs, sausage	15	20	34
Total	55	70	124
Lard, rendered	12	15	27
Lamb:			Pounds
Live weight			85
Whole carcass			41
Trimmed cuts:	Percent of live weight	Percent of carcass weight	Pounds
Legs, chops, shoulders	37	75	31
Breast and stew	8	15	7
Total	45	90	38

Poultry (approximate):	Live weight Pounds	Dressed and drawn Pounds	Dressed and drawn Percent of live weight
Chickens	2-4	1¼ – 2½	62
Hens	4-8	2½ – 5½	65
Turkeys	10-20	7½ – 15	75

TABLE 12.—EGGS FOR FREEZING—PREPARING AND PACKAGING.

Product	How to Prepare	How to Package
Whole Eggs	Break the individual eggs into a small bowl and then place each in the well of a muffin pan, paper cup, or other appropriate mold. They are then placed in the freezer and frozen solid.	Eggs may be removed from the container by placing them in shallow hot water for a few seconds. Each whole egg may then be wrapped individually and put back in the freezer. With this method of freezing, the required number of eggs for any recipe is readily available. If the eggs are frozen in small paper cups, they may be wrapped after being frozen without being removed from the cups. Eggs should be packaged in moisture-vapor-proof containers or wrappings.
Mixed Whole Eggs	Add 1 tablespoon of corn sirup or sugar or 1 teaspoon of salt to each cup of liquid whole eggs. Break all yolks. Mix thoroughly but avoid beating air into the eggs. The mixing and the added sirup, sugar, or salt aid in preventing gumminess in thawed yolks.	May be frozen in bulk or in pint or quart containers. For smaller units, the eggs may be frozen in muffin pans, paper cups, or ice cube trays. After freezing, the small units may be handled as described for whole eggs.
Egg Yolks	Add 2 tablespoons of corn syrup or sugar or 1 teaspoon of salt to each cup of egg yolks and mix as for the mixed whole eggs.	Same as for mixed whole eggs.
Egg Whites	Egg whites may be frozen without mixing and with nothing added.	Same as for mixed whole eggs.

Approximate Measure: 1 tablespoon of yolks equals 1 egg yolk; and 1½ tablespoons of whites equals the white of 1 egg.

Questions and Answers on Home Freezing

This bulletin was prepared and the accompanying experimental work done in an effort to furnish answers to some of the many questions that have been raised regarding "Home Freezing in Massachusetts." This information may be summarized by the following questions and answers:

1. *Question:* What types of home freezing equipment and facilities are available?

Answer: Locker plants and home freezing cabinets are the two general methods available to the homemaker for freezing foods. Frozen food locker plants are of three general types: (1) those maintaining refrigerated lockers for rent but offering no special service for customers; (2) those renting lockers and offering a butchering, meat-cutting, packaging, and freezing service; and (3) those offering both butchering and meat-cutting service and also the preparation and packaging of fruits and vegetables.

During the past few years there has been a considerable development in frozen food locker plants in New England, and such facilities are available to a limited number of people. Since the end of the war there has been a marked increase in the manufacture of home freezing cabinets. At the present time upwards of 100 manufacturers are actually in production or have signified their intention to make home freezing units. These units vary in capacity all the way from 2½ cubic feet to 50 cubic feet. Cabinets up to 15-18 cubic feet in capacity are often considered a home type while the larger ones are considered "farm" freezers. Many of the home freezers are being advertised extensively and are readily available on the market. Home refrigerators are also available with a special storage compartment for frozen foods.

2. *Question:* Should I buy a home freezer or hire a commercial locker?

Answer: This is a question that can be answered only by the individual concerned after careful consideration of all the factors involved in home or locker freezing. Such factors as convenience, desire for frozen foods, suitability of other methods of food preservation, economy and convenience of other means of providing the family table with frozen foods, availability of raw material, cost, etc., should be considered.

3. *Question:* What advantage does freezing have over canning?

Answer: Although the excellence of canned or heat-processed foods is generally admitted, such foods are as a rule cooked beyond the strict requirements for table use. The desirability of frozen foods is claimed to be due to the retention in a large measure of the natural appearance and unaltered quality for table use. This is particularly true in the case of fruits and meats.

4. *Question:* What about the comparative costs of home canning and freezing?

Answer: An investigation carried on here has shown that home freezing is definitely more expensive than canning. For example, on a basis of equipment costs and depreciation, power, containers, and storage, the unit cost for preserving a pound of food by freezing was approximately four to five times as much as for canning. This figure is based on an initial cost of $30 per cubic foot for freezer capacity, which is somewhat lower than current retail prices. These freezing costs may be reduced by a well-planned freezing program.

5. *Question:* If I purchase a new freezer and preserve my foods by freezing rather than by other methods, will our yearly food cost be increased significantly?

Answer: On the basis of recommended food preservation budgets as prepared by our Extension Service, it would appear that the change to freezing may add as much as $50 to $70 per year to the food budget.

6. *Question:* Are all foods adaptable for freezing?

Answer: Yes, most foods may be satisfactorily preserved by home freezing, if they are prepared, packaged, and stored properly. Most fruits, vegetables, meats, fish, poultry, butter, eggs, and certain specialty and pre-cooked foods are adapted to freezing. However, tomatoes have not been satisfactory when frozen and it is preferable to can them. Some difficulties have been encountered in freezing green beans.

7. *Question:* What place does home freezing have in the food preservation schedule?

Answer: In rural areas where people raise and slaughter much of their own meat, home freezing should be more important than in semi-rural and urban areas such as make up much of this State. In any case, home freezing has a certain value from the standpoint of convenience and the personal satisfaction derived from it. In normal times the economy of purchasing meat in large quantities for freezing is questionable. This would mean that if one attempted to justify the need for home freezing it would have to be for the freezing of fruits and vegetables. In this area, tomatoes and green beans probably constitute 50 to 60 percent of all the food usually canned at home and, as indicated previously, these two products are not so well adapted to freezing and might just as well be canned. With small fruits such as strawberries and raspberries, freezing is certainly unexcelled as a method of preservation. All things considered, home freezing does not appear to be as important in Massachusetts as it may prove to be in certain other sections of the country. We think of freezing as best used to supplement, rather than to replace other methods of food preservation.

8. *Question:* It certainly sounds as though an individual should give careful thought to his food needs and whether or not home freezing will measure up to expectations before investing in a home freezer.

Answer: Yes, although on first thought home freezing certainly sounds like an attractive proposition, a person should give some thought to the matter of what he expects to get out of freezing, and whether or not a home freezer will come up to his expectations and needs before he purchases a unit. From contacts we have had with home freezer owners, it would appear that although many are well pleased with freezing, others are quite dissatisfied and disappointed. However, in some cases of dissatisfaction, the trouble seems to have been caused by the use of improper preparation and freezing methods. In this respect, we cannot stress too strongly the importance of obtaining good instructions for the preparation, packaging, and freezing of foods and following these instructions.

9. *Question:* Is it true that only certain varieties of fruits and vegetables are suitable for freezing?

Answer: Yes, in freezing, varieties are probably more important than in home canning. Some varieties of fruits and vegetables retain their color and texture, after thawing, to a greater extent than others. Local conditions of soil and climate also affect the freezing qualities of fruits and vegetables. Varieties that are suitable in some sections may be inferior to others when grown in another part of the country. These factors should be considered when planning the home garden. In general those varieties that are of good quality when cooked fresh are good frozen. Your State College can supply further information on varieties suitable for freezing.

10. *Question:* Can I use a sirup like Karo for freezing fruits?

Answer: Yes, Karo or other types of corn sirup may be used in freezing fruits. In general it is recommended that from 1/3 to 1/2 of the sugar called for may be replaced by one of these sirups. Some sirups are on the market which it is claimed can be used in larger amounts.

11. *Question:* Should I pack vegetables dry or in a brine?

Answer: As a rule, a dry pack is more satisfactory than a brine pack and is to be recommended.

12. *Question:* Should boiling water or steam be used for blanching vegetables?

Answer: Boiling water rather than steam is recommended for blanching vegetables for freezing in the home, as it can be controlled more accurately and easily.

13. *Question:* What types of packages should be used for frozen foods?

Answer: There are many types of containers available that are satisfactory for frozen foods. They should be made of a moisture-vapor-resistant material that can be sealed tightly. Each home processor must select the one or ones best suited to the products handled and the available storage conditions.

14. *Question:* Why must the moisture be wiped out of the inside of a cellophane bag before it is sealed?

Answer: When cellophane bags are heat-sealed, the part where the seal is made must be dry so that a satisfactory seal can be made.

15. *Question:* How should foods be frozen and stored?

Answer: According to the Department of Agriculture:

Freeze foods as soon as possible after they are packed. Keep packages cold in the refrigerator until all are ready for freezing. If you take food to a locker plant, carry packages in an insulated box. At the locker plant, have foods frozen in the fast-freezing room, if one is available, before placing in your locker. If you have a home freezer, be sure the temperature oi the freezing compartment is 0°F. or lower.

Follow these rules to speed freezing:

Don't freeze too many packages at once. The manufacturer of your freezer can tell you how much food to freeze at one time or in a 24-hour period.

Place packages against freezing plates or coils, but spread them out so air can move between them.

Remember that thick or heavily wrapped packages take longer to freeze than those of medium size with only enough wrapping to protect the food.

After freezing, store food at 0°F. or lower. At higher temperatures, frozen foods lose both eating quality and vitamin values.

To keep track of the amount and kinds of frozen foods in the freezer, post an up-to-date list near the freezer. List the foods as you put them into the freezer, and check them off as you take them out, so packages won't be lost or forgotten.

16. *Question:* What happens to the food in a home freezing unit when the current fails or there is a breakdown?

Answer: Under these conditions the temperature in the cabinet gradually rises, and the frozen products thaw out if the unit is shut down long enough. The length of time required for the food to thaw out and possibly spoil will depend upon the size of the cabinet and the amount of food in it. Tests have shown that frozen foods may be safely held in freezer cabinets of 10-12 cubic feet capacity for 3–5 days after the current has been shut off. If it looks as though the freezer will have to be shut off for any prolonged period of time, it would be advisable to try to transfer the food immediately to a locker plant or other frozen food storage facility. Dry ice may be added to the cabinet to help maintain a low temperature. If the electricity is shut off or the freezer fails, do not open the cabinet. Food in a loaded cabinet will usually stay frozen for at least 2 days.

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Appendix 1.

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Appendix 2.

Partial List of Sources of Supplies for Home and Locker Freezing

(In presenting this partial list of manufacturers and dealers of home freezing supplies no guarantee of approval by the University of Massachusetts is implied and no discrimination is intended.)

Packaging Materials for Frozen Foods

Benj. C. Betner Co., Devon, Pa.
Container Corp. of America, 111 West Washington St., Chicago, Ill.
H. D. Catty Corp., 49 Portland St., Boston 14, Mass.
Dixie Cup Co., Easton, Pa.
Dobeckmun Co., 3301 Monroe Ave., Cleveland, Ohio.
H J. Dowd Co., Inc., 217 Thorndike St., E. Cambridge, Mass.
E. I. DuPont de Nemours & Co., Wilmington 92, Delaware.
Robert Gair Co., Inc., 155 East 44th Street, New York, N. Y.
Interstate Folding Box Co., Middletown, Ohio
Jewett Associates, 1053 Main Street, Buffalo 8, N. Y.
Lindley Box & Paper Co., Marion, Ind.
A. E. MacAdam & Co., 95 Lexington Ave., Brooklyn 5, N. Y.
Marathon Corp., Menasha, Wis.
Montgomery Ward & Co., Albany, N. Y.
Reynolds Metals Co., Reynolds Metals Bldg., Richmond 19, Va.
Thomas M. Royal & Co., Philadelphia 20, Pa.
Sealright Co., Inc., Fulton, N. Y.
Sears Roebuck Co., Boston, Mass.
Shellmar Products Co., Mount Vernon, Ohio.
Sylvania Industrial Corp., 122 East 42nd St., New York, N. Y.
Whitney Bros., Inc., 34 Farnsworth St., Boston, Mass.

Stockinet

Adler Co., Harrison and Queen City Aves., Cincinnati 14, Ohio.
A. E. MacAdam & Co., Inc., 95 Lexington, Brooklyn 5, N. Y.
E. W. Twitchell, Inc., 775 Public Ledger Bldg., Philadelphia, Pa.
Yorkville Paper Co., Inc., 431 East 77th St., New York 21, N. Y.

Heat Sealing Equipment

Amsco Packaging Machinery, Inc., Long Island City, N. Y.
H. D. Catty Corp., 49 Portland St., Boston 14, Mass.
Cleveland Lathe & Machine Co., 5511 Euclid Ave., Cleveland 3, Ohio.
Paul R. Karstrom, 2620 South Indiana Ave., Chicago 16, Ill.
Pack-Rite Machines, 828 North Broadway, Milwaukee 2, Wis.
Schuman Equipment Co., 137 Bausman St., Pittsburgh 10, Pa.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 438 SEPTEMBER, 1946

The Value of Limited Trapnesting in Poultry Breeding

By F. A. Hays

Limited trapnesting reduces labor costs and affords a method by which breeders may secure records on larger numbers of birds. Data reported in this study indicate that safe estimates of complete performance may be made from certain short-time records.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

THE VALUE OF LIMITED TRAPNESTING IN POULTRY BREEDING

By F. A. Hays,
Research Professor of Poultry Husbandry

Trapnesting is an expensive operation on the poultry breeding farm. While there are no specific records on costs, it has been estimated that daily trapnesting adds about one dollar a year to the cost of keeping a hen. There is no question, however, but that trapnesting and record keeping are to a great extent responsible for the remarkable progress made in breeding poultry for egg production during the last twenty-five years.

Selective breeding for inherited physiological characters that affect egg production has been made possible through the trapnest. In other words, high egg production is dependent on a complex of inherited physiological characters. Limited trapnesting will enable the breeder to discover valuable breeding birds with respect to some of these characters but will neglect other important characters. To the breeder it is important that he follow a practice that will give him the most complete information to guide his breeding operations.

Some most important information obtainable from trapnest records may be briefly considered. This includes age at sexual maturity, intensity of laying, winter pause, egg size and character, broodiness, spring intensity, summer intensity, spring and summer pauses, fall intensity, and persistency. In birds used for breeding, complete records may be secured on fertility, early and late embryonic deaths, and hatchability together with information on the character of chicks produced.

PREVIOUS WORK

Several attempts were made at the beginning of the present century to estimate annual egg production by using limited periods of records. Later, at the Fourth World's Poultry Congress, Voitellier (1930) reported some specific observations on 50 hens representing 10 different breeds in the National Egg Laying Competition at Versailles, France. The birds selected represented different types of producers, from 70–80 eggs up to more than 200 eggs in 48 weeks. He applied three short-time tests: One day each week, two days each week, and every fourth week out of the 48. All of these measures proved fairly satisfactory for high producing hens. For the group of hens as a whole, the methods ranked in efficiency: 1 week, 2 days a week, and 1 day a week.

Dudley (1931) reported an investigation of two types of limited trapnesting, including 748 White Leghorns and White Wyandottes in English egg-laying contests. The birds were rather mediocre producers, and the measures used were four consecutive days in the middle of each lunar month and one day each week for 48 weeks. He gives the following averages:

	Average 48-Week Production	Average 48-Day Production	
		4 Consecutive Days Monthly	One Day Weekly
National Institute Leghorns	168	24.4	24.0
Harper Adams Leghorns	183	26.2	26.5
Harper Adams Wyandottes	186	26.5	26.5

Dudley found the correlation between annual production and the production on four consecutive days to be about .93 in Leghorns and .85 in Wyandottes; between annual production and production for one day weekly, .91 for Leghorns and .92 for Wyandottes. The regression of annual production on the production. observed by either short-time measure was not exactly linear. The number of eggs laid in either short period did not give an accurate estimate for the low producers or for the higher producers, but was satisfactory for the medium producers.

By applying regression lines, Dudley secured the following results:

Difference Between Estimated and Actual Annual Production	Percentage of Birds by the Two Measures	
	4 Consecutive Days Monthly	One Day Weekly
0 – 12 eggs	58	56
13 – 24 eggs	28	30
25 – 36 eggs	9	11
37 eggs or more	5	3

In his study the correlation between annual egg weight and egg weight records obtained by either short measure was .95, and they were equally good for calculated annual egg weight. Regression was linear for both.

Thompson (1933) u ed the records of 3937 White Leghorn pullets, hatched in 1929 and 1930 and entered in New Jersey egg-laying contests, to study the relative efficiency ot three short-time trapnest records: the first 120-day record; the last 30-day record from August 25 to September 23 at the close of the year; and a combination of the two. He stressed that regression of annual production on the production of all these short periods was non-linear and developed a curved regression line which seemed to be satisfactory for estimating the probable annual record from a known short-time record.

Thompson and Jeffrey (1936) applied three partial trapnest measures to the annual contest records of 2028 White Leghorns: (a) winter production (Oct. to Feb. 1); (b) summer–fall production (June to Oct. 1); and (c) a and b combined as one measure. The correlation between winter and annual production was +.7075 c ratio; between summer–fall and annual production +.8017 c ratio; and between winter plus summer–fall and annual production .9368 c ratio. A curved regression line was calculated for the three measures and the third was found to be the most accurate for predicting annual production. When the winter and summer–fall records were applied to 100 hens, 46 percent of the birds showed a difference between predicted and actual annual records of from 0 to 9 eggs; 25 percent, from 10 to 19 eggs; 12 percent, from 20 to 29 eggs; and 17 percent, 30 eggs or more. A comparison of these results with those of Dudley seems to indicate that Dudley's measures of one day weekly and four consecutive days each month are a slightly better criterion of annual production than the winter and summer–fall record used by Thompson and Jeffrey.

Olsen (1939) reported on the record of 500 White Leghorns and 390 Rhode Island Reds at the Beltsville Research Center, using two short-time measures: trapnesting one day a week throughout the year; and trapnesting one day a week through August and daily in September to the end of a 52-week laying year. He obtained a correlation of .91 in Leghorns and .89 in Rhode Island Reds between the number of eggs laid in one-day-a-week trapnesting and the annual record.

When this weekly record was supplemented by daily trapnesting in September, there was no significant increase in the accuracy of the records. Olsen calculated the regression line for one-day-a-week records and estimated the production of 100 Leghorns. He found that 44 percent of the calculated records were within 10 eggs; 58 percent, within 15 eggs; 73 percent, within 20 eggs; 85 percent, within 25 eggs; and 89 percent, within 30 eggs of the actual production. His second measure was no more accurate than the first.

Lerner and Taylor (1940), from a study of 714 Leghorn pullets, conclude that, where the number of eggs laid is the only measure of breeding value used, trapnesting for the winter months is as efficient a guide to family selection as is trapnesting for the year. Neither system is accurate if the records of the dams alone are used. These workers point out that the components of the annual record need to be considered in an efficient breeding program.

PORTIONS OF COMPLETE RECORDS MAY BE OF VALUE

For accurately determining the value of limited trapnesting, the method should be applied to a flock over a period of years as the only guide in selective breeding. Under such conditions data would be obtained on the effectiveness of the method. It would be desirable also to study the effectiveness of limited trapnesting supplemented by complete trapnesting and also to make use of complete trapnesting on a control flock.

So far as we are aware, the value of limited trapnesting has been deduced from the records of birds constantly under complete trapnesting. The data to be presented from the Massachusetts Station have been taken from pedigreed Rhode Island Reds that had complete trapnest records and on which progeny testing was used to a considerable extent. It cannot be said, therefore, that the data suffice to answer the question as to what might happen when limited trapnesting alone was applied. In other words, the question arises as to whether or not inherited fecundity characters could be combined in the same way through limited trapnesting as has been done through complete trapnesting.

Data to be presented cover a seven-year period from 1936 to 1942 inclusive. The records made by 1684 Rhode Island Red females during their first laying year are considered. These birds were all bred for characters associated with high fecundity. The stock was hatched in March and April, and complete daily trapnest records were secured for the first laying year. Annual records as used in this study include a 365-day period beginning with the first egg, differing from contest records which usually begin October 1 and terminate September 22.

Kinds of Limited Trapnesting Used

A. First two days of each month beginning October 1 and ending September 2.
B. First week of each month beginning October 1 and ending September 7.
C. Daily during October.
D. Daily during August at the end of the year.
E. Daily to January 1.

Information Desired Through Limited Trapnesting

1. Probable annual egg record.
2. Probable egg weight to January 1.
3. Probable hatching season egg weight.
4. Probable annual egg weight.
5. Probable age at first egg.

6. Probable clutch size: winter, spring, summer, and fall.
7. Probable winter pause duration.
8. Probable annual persistency.
9. Probable length of biological year.

LIMITED TRAPNESTING FOR ESTIMATING THE PROBABLE ANNUAL EGG RECORD

In this section the five short-time measures of production are considered for their accuracy solely from the standpoint of annual egg production. The correlation coefficients, the calculated and actual egg records, and the percentage accuracy of the short-time measures are shown in Table 1. Table 2 compares the actual production with the production calculated by the regression formulas.

Table 1.—The Value of Limited Trapnesting for Estimating Probable Annual Egg Record.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Annual Production		Accuracy Percent
			Estimated	Actual	
A. First 2 days of each month, Oct.–Sept. (24 days)	1684	+.7750 ± .0066	204*	216	95
			208**		96
B. First week of each month, Oct.–Sept. (84 days)	1684	+.9103 ± .0028	206*	216	95
			209**		97
C. Daily in October only (31 days)	1432	+.2209 ± .0170***	195**	218	89
D. Daily in August only (31 days)	1595	+.6302 ± .0102	221*	219	99
			187**		85
E. Daily from first egg to January 1	1683	+.4338 ± .0133	223*	216	97

*Calculated by the regression formula.
** Calculated from the limited records by the following factors: 15.2 for the 24-day record (24/365 of a year); 4.34 for the 84-day record; and 11.77 for the two 31-day records.
*** Regression was found to be non-linear. The association is therefore measured by the correlation ratio which was .3003.

Trapnesting the first two days of each month is a convenient method of limited trapnesting which has been frequently used for estimating annual egg weight. The two-day observations began October 1 and ended September 2, making 24 days of trapnesting in the year. Table 1 shows an accuracy of 95 or 96 percent for this method, depending on how the annual production is calculated.

Breeders desire to know what birds to discard and what birds to retain when the chief interest is high annual records. The regression table supplies this information. Table 2 A shows a remarkable agreement between calculated and actual record. For example, if a breeder selected hens that laid 14 eggs on the 24 days trapnested, they would be expected to lay about 215 eggs in a year. If he was looking for 250-egg hens, the 24-day record should show about 18 eggs.

Trapnesting the first week of each month was but slightly more satisfactory than trapnesting for the first two days of each month for estimating the probable annual records (Tables 1 and 2 B).

TABLE 2.—LIMITED TRAPNESTING AS A MEANS OF ESTIMATING ANNUAL EGG PRODUCTION.

A. Regression[1] of Annual Production on 24-Day Egg Record (First 2 days of month)

24-Day Egg Record	Number of Birds	Annual Production: Estimated	Annual Production: Actual
3– 4	6	115	128
5– 6	38	135	132
7– 8	78	155	149
9–10	163	174	174
11–12	291	194	194
13–14	370	214	215
15–16	396	234	236
17–18	243	254	253
19–20	83	273	266
21–22	16	293	281
	1684		

B. Regression[1] of Annual Production on 84-Day Egg Record (First week of month)

84-Day Egg Record	Number of Birds	Annual Production: Estimated	Annual Production: Actual
16–20	5	101	117
21–25	38	120	122
26–30	56	139	137
31–35	99	158	154
36–40	175	177	178
41–45	242	196	196
46–50	331	215	215
51–55	292	234	236
56–60	275	253	253
61–65	128	272	270
66–70	39	291	288
71–75	4	310	295
	1684		

C. Regression[2] of Annual Production on 31-Day Egg Record (October only)

31-Day Egg Record	Number of Birds	Annual Production: Estimated	Annual Production: Actual
1– 2	84	201	195
3– 4	89	204	211
5– 6	89	206	216
7– 8	79	208	209
9–10	65	210	214
11–12	76	212	211
13–14	83	214	217
15–16	93	217	216
17–18	93	219	209
19–20	120	221	216
21–22	109	223	206
23–24	136	225	221
25–26	136	227	226
27–28	104	230	240
29–30	62	232	251
31	14	233	257
	1432		

D. Regression[1] of Annual Production on 31-Day Egg Record (August only)

31-Day Egg Record	Number of Birds	Annual Production: Estimated	Annual Production: Actual
1– 2	68	167	168
3– 4	70	174	170
5– 6	92	181	177
7– 8	83	188	194
9–10	96	196	197
11–12	97	203	204
13–14	116	210	213
15–16	149	217	214
17–18	139	225	227
19–20	175	232	229
21–22	206	239	237
23–24	143	246	246
25–26	93	254	256
27–28	46	261	261
29–30	20	268	277
31	2	274	265
	1595		

E. Regression[2] of Annual Production on Production to Jan. 1

Egg Record to Jan 1	Number of Birds	Annual Production: Estimated	Annual Production: Actual
1–10	5	167	171
11–20	30	177	173
21–30	90	186	184
31–40	207	195	189
41–50	307	205	204
51–60	331	214	220
61–70	284	223	227
71–80	205	232	233
81–90	119	242	233
91–100	70	251	248
101–110	27	260	255
111–120	5	270	267
121–130	3	279	265
	1683		

[1] Regression linear.

[2] Regression non-linear.

Trapnesting in October only at the beginning of the first laying year did not furnish a dependable criterion of annual production (Tables 1 and 2 C).

Trapnesting in August only at the end of the year was an excellent criterion for predicting the first-year record as is shown by the results in Tables 1 and 2 D. August records are also known to be especially valuable in judging persistency.

Trapnesting daily from first egg to January 1 is a satisfactory measure from the standpoint of number of eggs laid, but not as accurate as trapnesting two days each month, one week each month, or during August at the close of the laying year (Table 1 and 2 E). This type of trapnesting does have other advantages, however.

LIMITED TRAPNESTING FOR ESTIMATING EGG WEIGHT TO JANUARY FIRST

In the selection of pullet breeders there is a very great advantage in being able to forecast their probable egg weight during the breeding season.

The correlation ceofficients, the calculated and actual average egg weights to January 1, and the percentage accuracy of the several short-time measures are shown in Table 3. The egg weights as calculated by the regression formulas are shown in Table 4, in comparison with the actual egg weights.

The data show that a close approximation of egg weight to January 1 may be obtained by weighing the eggs of pullets laid on the first two days of October, November, and December; by weighing the eggs laid on the first week of those three months; or by weighing the eggs daily throughout the month of October.

TABLE 3.—THE VALUE OF LIMITED TRAPNESTING FOR ESTIMATING PROBABLE EGG WEIGHT TO JANUARY 1.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Egg Weight to Jan. 1 Grams		Accuracy Percent
			Estimated	Actual	
A. First 2 days of Oct., Nov., Dec.	1626	.8742 ± .0039	51.8	54.8	95
B. First week of Oct., Nov., Dec.	1671	.9343 ± .0021	54.2	54.8	99
C. Daily, October only	1424	.8567 ± .0048	51.1	54.7	93

TABLE 4.—LIMITED TRAPNESTING AND WEIGHING AS A MEANS OF ESTIMATING EGG WEIGHTS TO JANUARY 1.

A. Regression of Egg Weight to January 1 on 6-day Egg Weight Record (First 2 days of Oct., Nov., and Dec.)

6-Day Weighings Grams	Number of Birds	Egg Weight to Jan. 1 — Grams	
		Estimated	Actual
34–35	1	39.2	43.0*
36–37	1	40.8	41.0
38–39	1	42.4	41.0
40–41	2	43.9	41.0
42–43	7	45.5	45.0
44–45	20	47.1	47.2
46–47	60	48.7	48.2
48–49	108	50.3	50.2
50–51	204	51.8	52.0
52–53	267	53.4	53.5
54–55	320	55.0	55.1
56–57	298	56.6	56.6**
58–59	171	58.2	58.0
60–61	95	59.7	59.7***
62–63	44	61.3	61.1
64–65	17	62.9	61.9
66–67	6	64.5	64.6
68–69	2	66.1	67.0
70–71	1	67.6	71.0
	1625		

B. Regression of Egg Weight to January 1 on 21-day Egg Weight Record (First week of Oct., Nov., and Dec.)

21-Day Weighings Grams	Number of Birds	Egg Weight to Jan. 1 — Grams	
		Estimated	Actual
36–37	2	38.9	41.0
38–39	4	40.7	40.0
			*
40–41	1	42.5	45.0
42–43	7	44.3	44.4
44–45	18	46.1	45.8
46–47	51	47.9	48.1
48–49	111	49.7	49.6
50–51	178	51.5	51.5
52–53	307	53.3	53.3
54–55	369	55.1	55.0
56–57	315	56.9	56.8**
58–59	177	58.7	58.7
			***
60–61	79	60.5	60.5
62–63	34	62.3	62.2
64–65	13	64.1	64.8
66–67	2	65.9	67.0
68–69	2	67.7	66.0
70–71	1	69.5	71.0
	1671		

C. Regression of Egg Weight to January 1 on 31-day Egg Weight Record (October only)

31-Day Weighings Grams	Number of Birds	Egg Weight to Jan. 1 — Grams	
		Estimated	Actual
30–31	1	37.3	37.0
32–33	2	38.9	43.0*
34–35	2	40.5	43.0
36–37	0	42.2	—
38–39	2	43.8	47.0
40–41	5	45.4	46.2
42–43	17	47.0	48.8
44–45	34	48.6	48.3
46–47	107	50.3	49.9
48–49	185	51.9	52.0
50–51	280	53.5	53.4
52–53	278	55.1	55.0
54–55	260	56.7	56.8**
56–57	159	58.4	58.2
			***
58–59	50	60.0	60.6
60–61	27	61.6	61.5
62–63	11	63.2	63.7
64–65	4	64.8	66.5
	1424		

Regression was linear in all three cases. * 1½ ounces. ** 2 ounces. *** 2 1/12 ounces.

LIMITED TRAPNESTING FOR ESTIMATING HATCHING-SEASON EGG WEIGHT

In this locality the normal hatching season includes March and April. During this period pullets should be producing hatching eggs of maximum size for the first laying year. In this study the mean weight of eggs laid in March is considered to be the hatching-season egg weight. Since it is desirable to use hatching eggs from pullets, only if these eggs are to average about 25 ounces to the dozen, considerable care is necessary in selecting for egg size. Several short-time measures of egg weight may be applied in estimating hatching-season egg weight.

Table 5 gives the correlation coefficients, the calculated and actual hatching-season egg weights, and the percentage accuracy of the short-time measures used. The hatching-season egg weights as calculated by the straight line regression equations are compared with the actual weights in Table 6, although none of the regressions was strictly linear.

A satisfactory estimate of hatching-season egg weight may be obtained from limited records, except in the case of birds which lay very small eggs up to January 1, and these would probably never be used for breeding. Three short-time records seem to be satisfactory. Continuous weighing up to January 1 has some advantages. Weighing all eggs laid during the first week of October, November, and December is very satisfactory; and weighing on the first two days of these three months gave very good results. Weights taken for the month of Ocober were not a safe criterion of hatching-season egg weight.

TABLE 5.—THE VALUE OF LIMITED TRAPNESTING FOR ESTIMATING PROBABLE HATCHING-SEASON EGG WEIGHT.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Hatching-Season Egg Weight—March Grams		Accuracy Per-cent
			Estimated	Actual	
A. First 2 days of Oct., Nov., Dec.	695	.6939 ± .0133	56.8	60.5	94
B. First week of Oct., Nov., Dec.	705	.7196 ± .0122	59.8	60.4	99
C. Daily, October only	639	.6795 ± .0144	57.7	60.6	95
E. Daily from first egg to Jan. 1	539	.7427 ± .0130	58.9	60.6	97

TABLE 6.—LIMITED TRAPNESTING AND WEIGHING AS A MEANS OF ESTIMATING HATCHING-SEASON EGG WEIGHT.

A. Regression of Hatching-Season Egg Weight on 6-day Egg Weight Record (First 2 days of Oct., Nov., Dec.)

6-day Weighings Grams	Number of Birds	Hatching-Season Egg Weight, grams	
		Estimated	Actual
30–31	1	45.6	55.0
32–33	0	46.8	—
34–35	1	48.1	45.0
36–37	1	49.3	47.0
38–39	0	50.6	—
40–41	1	51.8	55.0
42–43	5	53.0	55.4
44–45	7	54.3	53.2
46–47	23	55.5	55.8
48–49	35	56.8	57.1**
50–51	77	58.0	57.7
52–53	102	59.2	59.2***
54–55	153	60.5	60.3
56–57	144	61.7	61.6
58–59	75	63.0	62.8
60–61	42	64.2	64.6
62–63	17	65.4	67.2
64–65	6	66.7	68.6
66–67	5	67.9	67.8
	695		

B. Regression of Hatching-Season Egg Weight on 21-day Egg Weight Record (First week of Oct., Nov., Dec.)

21-day Weighings Grams	Number of Birds	Hatching-Season Egg Weight, grams	
		Estimated	Actual
36–37	1	47.7	47.0
38–39	2	49.2	50.0
40–41	1	50.6	55.0
42–43	6	52.0	56.0
44–45	8	53.4	53.7
46–47	21	54.8	55.3
48–49	37	56.3	56.2
			**
50–51	58	57.7	57.4
52–53	114	59.1	58.8
			***
54–55	170	60.5	60.6
56–57	161	61.9	61.9
58–59	74	63.4	62.9
60–61	34	64.8	65.2
62–63	10	66.2	67.8
64–65	6	67.6	71.0
66–67	1	69.0	75.0
68–69	1	70.5	63.0
	705		

C. Regression of Hatching-Season Egg Weight on 31-day Egg Weight Record (October only)

31-day Weighings Grams	Number of Birds	Hatching-Season Egg Weight, grams	
		Estimated	Actual
32–33	1	47.0	61.0
34–35	2	48.3	53.0
36–37	0	49.7	—
38–39	1	51.0	55.0
40–41	4	52.3	56.5
42–43	6	53.7	55.3
44–45	4	55.0	55.0
46–47	27	56.4	56.2
			**
48–49	62	57.7	57.1
50–51	101	59.0	58.6***
52–53	148	60.4	60.3
54–55	139	61.7	61.6
56–57	91	63.1	63.1
58–59	26	64.4	64.7
60–61	17	65.7	67.2
62–63	8	67.1	68.0
64–65	2	68.4	74.0
	639		

E. Regression of Hatching-Season Egg Weight on Egg Weight to January 1

Weighings to Jan. 1 Grams	Number of Birds	Hatching-Season Egg Weight, grams	
		Estimated	Actual
38–39	1	48.6	55.0
40–41	1	50.1	47.0
42–43	5	51.5	51.0
44–45	13	53.0	55.6
46–47	17	54.5	54.8
48–49	37	56.0	56.5
			**
50–51	66	57.5	57.0
52–53	110	58.9	59.0***
54–55	169	60.4	60.2
56–57	162	61.9	62.0
58–59	79	63.4	63.0
60–61	27	64.9	65.5
62–63	18	66.3	68.0
64–65	5	67.8	69.8
66–67	1	69.3	75.0
	539		

Regression was non-linear in all four cases. ** 2 ounces. ***2 1/12 ounces.

LIMITED TRAPNESTING FOR ESTIMATING ANNUAL EGG WEIGHT

The average weight of the eggs laid during the entire first laying year is very important economically. It is desirable, however, to reduce the number of weighings as much as possible without interfering with the accuracy of the estimate of the annual weight. Godfrey (1933) found that the mean annual egg weight may be accurately estimated from the mean weight of one egg each month, the mean weight of the first ten eggs laid, the mean weight of eggs laid in March and April, and the mean weight of eggs laid during the first four days of December, January, February, and March.

Five abbreviated types of weighing have been tested for accuracy in this study. Table 7 gives the correlations between the short-time weights and the actual recorded average weight for the first year, the estimated weight as calculated from the regression equation, and the actual weight. In Table 8 the estimated annual egg weights as calculated from the regression equations are placed beside the actual means.

The results indicate that the annual egg weight may be estimated with a high degree of accuracy by weighing eggs the first two days of each month, by weighing eggs for the first week of each month, by weighing eggs daily during August at the end of the laying year, and by weighing eggs daily from first egg to January 1. Estimates based on weights for the month of October at the beginning of the pullet laying year are not very reliable.

TABLE 7.—THE VALUE OF LIMITED TRAPNESTING AND WEIGHING FOR ESTIMATING PROBABLE ANNUAL EGG WEIGHT.

Kinds of Limited Trapnesting and Weighing	Number of Birds	Correlation Coefficient*	Annual Egg Weight, Grams	
			Estimated	Actual
A. First 2 days of each month, Oct.–Sept. (24 days)	507	.9346 ± .0038	58.5	58.3
B. First week of each month, Oct.–Sept. (84 days)	507	.9567 ± .0025	59.3	58.3
C. Daily in October only (31 days)	473	.8010 ± .0111	55.7	58.4
D. Daily in August only (31 days)	467	.8291 ± .0098	61.7	58.4
E. Daily from first egg to Jan. 1	506	.8163 ± .0100	58.7**	59.5**

* Regression was linear in all cases except the October weighing. The estimated annual egg weight was calculated from the linear equation, however.

** Weights are for the remainder of the year, and the correlation coefficient shows the relation between egg weight up to January 1 and after January 1.

TABLE 8.—LIMITED TRAPNESTING AND WEIGHING AS A MEANS OF ESTIMATING ANNUAL EGG WEIGHT.

A. Regression[1] of Annual Egg Weight on 24-day Egg Weight Record (First 2 days of month)

24-Day Weighings Grams	Number of Birds	Annual Egg Weight, grams Estimated	Annual Egg Weight, grams Actual
42- 43	1	44.7	45.0
44- 45	1	46.5	47.0
46- 47	1	48.3	47.0
48- 49	6	50.2	49.6
50- 51	23	52.0	51.5
52- 53	46	53.9	53.8
54- 55	76	55.7	55.7*
56- 57	106	57.5	57.8
58- 59	109	59.4	59.5**
60- 61	80	61.2	61.0
62- 63	32	63.1	62.7
64- 65	14	64.9	64.5
66- 67	11	66.7	67.0
68- 69	0	68.6	—
70- 71	0	70.4	—
72- 73	1	72.3	73.0
	507		

B. Regression[1] of Annual Egg Weight on 84-day Egg Weight Record (First week of month)

84-Day Weighings Grams	Number of Birds	Annual Egg Weight, grams Estimated	Annual Egg Weight, grams Actual
44- 45	2	45.7	46.0
46- 47	0	47.7	—
48- 49	5	49.6	48.6
50- 51	22	51.5	51.1
52- 53	41	53.5	53.5
54- 55	73	55.4	55.6*
56- 57	111	57.4	57.5
58- 59	107	59.3	59.4**
60- 61	92	61.2	61.1
62- 63	29	63.2	63.1
64- 65	13	65.1	65.1
66- 67	9	67.1	66.7
68- 69	1	69.0	67.0
70- 71	1	70.9	71.0
72- 73	1	72.9	73.0
	507		

C. Regression[2] of Annual Egg Weight on 31-day Egg Weight Record (October only)

Oct. Weighings Grams	Number of Birds	Annual Egg Weight, grams Estimated	Annual Egg Weight, grams Actual
32- 33	1	44.6	55.0
34- 35	2	46.0	51.0
36- 37	0	47.4	—
38- 39	1	48.8	51.0
40- 41	4	50.2	52.0
42- 43	6	51.5	52.3
44- 45	4	52.9	52.0
46- 47	27	54.3	53.7
48- 49	51	55.7	55.0
50- 51	84	57.1	57.1*
52- 53	100	58.4	58.3**
54- 55	92	59.8	59.8
56- 57	62	61.2	61.3
58- 59	17	62.6	62.5
60- 61	13	64.0	65.1
62- 63	7	65.3	65.8
64- 65	2	66.7	72.0
	473		

D. Regression[2] of Annual Egg Weight on 31-day Egg Weight Record (August only)

Aug. Weighings Grams	Number of Birds	Annual Egg Weight, grams Estimated	Annual Egg Weight, grams Actual
48- 49	4	50.6	49.0
50- 51	15	52.1	52.6
52- 53	19	53.6	53.0
54- 55	53	55.0	54.8
56- 57	59	56.5	56.3*
58- 59	102	58.0	58.4**
60- 61	111	59.5	59.8
62- 63	47	61.0	60.7
64- 65	26	62.4	62.0
66- 67	21	63.9	63.4
68- 69	7	65.4	64.7
70- 71	1	66.9	65.0
72- 73	1	68.4	71.0
74- 75	0	69.8	—
76- 77	0	71.3	—
78- 79	1	72.8	73.0
	467		

E. Regression[1] of Egg Weight after Dec. 31 on Egg Weight to Jan. 1

Weighings to Jan. 1 Grams	Number of Birds	Egg Weight after Dec. 31, (grams) Estimated	Egg Weight after Dec. 31, (grams) Actual
38- 39	1	48.3	51.0
40- 41	1	49.8	49.0
42- 43	5	51.3	51.0
44- 45	13	52.8	54.5
46- 47	17	54.2	54.1
48- 49	36	55.7	55.1
50- 51	63	57.2	56.9*
52- 53	99	58.7	58.9**
54- 55	108	60.2	60.3
56- 57	91	61.6	61.4
58- 59	37	63.1	62.6
60- 61	19	64.6	65.3
62- 63	10	66.1	67.0
64- 65	5	67.6	67.0
66- 67	1	69.0	75.0
	506		

[1] Regression linear.
[2] Regression non-linear.

* 2 ounces.

** 2 1/12 ounces.

LIMITED TRAPNESTING FOR ESTIMATING AGE AT FIRST EGG

Age at first egg is recognized as having an important association with egg production. For pullets hatched during March and April, a reasonable approximation of age at sexual maturity may be secured by trapnesting through the month of October.

Of the total population of 1684 pullets, 1268 or about 75 percent laid some eggs during October. The mean number of eggs laid was 16.6 and the mean age at first egg was 187 days. The correlation between the number of eggs laid in October and age at first egg was $-.4619 \pm .0149$, with slight deviation from linear regression. The correlation ratio was .4853.

The regression of age at first egg on October production is recorded in Table 9. The estimates agree closely with the actual ages. The data indicate that any bird that laid any eggs during October is likely to fall below the limit of 216 days at sexual maturity. It would be reasonably safe, therefore, for the breeder to classify birds that failed to begin laying in October as late in sexual maturity.

TABLE 9.—LIMITED TRAPNESTING AS A MEANS OF ESTIMATING AGE AT FIRST EGG.

C. Regression[2] of Age at First Egg on October Egg Record.

October Egg Record	Number of Birds	Age at First Egg	
		Estimated	Actual
1 – 2	77	198.12	197.75
3 – 4	76	196.62	193.05
5 – 6	75	195.12	193.30
7 – 8	70	193.62	194.07
9 – 10	61	192.12	189.75
11 – 12	68	190.62	192.59
13 – 14	74	189.12	192.88
15 – 16	80	187.62	189.75
17 – 18	81	186.12	189.44
19 – 20	106	184.62	185.54
21 – 22	97	183.12	184.91
23 – 24	117	181.62	180.31
25 – 26	125	180.12	178.74
27 – 28	92	178.62	177.22
29 – 30	56	177.12	175.21
31	13	176.00	175.27
	1268		

[2] Regression not strictly linear.

LIMITED TRAPNESTING FOR ESTIMATING INTENSITY

Winter Clutch Size

The relation of intensity to egg weight and egg production has been reported by Hays (1944) and need not be reconsidered here. Suffice it to say that winter clutch size is a very satisfactory measure of intensity and that intensity is one of the most important inherited characters affecting egg production. In order to breed successfully for increased egg production, it is necessary to select for high intensity, and intensity can only be recorded by trapnesting. It therefore becomes very important to learn what information on intensity may be secured by limited trapnesting.

The five short-time measures already used were studied to determine their value for estimating winter clutch size, with results shown in Tables 10 and 11.

Three methods of limited trapnesting were found to give a good estimate of winter clutch size: trapnesting the first two days of each month from October through February; trapnesting the first week of each month from October through February; and trapnesting daily from first egg to January 1. Trapnest records for October at the beginning of the year and for August at the end of the year did not furnish dependable criteria of winter clutch size.

Table 10.—The Value of Limited Trapnesting for Estimating Winter Clutch Size.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Winter Clutch Size Estimated	Winter Clutch Size Actual	Accuracy Percent
A. First 2 days of each month, Oct.–Feb. (10 days)	1676	.4001 ± .0138	3.31	3.25	98
B. First week of each month, Oct.–Feb. (35 days)	1683	.4857 ± .0126	3.13	3.24	97
C. Daily, October only (31 days)	1432	.2371 ± .0168	*		
D. Daily, August only (31 days)	1595	.1554 ± .0165	*		
E. Daily from first egg to Jan. 1	1683	.3911 ± .0139	3.47	3.24	93

* Regression was so definitely non-linear that figures calculated from a straight-line formual were obviously inaccurate.

Spring Clutch Size

Large clutch size in March, April, and May is important in a laying flock. It is desirable, therefore, to determine the usefulness of limited trapnest records for estimating spring intensity. Results obtained by the five methods employed are shown in Tables 12 and 13.

In general, for estimating the probable spring clutch for the months of March, April and May, the types of limited trapnesting may be rated as follows: A trapnest record for the first week of each month is most accurate, followed closely by trapnest records on the first two days of each month. The August trapnest record at the close of the laying year also gives a good measure of previous spring

TABLE 11.—LIMITED TRAPNESTING AS A MEANS OF ESTIMATING WINTER INTENSITY (CLUTCH SIZE).

A. Regression[1] of Winter Clutch Size on 10-day Egg Record (First 2 days each month, Oct. through Feb.)

10-Day Egg Record	Number of Birds	Winter Clutch Size: Estimated	Winter Clutch Size: Actual
1	30	1.9	2.1
2	86	2.2	2.3
3	157	2.5	2.4
4	279	2.8	2.8
5	354	3.2	3.2
6	338	3.5	3.4
7	225	3.8	3.9
8	132	4.1	4.1
9	61	4.4	4.4
10	14	4.7	4.3
	1676		

B. Regression[1] of Winter Clutch Size on 35-day Egg Record (First week each month, Oct. through Feb.)

35-Day Egg Record	Number of Birds	Winter Clutch Size: Estimated	Winter Clutch Size: Actual
1– 5	24	1.3	1.9
6–10	97	1.9	2.1
11–15	330	2.5	2.5
16–20	561	3.1	3.1
21–25	459	3.7	3.7
26–30	199	4.3	4.4
31–35	13	4.9	5.8
	1683		

C. Regression[2] of Winter Clutch Size on 31-day Egg Record (October only)

31-Day Egg Record	Number of Birds	Winter Clutch Size: Estimated	Winter Clutch Size: Actual
1– 2	84	2.7	2.7
3– 4	89	2.7	3.2
5– 6	89	2.8	3.2
7– 8	79	2.9	2.8
9–10	65	3.0	2.9
11–12	76	3.1	3.1
13–14	83	3.1	3.1
15–16	93	3.2	3.2
17–18	93	3.3	3.0
19–20	120	3.4	3.0
21–22	109	3.5	3.1
23–24	136	3.5	3.2
25–26	136	3.6	3.4
27–28	104	3.7	3.9
29–30	62	3.8	4.8
31	14	3.8	6.5
	1432		

D. Regression[2] of Winter Clutch Size on 31-day Egg Record (August only)

31-Day Egg Record	Number of Birds	Winter Clutch Size: Estimated	Winter Clutch Size: Actual
1– 2	68	2.8	3.0
3– 4	70	2.9	2.8
5– 6	92	2.9	3.0
7– 8	83	3.0	3.2
9–10	96	3.1	3.1
11–12	97	3.1	3.2
13–14	116	3.2	3.1
15–16	149	3.2	3.0
17–18	139	3.3	3.2
19–20	175	3.4	3.2
21–22	206	3.4	3.1
23–24	143	3.5	3.5
25–26	93	3.5	4.0
27–28	46	3.6	4.2
29–30	20	3.7	4.2
31	2	3.7	3.5
	1595		

E. Regression[1] of Winter Clutch Size on Egg Record to Jan. 1

Egg Record to Jan. 1	Number of Birds	Winter Clutch Size: Estimated	Winter Clutch Size: Actual
1– 10	5	1.7	2.1
11– 20	30	2.0	2.2
21– 30	90	2.3	2.3
31– 40	207	2.6	2.6
41– 50	307	2.9	2.8
51– 60	331	3.2	3.3
61– 70	284	3.5	3.5
71– 80	205	3.8	3.8
81– 90	119	4.1	3.9
91–100	70	4.4	4.4
101–110	27	4.7	4.3
111–120	5	5.0	4.7
121–130	3	5.3	4.8
	1683		

[1] Regression linear.

[2] Regression non-linear.

clutch size. Trapnesting from the first egg to January 1 gives only an approximation of probable subsequent spring clutch size, while the trapnest record in October at the beginning of the year has no value for predicting spring intensity.

TABLE 12.—THE VALUE OF LIMITED TRAPNESTING FOR ESTIMATING SPRING CLUTCH SIZE.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Correlation Ratio
A. First 2 days of each month, Oct.–Sept. (24 days)	1459	.3868 ± .0150	
B. First week of each month, Oct.–Sept. (84 days)	1459	.4361 ± .0143	
C. Daily, October only (31 days)	1266	.0560 ± .0189	.2031
D. Daily, August only (31 days)	1373	.3177 ± .0164	.4132
E. Daily from first egg to Jan. 1	1458	.0835 ± .0175	

Summer Clutch Size

Egg production during June, July, and August has an important bearing on the annual record, according to the work of a number of investigators. Summer intensity may be measured in a number of ways, and mean clutch size is reasonably satisfactory. Summer intensity should be given due consideration by the breeder and the value of limited trapnesting for this purpose requires attention.

Results obtained by the five methods employed are presented in Tables 14 and 15. However, the regression of summer clutch size on October egg production, and on egg production to January 1 was not calculated because of the lack of correlation found.

TABLE 14.—THE VALUE OF LIMITED TRAPNESTING FOR ESTIMATING SUMMER CLUTCH SIZE.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Correlation Ratio
A. First 2 days of each month, Oct.–Sept. (24 days)	1451	.4403 ± .0143	
B. First week of each month, Oct.–Sept. (84 days)	1451	.4965 ± .0133	.5181
C. Daily, October only (31 days)	1259	.0087 ± .0190	.1707
D. Daily, August only (31 days)	1375	.5446 ± .0128	.6383
E. Daily from first egg to Jan. 1	1450	.0949 ± .0176	

TABLE 13.—LIMITED TRAPNESTING AS A MEANS OF ESTIMATING SPRING INTENSITY (CLUTCH SIZE).

A. Regression[1] of Spring Clutch Size on 24-Day Egg Record (First 2 days of each month)

24-Day Egg Record	Number of Birds	Spring Clutch Size Estimated	Spring Clutch Size Actual
3– 4	6	1.2	1.8
5– 6	36	1.8	2.2
7– 8	71	2.3	2.4
9–10	146	2.8	3.1
11–12	257	3.4	3.4
13–14	318	3.9	3.8
15–16	341	4.5	4.5
17–18	200	5.0	5.3
19–20	69	5.5	6.3
21–22	15	6.1	5.1
	1459		

B. Regression[1] of Spring Clutch Size on 84-Day Egg Record (First week of each month)

84-Day Egg Record	Number of Birds	Spring Clutch Size Estimated	Spring Clutch Size Actual
16–20	5	1.1	1.7
21–25	36	1.6	1.9
26–30	54	2.1	2.3
31–35	90	2.6	2.8
36–40	163	3.1	3.0
41–45	210	3.6	3.4
46–50	290	4.1	3.8
51–55	236	4.6	4.5
56–60	226	5.1	5.0
61–65	114	5.6	6.0
66–70	31	6.1	7.0
71–75	4	6.6	7.7
	1459		

D. Regression[2] of Spring Clutch Size on 31-Day Egg Record (August only)

31-Day Egg Record	Number of Birds	Spring Clutch Size Estimated	Spring Clutch Size Actual
1– 2	63	2.6	3.1
3– 4	65	2.8	2.9
5– 6	83	3.0	3.5
7– 8	76	3.2	3.7
9–10	85	3.4	3.5
11–12	90	3.7	3.4
13–14	105	3.9	3.7
15–16	124	4.1	3.5
17–18	118	4.3	4.4
19–20	145	4.5	4.1
21–22	173	4.8	4.2
23–24	118	5.0	4.8
25–26	75	5.2	5.7
27–28	33	5.4	7.2
29–30	18	5.6	9.5
31	2	5.8	5.5
	1373		

E. Regression[1] of Spring Clutch Size on Egg Record to Jan. 1

Egg Record to Jan. 1	Number of Birds	Spring Clutch Size Estimated	Spring Clutch Size Actual
1– 10	4	3.5	6.0
11– 20	23	3.6	3.5
21– 30	79	3.7	3.6
31– 40	171	3.8	3.8
41– 50	261	3.9	3.7
51– 60	295	4.0	4.1
61– 70	252	4.1	4.2
71– 80	182	4.2	4.6
81– 90	101	4.3	4.0
91–100	58	4.4	4.4
101–110	25	4.5	4.0
111–120	5	4.6	5.7
121–130	2	4.7	3.0
	1458		

[1] Regression linear.

[2] Regression non-linear.

TABLE 15.—LIMITED TRAPNESTING AS A MEANS OF ESTIMATING SUMMER INTENSITY (CLUTCH SIZE).

A. Regression[1] of Summer Clutch Size on 24-Day Egg Record (First 2 days of each month)				B. Regression[2] of Summer Clutch Size on 84-Day Egg Record (First week of each month)				D. Regression[2] of Summer Clutch Size on 31-Day Egg Record (August only)			
24-Day Egg Record	Number of Birds	Summer Clutch Size: Estimated	Summer Clutch Size: Actual	84-Day Egg Record	Number of Birds	Summer Clutch Size: Estimated	Summer Clutch Size: Actual	31-Day Egg Record	Number of Birds	Summer Clutch Size: Estimated	Summer Clutch Size: Actual
3–4	6	0.8	1.8	16–20	5	0.7	1.7	1–2	63	1.3	2.0
5–6	36	1.3	1.8	21–25	35	1.1	1.6	3–4	65	1.6	1.9
7–8	67	1.7	1.8	26–30	49	1.5	1.9	5–6	84	1.8	2.0
9–10	142	2.2	2.3	31–35	88	1.9	2.0	7–8	76	2.1	2.3
11–12	256	2.6	2.4	36–40	162	2.3	2.2	9–10	85	2.3	2.5
13–14	319	3.0	2.9	41–45	210	2.7	2.5	11–12	90	2.6	2.3
15–16	340	3.5	3.5	46–50	290	3.1	2.9	13–14	105	2.9	2.8
17–18	201	3.9	4.1	51–55	236	3.5	3.4	15–16	124	3.1	2.7
19–20	69	4.4	4.3	56–60	227	3.9	3.7	17–18	118	3.4	3.1
21–22	15	4.8	5.2	61–65	114	4.3	4.6	19–20	145	3.6	3.0
				66–70	31	4.7	5.8	21–22	173	3.9	3.6
				71–75	4	5.1	5.4	23–24	118	4.2	4.1
								25–26	76	4.4	5.1
								27–28	33	4.7	5.8
								29–30	18	4.9	8.1
								31	2	5.1	8.0
	1451				1451				1375		

[1] Regression linear

[2] Regression non-linear

For predicting summer clutch size, trapnesting on the first two days of each month probably is the most satisfactory, with trapnesting one week each month and August trapnesting of about equal value. Trapnesting in October at the beginning of the year or from first egg to January 1 cannot be used to predict summer intensity.

Fall Clutch Size

Various types of limited trapnesting may be tested for predicting possible fall clutch size during September and October. The importance of heavy fall production has been fully emphasized by many students of the problem.

All five of the methods used in this study were employed to determine their value for estimating fall clutch size, with results given in Tables 16 and 17. No correlation was shown for October and only very slight correlation for production to January 1; therefore no regression tables are given for these two measures.

Of the types of limited trapnesting studied, records for the first week of each month are the most accurate for predicting fall intensity. Trapnesting two days of each month is also useful, and August records at the close of the first laying year have considerable value. October records at the beginning of the year and complete trapnest records from first egg to January 1 have no value for predicting fall clutch size.

TABLE 16.—THE VALUE OF LIMITED TRAPNESTING FOR ESTIMATING FALL CLUTCH SIZE.

Kinds of Limited Trapnesting	Number of Birds	Correlation Coefficient	Correlation Ratio
A. First 2 days of each month, Oct.–Sept. (24 days)	1289	$.2249 \pm .0178$	
B. First week of each month, Oct.–Sept. (84 days)	1289	$.2551 \pm .0176$	
C. Daily, October only (31 days)	1119	$-.0093 \pm .0202$	
D. Daily, August only (31 days)	1264	$.2991 \pm .0173$	.4025
E. Daily from first egg to Jan. 1	1288	$.0761 \pm .0187$	

Table 17.—Limited Trapnesting an a Means of Estimating Fall Intensity (Clutch Size).

A. Regression[1] of Fall Clutch Size on 24-Day Egg Record (First 2 days of each month)				B. Regression[1] of Fall Clutch Size on 84-Day Egg Record (First Week of each Month)				D. Regression[2] of Fall Clutch Size of 31-Day Egg Record (August only)			
24-Day Egg Record	Number of Birds	Fall Clutch Size		84-Day Egg Record	Number of Birds	Fall Clutch Size		31-Day Egg Record	Number of Birds	Fall Clutch Size	
		Estimated	Actual			Estimated	Actual			Estimated	Actual
3–4	3	1.3	1.5	16–20	4	1.3	2.0	1–2	34	1.5	1.8
5–6	25	1.5	1.8	21–25	19	1.4	1.6	3–4	48	1.6	1.8
7–8	48	1.6	1.6	26–30	32	1.6	1.6	5–6	71	1.7	1.7
9–10	113	1.8	2.0	31–35	66	1.7	1.8	7–8	64	1.8	1.9
11–12	212	2.0	1.9	36–40	132	1.9	1.9	9–10	77	1.9	2.0
13–14	293	2.2	2.1	41–45	183	2.0	2.0	11–12	85	2.0	1.8
15–16	317	2.4	2.3	46–50	258	2.2	2.1	13–14	95	2.1	2.1
17–18	195	2.5	2.6	51–55	231	2.3	2.3	15–16	118	2.2	2.0
19–20	68	2.7	3.0	56–60	219	2.5	2.4	17–18	114	2.3	2.2
21–22	15	2.9	2.3	61–65	110	2.6	2.8	19–20	141	2.4	2.1
	1289			66–70	31	2.8	3.5	21–22	173	2.5	2.2
				71–75	4	2.9	2.5	23–24	117	2.6	2.6
					1289			25–26	74	2.7	3.0
								27–28	33	2.8	4.1
								29–30	18	2.9	4.4
								31	2	3.0	2.5
									1264		

[1] Regression linear

[2] Regression non-linear

LIMITED TRAPNESTING FOR ESTIMATING DURATION OF WINTER PAUSE

Probably the only type of limited trapnesting that will give information on length of winter pause is continuous trapnesting from first egg to January 1. In this report only birds with a pause of eight or more days between November 1 and March 1 are considered. There was a population of 714 which gave a correlation between egg production and pause duration of $-.2111 \pm .0241$. Regression was non-linear and the correlation ratio was .2954. This is a rather significant negative correlation which is somewhat spurious.

The regression of pause duration on production to January 1 was calculated, and predicted and actual pauses are recorded in Table 18. The estimates agree rather well with the actual length of pause, except for the very low producing birds. For practical purposes, trapnest records up to January 1 should be useful in reducing the length of winter pauses.

TABLE 18.—LIMITED TRAPNESTING AS A MEANS OF ESTIMAT NG DURATION OF WINTER PAUSE.

E. Regression[2] of Pause Duration on Production to January 1.

Winter Egg Record	Number o Birds	Duration of Winter Pause	
		Estimated	Actual
1 – 10	4	46.7	62.5
11 – 20	19	44.6	56.7
21 – 30	58	42.5	47.2
31 – 40	108	40.4	39.4
41 – 50	154	38.3	36.2
51 – 60	110	36.2	33.1
61 – 70	108	34.1	35.4
71 – 80	85	32.0	30.3
81 – 90	41	29.9	34.9
91 – 100	17	27.8	27.8
101 – 110	7	25.7	28.2
111 – 120	3	23.6	29.2
	714		

[2] Regression was not linear.

LIMITED TRAPNESTING FOR ESTIMATING PERSISTENCY

Workers generally agree that high production near the end of the first laying year is one of the most important characters of a heavy layer. Knox, Jull and Quinn (1935) recommended August and September production as one of the best measures of persistency. Lerner and Taylor (1937) found age at last egg to be a reliable measure of persistency.

At the Massachusetts Station annual persistency has been measured by the number of days from first pullet egg to the cessation of laying within 365 days. Biological persistency has been measured by the number of days from first egg to the cessation of laying associated with annual molt. Of the five types of partial trapnesting, August records should have value for predicting both types of persistency.

Annual Persistency

In a population of 1375, the simple correlation between August production and annual persistency was .2907 ± .0167, but regression was non-linear. The correlation ratio was .3473. These values are of considerable significance, and the regression coefficient has been used for estimating persistency in Table 19. The estimated values agree very well with actual values, indicating that August trapnest records should give valuable information on annual persistency.

Table 19—Limited Trapnesting as a Mean of Estimating Persistency.

Regression[2] of Annual Persistency on (D) August Production				Regression[1] of Length of Biological Year on (D) August Production			
August Egg Record	Number of Birds	Annual Persistency		August Egg Record	Number of Birds	Length of Biological Year	
		Estimated	Actual			Estimated	Actual
1– 2	63	323.6	304.2	1– 2	12	356.8	352.2
3– 4	65	326.3	320.5	3– 4	13	359.2	337.8
5– 6	84	329.0	324.7	5– 6	20	361.6	353.5
7– 8	76	331.7	340.4	7– 8	20	364.0	372.5
9–10	85	334.4	343.8	9–10	23	366.4	380.3
11–12	90	337.0	343.5	11–12	18	368.7	373.3
13–14	105	339.7	343.7	13–14	34	371.1	376.7
15–16	124	342.4	346.1	15–16	48	373.5	368.4
17–18	118	345.1	348.4	17–18	47	375.9	381.7
19–20	145	347.8	346.9	19–20	56	378.3	379.1
21–22	173	350.4	350.2	21–22	83	380.6	379.0
23–24	118	353.1	349.8	23–24	66	383.0	380.3
25–26	76	355.8	348.9	25–26	38	385.4	385.5
27–28	33	358.5	353.1	27–28	19	387.8	387.6
29–30	18	361.2	355.7	29–30	17	390.2	387.9
31	2	363.2	359.0	31	1	392.0	405.5
	1375				515		

[1] Regression linear. [2] Regression non-linear.

Length of Biological Year

In a population of 515, the correlation between August production and length of the biological year was .2270 ± .0282, with linear regression. The magnitude of this constant would indicate an important association. Regression of length of biological year on August production was calculated, and estimated and actual persistency are set down in Table 19. The estimates agree very well with the actual length of the biological year. These data, together with those in the previous section, indicate that August egg records furnish valuable information on persistency.

SUMMARY

This report includes the first-year records of 1684 Rhode Island Red females hatched from 1936 to 1942. This stock has been bred since 1916 for characters associated with high fecundity. All birds were trapnested from their first pullet egg for a full year. Several different types of limited trapnesting and egg weighing have been applied to these data to test their accuracy for predicting the true record: A, the first two days of each month for varying periods; B, the first week of each month for varying periods; C, daily in October at the beginning of the year; D, daily in August at the end of the year; and E, daily from the first egg to January 1. The value of these limited records has been considered for estimating annual egg production, egg weight to January 1, hatching-season egg weight, annual egg weight, age at first egg, intensity (winter, spring, summer, and fall clutch size), winter pause duration, and annual and biological persistency.

From these data, the following conclusions have been drawn:

1. An accurate estimate of the probable annual egg production can be made by trapnesting two days each month or the first week of each month for twelve months, or daily for the month of August. Trapnesting daily from first egg to January 1 furnishes dependable information, but is not so accurate as the preceding for predicting annual production. Trapnesting during October does not furnish a reliable criterion of annual production.

2. Mean egg weight to January 1 can be predicted with a high degree of accuracy from either two-day weighings or one-week weighings in October, November, and December or from daily weighings in October.

3. An estimate of hatching-season (March) egg weight can be made with considerable accuracy from weights taken on the first two days or in the first week of October, November, and December or from weights taken daily from first egg to January 1. Egg weights taken daily in October are not entirely satisfactory for estimating hatching-season egg weight.

4. Annual egg weight may be closely estimated by weighing the eggs on the first two days of each month or during the first week of each month, daily in August, or daily from the first pullet egg to January 1. Estimates based on egg weights taken daily in October were not reliable.

5. Age at first egg may be estimated rather satisfactorily by trapnesting daily in October at the beginning of the laying year, if the birds are hatched in March and April.

6. Trapnesting for the first two days of each month or for the first week of each month from October through February gives a reasonable measure of winter intensity, as does daily trapnesting from the first pullet egg to January 1. Complete October or August records do not give a very accurate measure of winter intensity. Trapnest records made on the first week of each month or on the first two days of each month, or daily in August at the end of the year may be used for estimating spring intensity, and are also satisfactory for estimating summer and fall intensity.

7. Daily trapnesting to January 1 affords a good measure of winter pause duration.

8. Trapnesting daily in August affords a rather satisfactory measure of persistency.

9. Limited trapnest records do furnish much valuable information, but in an advanced breeding program they are much less valuable than complete trapnest records.

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4M—2-47-25383.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 439 JULY 1947

Clearing and Improvement of Farm Land in Massachusetts

By Charles R. Creek, Joseph F. Hauck
and Virgil L. Hurlburt

The primary purposes of this study have been to appraise the methods used in land improvement, to evaluate the results in terms of cost-benefit comparisons, and to study the significance of land reclamation for the future of agriculture in Massachusetts.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

CLEARING AND IMPROVEMENT OF FARM LAND IN MASSACHUSETTS

By Charles R. Creek, Assistant Research Professor of Farm Management, Joseph F. Hauck[1] and Virgil L. Hurlburt[2]

INTRODUCTION

Since 1940 an increasing number of Massachusetts farmers have made use of heavy equipment to improve farm lands. Power machines, such as the bulldozer and the gas shovel, have made possible the completion of tasks that were impossible with hand tools and the usual farm machinery. In most instances improvement work has been limited to a few acres on an established farm, but in a few cases whole farms have been developed on land that had been abandoned for many years. By land reclamation the acreage of cropland, orchard, pasture, and poultry range has been increased, fields have been enlarged, and obstructions that have interfered with intensive use of land have been removed. In addition, drainage of lowlands has increased the acreage of crop and pasture land.

Some of the land improvement work in recent years has been done at high cost per acre. However, tasks that formerly were costly in terms of human labor now often require only a few hours with power equipment. Savings in time and man labor have paid for use of the machinery. The increase in land improvement activity raises many questions in the minds of farmers and of farm leaders. On what kinds of land will improvement work pay for itself? What are the least expensive and the most effective methods? What other possibilities are there of increasing the size and the operating efficiency of a farm? What factors must be considered by the landowner in deciding whether or not to undertake the particular task of clearing? Is it sound agricultural policy to encourage farm land improvement when in the same community other farm lands are going out of agricultural use?

During the summer of 1945 and early in 1946 a number of farmers who had made land improvements were interviewed. Data were obtained on the kinds and amounts of work performed, the time and the charges for heavy equipment, the costs of the job, and past and intended use of the land. The owners or operators of bulldozers and power shovels who were doing the work, by the job or at a specified rate per hour, were also interviewed. The summarization and presentation of these data may serve as guides to other land owners who are contemplating land improvement work.

In this study attention has been devoted to use of heavy equipment and power machinery which is not usually found on the farm. The physical methods of land improvement[3] have been appraised generally in the course of the study and attention necessarily has been devoted to engineering problems. However, interest and analysis have been concentrated upon the economic significance of this work. The primary purposes behind the study as a whole have been to appraise the methods used in farm land improvement, to examine the results in

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[3]The terms "land improvement," "land reclamation," and "land clearing" are used in this report to denote methods used and types of activity.

terms of cost-benefit comparisons, and to study the significance of land reclamation for the future of agriculture in Massachusetts.

The methods employed in land improvement work in Massachusetts in recent years are quite different from such activity a century ago. The economic setting and the outlook for the future have changed. A hundred years ago farming was a much larger part of the whole economy. There were relatively fewer other opportunities and means of making a living. Also, farming was largely on a self-sufficing basis, with most of the essentials for living coming from the farm. It is another proposition to clear land and make a living in a complex exchange economy in which most of the requirements for living are obtained by purchase with money obtained from sale of farm products. Part of the larger change in outlook is indicated by the changes in number of farms, acreages in farms, and acreage of improved land.

According to the census of agriculture, there were 31,897 farms in Massachusetts in 1939 with a total of 837,632 acres of improved land, an average of 26 acres per farm. In 1849 there were 34,069 farms listed which contained 2,133,436 acres of improved land or 62 acres per farm. Changes in types of farming were largely responsible for this variation in improved acreage per farm. A larger number of intensive vegetable, small fruit, cash crop, and poultry farms with a limited acreage of improved land were listed in recent years of the census. An increase in the number of part-time farms has tended to reduce the average acreage per farm. The commercial dairy, cash crop, vegetable, and fruit farm of recent years contained a greater acreage of improved land than was indicated in the census for 1939.

From a regional and national point of view there is now sufficient land in farms to supply needed quantities of food and fiber. Future requirements for food probably can be met from increased production per acre. All farms will need to operate more efficiently. In many parts of the United States the future will undoubtedly mean fewer but larger farms. Larger economic units will be needed to support the people who make their living from farming. Likewise in Massachusetts, increasing the size of farm will mean fewer farms. If the adjustments in size of farm can be made only through expensive land improvement operations, it is all the more important that careful study be given to costs and probable returns, before the work is undertaken. It is also important to remember that what will work for the individual will not necessarily work for a group or for all the people in a town or a county.

The only data available on acreages of land improved by use of power equipment in recent years are a set of estimates. No accurate measurement or count

TABLE 1.—ESTIMATE OF FARM LAND IMPROVEMENT BY STATES, FOR 1940-44.

Type of Land Improvement	Unit	Mass.	Conn.	Vermont	R. I.	Maine*
Land cleared						
Timber and brush	acres	2,730	6,083	2,289	2,545	430
Stumps	acres	1,365	980	510	215	80
Boulders	acres	1,860	3,733	1,541	370	1,020
Fruit trees	acres	450	1,364	79	145	—
Other	acres	1,400	—	400	125	—
Land drained	acres	1,390	2,340	8,734	—	415
Total improved	acres	9,195	14,500	13,553	3,400	1,945
Stone walls removed	linear yards	10,100	30,666	7,330	3,000	1,600

* Estimates for Aroostook and York Counties in Maine.

has been made, but informed persons were contacted in many counties of five New England states, to obtain data on kinds and amounts of improvement work. Timber and brush removal were the most important kinds of land improvement work in Massachusetts, Connecticut, and Rhode Island. Drainage accounted for the greatest acreage of land improvement in Vermont because of the operations of Soil Conservation Districts for three years. Boulder and stump removal were important in Massachusetts, Connecticut, and Vermont, as was also the removal of stone walls to make larger fields. Approximately one-third of the land improvement work in these states in the five years 1940-44 was done in 1944 as farmer interest increased and farm income was available for the purpose. All of these types of land clearing were continued on farms in Massachusetts in 1945, and reclamation of wet lands by dynamiting ditches was increased by the Soil Conservation Districts.

Although data are not available year by year, farmers and machine operators agree that even during the war years, land improvement work expanded. There are several explanations, aside from the pressure of "food to win the war," and the long-time interest of progressive farmers in efficiency of operation. The higher farm incomes provided cash reserves that could be spent for land improvement. Owners of bulldozers and gas shovels were diverted from normal employment such as building work and road construction. Probably of more importance, however, it had been demonstrated that heavy equipment could perform the farm land improvement work effectively. The farmer who had enlarged a field, cleared off the boulders, or removed stone walls set an example for his neighbors. The use of heavy equipment for land improvement work was developed largely by the demonstration method on farms in Massachusetts.

When work was begun with the bulldozer or other equipment on the first farm in a community the operations were watched with considerable interest by neighboring farmers. As the work progressed and the speed, efficiency, and thoroughness of the operations were realized by other farmers, machines were hired for similar work on their farms. This means of expanding the area of land improvement work was particularly effective where field stones, boulders, and stone walls were removed. The thinning of young orchards and the removal of old trees to make way for replanting developed along this line with one grower in a community starting the method and others following his example. The results achieved by the Soil Conservation Districts in draining swamps and lowlands by blasting ditches also created considerable demand for this type of land reclamation work. The visual effect of seeded pasture, field crops, vegetables, and young orchards on land which was formerly covered with trees, brush, shrubs, stumps, or boulders convinced many farmers of the possibility of adding a few acres of land of a suitable soil type to their farm unit.

METHODS AND COSTS OF CLEARING AND IMPROVING LAND

Types of Equipment

A crawler or track type tractor with a *bulldozer blade* attached was the most widely used piece of heavy equipment for land improvement operations in Massachusetts. Various sizes and makes of these machines were used to remove stumps, boulders, and stone walls as well as to clear land of trees and brush and to grade soil to obtain level fields. The *grubber blade* with heavy teeth instead of the solid bulldozer blade reduced loss of topsoil in clearing operations. Soil shaken loose from roots sifted out between the teeth and was not piled with the debris of stumps and trees.

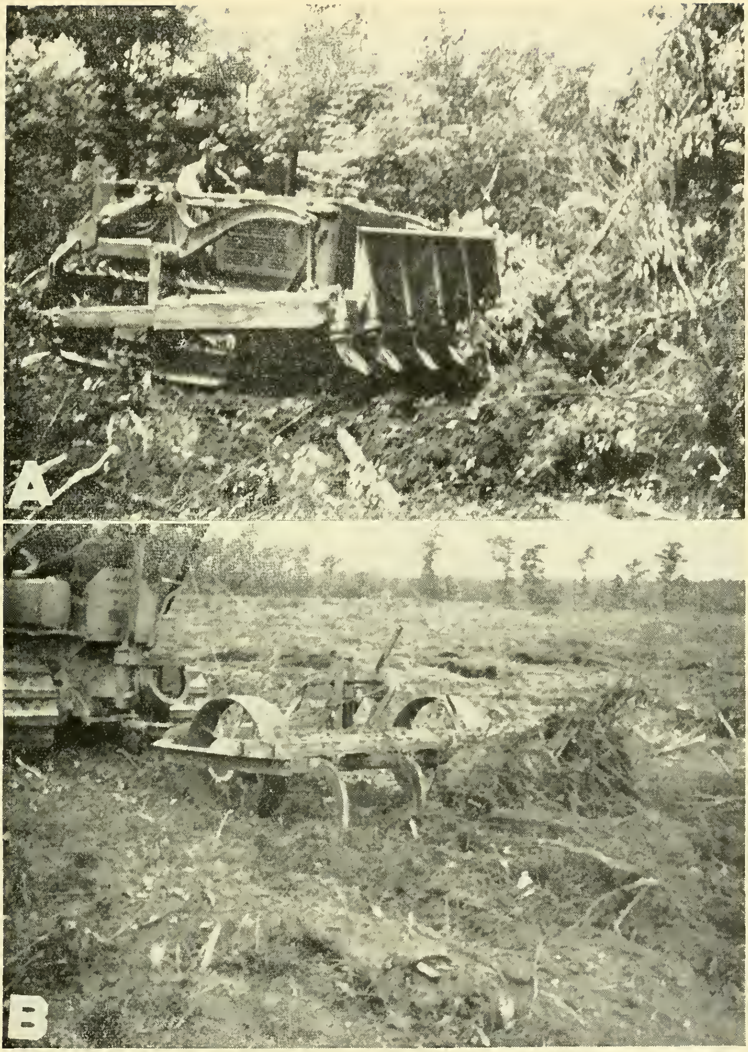

Figure 1.
A. Topsoil Is Saved when the Grubber Blade Is Used to Remove Brush and Trees.
B. Subsoil Tiller Brings Roots to the Surface after Cleared Land Is Turned with Brush-breaker Plow.

Large cutaway or *bog harrows* of the disk type were used to prepare land for seeding to grass and clover mixtures after boulders, trees, stumps, etc., were cleared with the bulldozer. In some cases such harrows were used after the land had been plowed, but in most instances the bog harrow was used instead of the plow to break up the new ground. A *disk harrow* was used to pulverize the soil and prepare a seedbed for pasture mixtures. Harrows were used instead of plows on land where large boulders and stumps were not removed.

Brush-breaker plows were used to turn over new land where brush, stumps, trees, and boulders had been cleared with bulldozers. Shrubs and bushes were plowed under with these heavy-duty plows, and roots, small stumps, and stones were turned up and removed. For vegetable crops and sometimes for potatoes a *deep tiller* was used to break up subsoil and to rake out stumps, roots, and stones not removed previously.

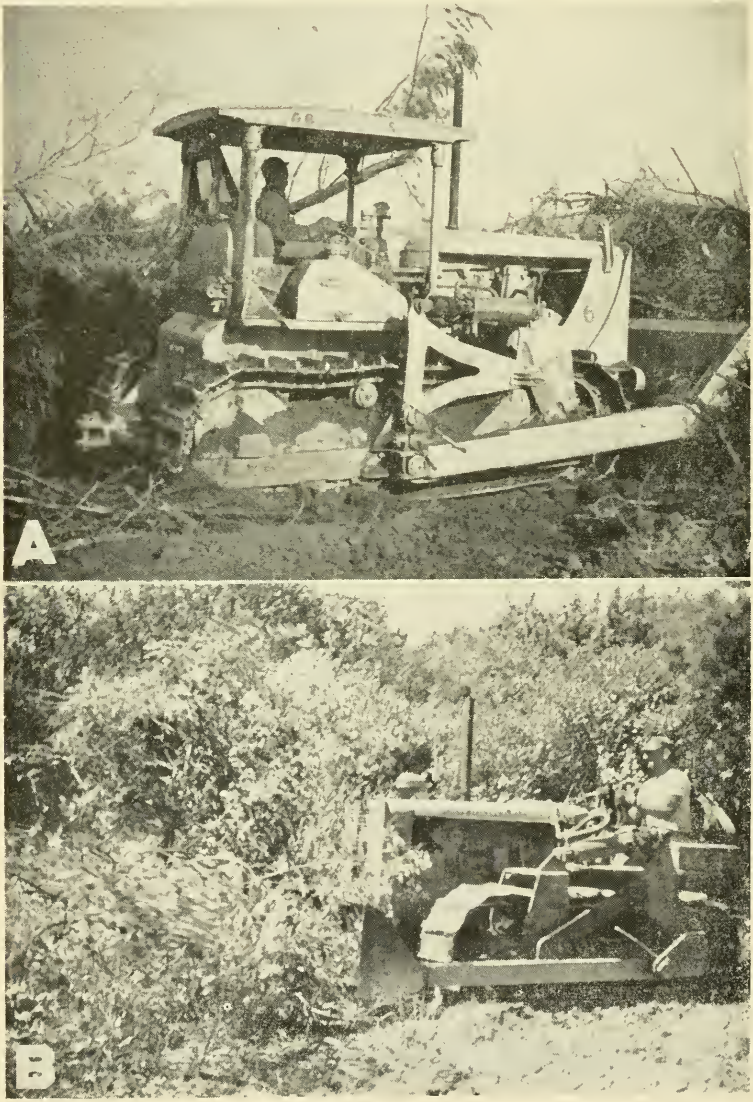

Figure 2.
A. Large Bulldozer Clearing Woodland for Orchard.
B. Bushes Are Removed with a Small Bulldozer.

Power shovels were used to dig drainage ditches and trenches where stone walls were to be buried. Shovels were also used to remove boulders and stumps and to load stone walls on trucks in cases where walls were hauled away. Some apple trees have been removed with small shovels, which were used also in the construction of cranberry bogs. Dragline excavators were used to remove topsoil from cranberry bog land and in digging drainage ditches on Soil Conservation District projects.

Other equipment which was used in various phases of land improvement activity included dump trucks, chain saws, and ordinary farm equipment such as tractors, plows, harrows, dumpcarts, and stoneboats.

Clearing Brush and Trees

Many areas of land with various combinations of brush and tree growth have been cleared in recent years for a variety of purposes. One of the first instances of woodland clearing with power machinery was on a tract of sandy loam soil for *vegetable crops*. Pine and deciduous trees to 18 inches in diameter, plus oak, birch, and brush were cleared from 300 acres with a bulldozer owned by the farmer. Trees were pushed out and cut for lumber and cordwood. Stumps and brush were piled in windrows with the bulldozer and burned. The land was then plowed to a depth of 15 inches with a brush-breaker plow, after which a deep tiller was used to bring roots and sticks to the surface to be picked up and hauled away. Costs of clearing this large area varied with the type of tree cover. Pine land was cleared more rapidly than oak or birch trees and brush. Costs were calculated at about $50 per acre to clear and plow pine land, and from $75 to $100 per acre for oak and hardwood cover of trees, stumps, and brush. One acre of scrub pine was cleared per day with the bulldozer but 12 to 15 hours were needed to remove the hardwood growth and stumps. Farm labor was used and the bulldozer was farmer owned, which reduced the cost per acre below contractor's charges for similar work.

Bulldozer costs for clearing deciduous trees and brush on a farm of upland stony loam soil for a new *apple orchard* ranged from $85 to $100 per acre plus $25 per acre for treatment and seeding to obtain a new sod for young trees. Costs were high because of the stony soil, the hardwood cover, and the thoroughness of the job. About 12 hours of bulldozer work per acre were needed in clearing this land.

In one case, woodland clearing at a contract price of $150 per acre for the bulldozer, gave poor results because the operator was not experienced in clearing for agricultural uses. Operations were stopped on another farm because too much topsoil was being removed with the brush and stones.

On farms where brush was cleared for *poultry range* and trees left for shade, the charges for bulldozer work were about $50 per acre. Where brush was cleared for seeded range or for pasture, the costs ranged from $45 to $100 per acre for bulldozer work and from $50 to $110 for total clearing. Woodland was cleared for orchards, vegetables, and cash crops at $85 to $150 per acre for the bulldozer work and about $10 per acre for picking up roots, sticks, and stones before the land was plowed. Costs of clearing for these crops were greater because a more thorough job was necessary in order to get the land in shape for plowing. Where pasture and poultry range were harrowed before seeding, less care was necessary in the clearing operations.

Clearing Shrubs and Bushes

Land that had reverted to a cover of bushes and shrubs was cleared for pasture and crops in various areas in Massachusetts. Much of this acreage had been tillable cropland and pasture but had been abandoned when prices of farm products were low in the early 1930's. Higher prices for farm products, particularly milk and potatoes, have encouraged the reclamation of this land for hay, pasture, and crops.

In one instance pasture land which had reverted to juniper, hardhack, sheep laurel, and other shrubs was cleared with a medium-sized bulldozer at the rate of one acre per eight-hour day. Many boulders were pushed out as well as a few small trees on this stony loam soil. Debris was pushed into a swamp and stones were piled in a row as the base for a road to a woodlot. This land was too stony to be plowed so the seedbed was prepared by repeated harrowings. Roots, sticks, and stones were picked up between harrowings and then the land was limed, fertilized, and seeded with a mixture of Ladino clover and grass. The cash costs for the bulldozer were about $45 per acre and additional costs for labor, seed, fertilizer, and lime added another $45 so that an improved seeded pasture was obtained for about $90 per acre.

Figure 3.
Seeded Improved Pasture (right) Was Made from Rough Land (left) by Bog Harrow Treatment.

In other worn-out pastures which had reverted to shrubs and bushes, the land was improved by repeated use of a bog harrow. Juniper and other large shrubs were pulled with a tractor, chain, and special type of hook. In areas relatively free of stones the cover was cut with a heavy-duty mower before harrowing. Clearing of hardhack and sheep laurel cover with a bog harrow has been found satisfactory because the cover can be disked under and topsoil is not removed. Another method consisted of harrowing alder swamps with a bog harrow when the ground was frozen in order to break the stems and allow grazing of shoots the following season. When the land became dry enough to be harrowed and seeded, a fertilized pasture was available for long-season grazing.

Costs of these methods of renovating old pastures were difficult to obtain because farm equipment and farm labor were used in slack seasons. The cash expense for operating machinery, for wages of hired labor, and for seed, fertilizer, and lime ranged from $35 to $60 per acre for improving old pastures that had reverted to shrubs and bushes. The grazing capacity of such pastures varied with the type of soil, amount of fertilization, moisture available, and the mixture of grasses and legumes seeded. It is important to seed the combination of grasses and clovers adapted to soil and moisture conditions of the reclaimed land.

A considerable area of abandoned crop and hay land which had reverted to blueberries, shrubs, and bushes has been reclaimed in recent years for potato production, especially in the Berkshire Hills region. Brush and bushes were cut or pulled out and the smaller growth was plowed under with heavy brush-breaker plows and crawler-type tractors. In some fields the cover was light and potatoes were grown the same season, or the next season in the case of fall plowing. In some cases the land was harrowed several times the following season to kill sprouts before a crop of potatoes could be grown. Stones and roots were picked to facilitate the use of machinery in potato growing. Cash costs of reclaiming this land were relatively low—from $15 to $30 per acre.

Figure 4.
Hilltop Potato Field after Brush and Shrubs Were Cleared from Former Hay Land.

Removing Stumps

Clearing of stumpland for pasture and crops increased after the 1938 hurricane when many stands of pine trees were blown over. The use of bulldozers and gas shovels for this work had become common by 1944 and heavy equipment had been used to remove stumps on several farms as early as 1940. Costs were high in these early years because efficient methods of removal and disposal of stumps had not been learned. In one instance a gas shovel was used to lift out pine and oak stumps and pile them in windrows for burning at a total cost of $160 per acre. These stumps were too green to burn and the windrows had to be broken up to allow them to dry out before they could be burned. Labor, bulldozer, and fuel-oil costs of burning these stumps amounted to $60 per acre, cost of the gas shovel was $80 per acre, and bulldozer charges for grading land and pushing out boulders amounted to $20 per acre. The gas shovel has been more expensive than the bulldozer for stump removal and the latter machine has been necessary for leveling the land after the shovel had removed stumps

A typical example of stump removal for pasture occurred on a Connecticut Valley farm where 20 acres of pine and hardwood stumps were pushed out with a bulldozer and the land leveled at a cost of $58 per acre. Less than 10 hours was required per acre to remove these stumps, which ranged from one to two feet in diameter. Some were used to fill low, wet areas in the lot while others were piled

Figure 5.
A. Removing Stumps with Grubber Blade Saves Topsoil.
B. Pushing Out Stump with Grubber Blade.

in windrows to be burned. Topsoil was deep enough here so that the field was graded and the stumps were covered in low areas to make a 20-acre level pasture over former swampy woodland. Total costs including picking roots, harrowing, fertilizer treatment, and seeding were less than $100 per acre for a Ladino clover and grass pasture with high grazing capacity.

Records on 13 farms where 75 acres of stumpland were cleared with a bulldozer showed costs ranging from $30 to $125 per acre for the bulldozer. About 12 hours were required per acre to push out hardwood stumps and grade the land. Pine stumps were removed on sandy soils in 6 to 10 hours per acre at a cost of $30 to $50 per acre for the bulldozer, while costs for hardwood stumps on a stony heavy soil were nearer $100 per acre. The use of a power shovel to lift stumps and of trucks to haul them in addition to the grading work with the bulldozer increased total machinery costs to about $125 per acre for pine and hardwood stumps up to 30 inches in diameter. One advantage of using a shovel or clam shell bucket was that soil was shaken from the roots as the stumps were pulled. The grubber blade type of bulldozer was equally effective when stumps were pushed into swamps.

Pine stumps were cleared on sandy soil for seeded poultry range at costs ranging up to $100 per acre where considerable grading and brush removal was required. In another instance, pine stumps to two feet in diameter on heavy loam soil were pushed out by the bulldozer in 6.5 hours for $33 per acre. Stumps were hauled away in a stoneboat by the owner, the land was plowed and harrowed, roots were picked up, and a hayland mixture was seeded after fertilizer treatment. Total cash costs of clearing and seeding were less than $50 per acre.

Hurricane stumps and broken stubs were pulled with a farmer-owned crawler tractor and chain on ten acres of clay loam soil for $12 per acre. Total costs were about $25 per acre for piling stumps in a windrow, picking stones and roots, and harrowing with a bog harrow. The land surface was uneven where stumps had been pulled and on this wet soil the grass seeding had died out where water was standing. Total costs were about $50 per acre for a seeded fertilized pasture. On farms where labor and equipment are available, stumps on small acreages can generally be removed at less cost by the farm crew than by hiring a bulldozer or power shovel, but grading will not be so effective and more time is required.

Removing Stone Walls

Where stone wall removal has been undertaken, the purpose has usually been to combine several small fields into one large field for more efficient use of machinery. Three methods have been used by farmers in Massachusetts depending upon the crops to be grown, size of wall, equipment available, and soil conditions: (1) use of bulldozer alone, (2) combination of bulldozer and gas shovel, and (3) use of bulldozer, gas shovel, and dump trucks.

Costs usually were lowest where a bulldozer was used to make an "allweather road" from stonewalls. A shallow trench about 8 feet wide and 3 feet deep was scooped out along the wall and the stone wall was pushed into the trench. Stones were spread in a layer about one foot deep and covered with soil to make a drained roadway about one foot above the level of the surrounding land. This method of removing stone walls has been used in orchards to make roads to other blocks of trees and also to provide longer rows for spraying or dusting with larger machinery. Stone walls were buried in shallow trenches in pasture and hayland in many instances and the strip was seeded. On one farm the walls were pushed into a trench in a swampy spot to furnish drainage for seeded pasture. Costs of removing stone walls by the bulldozer working alone ranged from 75 cents to

$1.25 per linear yard of stone wall about 2 feet wide by 4 to 5 feet high. Charges for the bulldozer were less than $1 per linear yard in most cases. Costs varied according to size of wall, size of bulldozer, type of soil, distance stones were pushed, and time spent in grading.

One of the most common methods of taking out stone walls is the combined use of bulldozer and power shovel to bury the stones. A trench about 6 feet deep and 8 to 12 feet wide was dug along the wall by the shovel and the stone wall was pushed in by the bulldozer. In many cases the shovel was used to cover the stones with gravel and subsoil from the top of the pile of dirt. The

Figure 6.
A. Burying Stone from Wall in Trench Dug by Bulldozer.
B. Removing Stone Wall and Stumps with Power Shovel and Dump Trucks.

bulldozer then pushed the other soil into the trench and graded topsoil over a strip 10 to 20 feet wide. The stones generally were covered about three feet deep and topsoil was graded as the last operation so that grass and crops could be grown. In the wet season of 1945 no difference could be noticed in the growth of silage corn, potatoes, and hay on the strips where stone walls had been buried that spring and the previous fall. The cost of this method ranged from 85 cents to $1.10 per linear yard of ordinary stone walls 3 by 3 feet or 4 by 2 feet in size. Generally two-thirds of the total cost was for the shovel and one-third for the bulldozer. A smaller proportion of time was spent with the shovel, however, because in most cases the charge per hour was higher than for the bulldozer.

Another method of taking out stone walls, especially where there were stumps along the wall, combined the use of the power shovel, bulldozer, and dump trucks. The shovel was used to load the stones from the wall and any stumps in the fence row on trucks to be hauled to a swamp or other waste land and dumped. The bulldozer was used to pile loose stones for the shovel, to push stumps on the bucket for loading, to push stones and stumps into the swamp after they were dumped, and to fill and grade the trench left by the removal of the wall. Because more equipment was used in this method, costs were higher, ranging from $1.15 to $2.25 per linear yard of wall. The more costly job included one stump per rod and the work was done on wet ground so that considerable time was lost by all the equipment. Under normal operating conditions costs by this method should range from $1.00 to $1.50 per linear yard. The rates charged for equipment in 1945 and 1946 were $6 to $9 per hour for the power shovel, $5 to $8 per hour for the bulldozer, and $3.50 per hour for each truck and driver.

A method of stone wall removal was reported where a stoneboat about 5 by 12 feet in size and made of sheet steel was used to haul the stones. This stoneboat was drawn along the wall, the stones were pushed on by the bulldozer, the load was drawn to the edge of a swamp by the bulldozer, and the stones pushed off into the swamp. When the distance is short and a large load can be hauled, this method may be economical. Such equipment could be used to haul stones a short distance to fill low wet areas or ditches where topsoil had been pushed off. The drained area could be utilized for crops or pasture after topsoil was graded over the stones.

Removing Field Boulders

Boulders in the hay and crop fields on Massachusetts farms are serious obstacles to the use of machinery in planting, growing, and harvesting crops. In some cases larger boulders have been broken by "mudcapping" with dynamite and the fragments removed with a stoneboat. Crawler type farm tractors have been used to pull out small boulders, but this was a slow and laborious procedure.

The acre cost of removing boulders with the bulldozer varied widely depending upon the number and size of boulders, size of bulldozer, experience of operator, and method used. Records show that a small bulldozer for which the rate charged was $4 to $5 per hour required more than twice as much time to remove the same quantity of boulders as a large machine at $8 to $10 per hour.

In removing boulders with a bulldozer the most common procedure was to push the soil from two sides of the boulder so that the blade could be placed under the boulder for a lifting and pushing motion to roll it to the surface. Boulders were pushed into a swamp or into a row to make a rough stone wall around the field. Boulders that were too large to be pushed out were buried in holes dug by the bulldozer or shovel and where a stone wall was buried some field boulders were pushed in also. In a few cases large boulders were drilled and split with a charge of dynamite so that the bulldozer could push them out.

Figure 7.
A. Boulders Recently Pushed Out With a Bulldozer.
B. Pushing Boulders into a Wall at Edge of Field.

Cost of removing boulders as the first step in pasture improvement ranged from \$30 to \$120 per acre for the bulldozer charge with \$50 to \$70 the most common amount. Additional costs of picking smaller stones and broken fragments ranged from \$10 to \$25 per acre to make total costs of \$70 to \$90 per acre before the land was harrowed or plowed. The time required to remove boulders ranged from 12 to 15 hours per acre in most cases.

Costs of clearing rough stony land for row crops were \$20 to \$30 higher per acre because a more thorough job was necessary. Where a power shovel was used to dig a trench and a bulldozer to push stones into the trench and bury them, costs were over $200 per acre for the machinery. Boulder and stone removal was more expensive than stump, brush, or woodland clearing for comparable purposes.

In cases involving a few scattered boulders on hay or cropland the costs of removal ranged from $20 to $40 per acre for the bulldozer and $5 to $10 per acre for picking stones. In one instance about 100 boulders were removed from 8 acres of hayland at a cost of $17 per acre. Scattered boulders were removed from vegetable land in southeastern Massachusetts with a large bulldozer at a cost of $35 per acre on land with 25 boulders per acre. Disposal of boulders was sometimes a problem on crop fields since considerable space was needed around the field boundary for them. Generally there were swamps or areas of waste land into which the boulders could be pushed.

Figure 8.
Fruit Tree Being Pushed Out by Bulldozer.

Removing Apple Trees

Bulldozers and power shovels have been used to remove old apple trees to make space for new orchards and to thin bearing orchards by removing alternate rows of trees. Costs have ranged from 30 to 50 cents per tree for removal and in recent years the sale of cordwood has paid the cost of cutting and removal.

In one operation a 20-year orchard was thinned and 240 trees in alternate rows taken out with a large bulldozer in about 10 hours at a cost of 36 cents per tree. Cordwood was cut, the brush burned, and stumps hauled away on a stoneboat. More space and light were available for the remaining 27 trees per acre.

Old apple trees up to two feet in diameter were removed from a stony loam soil with a small power shovel at a cost of 40 cents per tree. The method used was to push the tree over with the bucket against the trunk about 10 feet off the ground. The bucket was then placed under the roots to lift the tree out. Trees were dropped once or twice to shake dirt from the roots. In this operation the shovel took out two rows of trees in one trip through the orchard and left them in a windrow. Sale of cordwood paid for the cost of tree removal, cutting wood, and hauling stumps to a swamp with a tractor and stoneboat. Trees in rows were pushed out with the bulldozer in 2½ minutes per tree, and by the power shovel in 4 minutes per tree. In the latter case, trees were older and larger. The bulldozer was easier to maneuver than the gas shovel and was more adaptable for removal of scattered trees. The land was graded after tree removal and trees were pushed out of the orchard in some instances. Soil was shaken from roots and sod was not torn up by tracks when the gas shovel was used.

Figure 9.
A. Blasting a Ditch Through Swampy Pasture Land.
B. Ditch Blasted in Heavy Wet Land

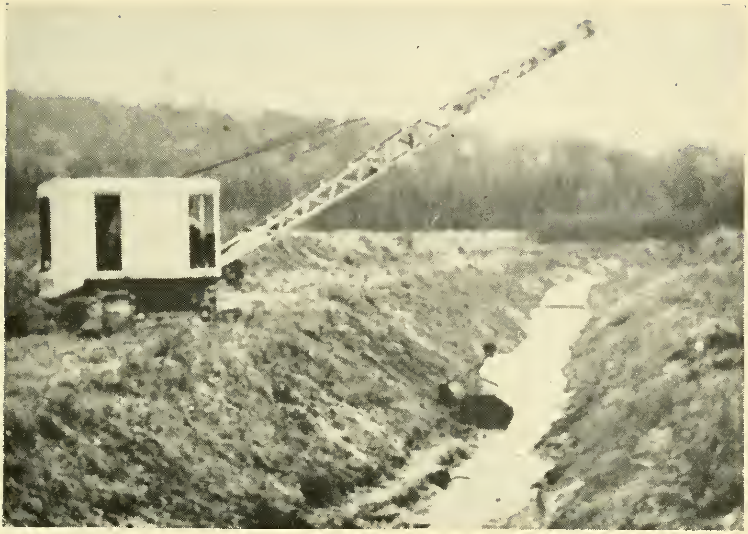

Figure 10.
Dragline Excavator Widening a Ditch on Soil Conservation District Drainage Project.

Drainage

The need for drainage of pasture, hay, or crop land has been a problem on practically every farm in Massachusetts. In many cases ditches and brooks have become so clogged with silt, grass, and weeds that water has backed up on pasture and crop land. Many acres of land have become unproductive and efficiency of farm operations has decreased because of the difficulty of using farm machinery on this wet land.

Restrictions on the sale and use of dynamite during wartime prevented the blasting of ditches for farm drainage and the cost of using power shovels was usually too great. However, records were obtained showing that ditches were dug at a cost of 10 to 15 cents per linear foot and drainage was provided at a cost of $15 to $25 per acre. In some cases insufficient drainage was obtained because of lack of cooperation by neighboring farmers in providing a proper outlet by continuing the ditch.

In the spring of 1946, the drainage program for land improvement gained considerable impetus when Soil Conservation Districts were organized and the blasting of ditches was begun under supervision of the district. Dynamite was purchased in ton lots to reduce the cost and a bonded operator was hired for blasting. The work has consisted chiefly of opening old ditches by blasting a deeper and wider channel. The quantity of dynamite used has depended upon the type of soil and the size of ditch needed to furnish sufficient drainage. A ditch about 10 feet wide and 5 feet deep was blasted through a sandy loam soil by placing a full stick of dynamite every 18 inches with a half stick between these. On the same soil a lateral ditch about 6 feet wide by 3 feet deep was blasted by placing one-half sticks at 15-inch intervals. Dynamite for the main ditch cost 10 cents per linear foot and for the lateral ditch 4 cents per foot. Total cost of blasting these ditches and the charge for a tractor and grader to open smaller ditches amounted to $20 per acre of cropland drained.

In another instance two neighbors cooperated with the Soil Conservation District to blast a ditch through a swamp. This ditch was almost completely filled with silt and coarse swamp grass. A channel 8 feet wide at the top and 3 feet deep was blasted by setting sticks of dynamite 15 inches apart. Twelve boxes of dynamite or 1200 sticks were set in this 1600-foot ditch by four men in 3½ hours. The blasts were made in 300-foot sections and the men worked in two crews setting dynamite from the ends of each section. Dynamite for this ditch cost $105, charges of the blaster for time, caps, and wire were $9, and labor at 50 cents per hour was $7. Total costs were about 8 cents per linear foot of ditch. The work was accomplished in less than half a day. Surface water had drained from 15 acres of swamp in two days and two acres of wet hayland were drained enough to be harvested.

Some of the advantages of blasting a ditch over digging with a power shovel were that cost was usually lower, less time was needed to obtain drainage, soil was scattered instead of piled along ditch, blasting was done in areas too wet to use shovel, and farm labor was used to set the dynamite instead of hiring extra labor.

Combinations of Improvement Activities

One of the most common combinations of land improvement activities was the removal of field boulders and stone walls on the same farm and at the same time. This occurred especially in southeastern Massachusetts on dairy and vegetable farms. In one such case 24 acres of land were cleared of boulders at a cost of $126 per acre for machinery plus $7 for picking stones. At the same time 500 linear yards of stone wall were buried in a low area of the pasture at a cost of $1 per yard. The stone wall removal increased the total cost per acre to $147 to obtain plowable pasture and cropland.

On another farm 630 yards of stone wall were removed from hayland and 6 acres of pine stumps were cleared with a combination of bulldozer, power shovel, and dump trucks. The walls were loaded on trucks and hauled away and the trench was graded at a total cost for machinery of $1.46 per linear yard. The stumps were pushed out by the bulldozer for $83 per acre. Loading with power shovel and hauling with trucks increased the cost to $118 per acre.

Without exception the woodland and brush clearing operations involved the removal of old stumps, particularly oak and chestnut. On the stony types of soil many boulders were removed at the same time, which partially accounted for the variation in costs per acre for clearing woodland. Stump and boulder removal were combined in a few instances and land was graded. In several cases of clearing land for pasture improvement a drainage program was needed, and conversely, much of the swamp land which was drained by blasting ditches was improved to make pasture.

Variations in Costs

The cost has varied per acre of land improved, yard of stone wall removed, foot of ditch blasted, and apple tree removed on these farms. Many of these variations in cost per unit can be reduced by using the most efficient and least costly method in future land improvement operations.

One of the more common reasons for differences in costs was the *size of bulldozer* used for the job, particularly in removing boulders and stone walls. Usually the smaller machines at a lower rate per hour removed boulders at greater costs per acre than larger bulldozers. An example of this variation in costs occurred in two separate clearing operations on one farm. Boulders were cleared from 10 acres in 1940 at a cost of $45 per acre with a large bulldozer at the rate of $9 per hour. Two years later a small machine at $5 per hour was used to remove boulders of similar size and number on an adjoining 14-acre field, and the cost was $164 per acre. The smaller machine could not push the largest boulders and costs were $20 per acre for drilling and blasting these large boulders into smaller pieces.

Stone walls were removed on this farm in these two years by the same machines with a similar cost relationship. A trench was dug with the larger machine, the stone wall pushed in, and topsoil graded over the stones at a total cost of 85 cents per linear yard. A wall in the adjoining field was buried by the smaller machine by the same methods at a cost of $1.20 per linear yard. The differences in cost per acre between large and small bulldozers were not as great for stump removal and clearing of woodland as for removing boulders and stone walls, but generally the larger machine with an experienced operator did the job at a lower cost.

Costs have also varied because of differences in *kinds of equipment and methods* of land improvement, especially in stone wall removal. In two cases where a stone wall was loaded on trucks with a power shovel and a bulldozer used to push stones and fill the trench, the costs were $1.75 per linear yard to remove the wall. Where walls of similar size were buried by the bulldozer in a trench dug by the power shovel, the costs were about $1 per yard. When the bulldozer was used to scoop a shallow trench in pasture or orchard and bury stone walls, the costs ranged from 65 cents to $1 per linear yard for walls of comparable size. It is questionable whether the latter method should be used to remove walls from cropland since the stones are covered with less than two feet of soil.

In the case of stump removal, the cost for machinery was about $115 per acre where a power shovel was used with either trucks to haul stumps or bulldozers to push them into piles. Where the stumps were pushed out and piled or buried by the bulldozer, the costs were about $80 per acre for similar stumps in the same type of soil. The bulldozer cost ranged from $40 to $100 per acre for removal of pine and hardwood stumps on sandy to stony loam soils.

The variation in costs of machinery because of differences in *amount of work done* in clearing was more difficult to measure. In the case of boulder removal for crop production, the costs for the bulldozer and for picking stones was $142 per acre on seven farms where 36 acres were cleared. The time required for the bulldozer was 25 hours per acre at $5 per hour. This land was formerly rough stony pasture and was cleared for hay, corn silage, and truck crops. On similar land where boulders were removed to improve the pasture, total costs for bulldozer and picking stones were $74 per acre on six farms for 38 acres of rough land. The time required was eight hours per acre at about $8 per hour. Scattered large boulders were removed from hayland and cultivated crop land for $28 per acre on five farms for 62 acres. Time required was only four hours per acre at about $6 per hour. Boulder removal was more thorough when crops were to be grown than when pasture was seeded. Stones were removed so that machinery could be used for plowing, planting, cultivating and harvesting. In the case of pasture the land was harrowed instead of being plowed and some of the largest boulders were not removed.

The same cost relationship was observed when stump or woodland was cleared for crops or for pasture. Stump land was cleared for pasture at about $65 per acre for machinery and hand labor for picking roots, but on similar land when cleared for cultivated crops the costs were about $80 because of more thorough removal of small stumps, roots, and sticks in order to plow and cultivate the land. When used for pasture the cleared land was usually harrowed, fertilized, and seeded without being plowed.

The comparative cost of any type of land improvement between machinery hired at a specified rate per hour or on a contract basis per unit was generally lower by the hourly rate particularly where woodland and brush were cleared. For example, rather heavy growth and stones were cleared on stony loam soil at $90 per acre at the hourly rate as contrasted to clearing of lighter growth on a sandy soil for a $125 per acre contract price. In the same way, stone wall removal with the bulldozer alone was contracted at $1 per linear yard while on a neighboring farm at the rate of $6 per hour the cost was 75 cents per yard to bury the wall. A contributing factor to these higher costs was the tendency of company farms and owners of rural estates to contract for their land improvement on a unit basis. Improvement work on commercial farms whether dairy, fruit, tobacco, or potato was more thoroughly planned and closely supervised than on the rural estates and costs were seldom excessive when measured against benefits accrued. A few instances were observed where land was cleared on a marginal type of soil at great expense and the cost could never be returned under any system of farm operation.

ECONOMICS OF LAND CLEARING AND IMPROVEMENT ON COMMERCIAL FARMS

The costs of land improvement work are usually high on an acre basis. Total costs per acre for an economic unit may be prohibitive when improvement costs are added to the other capital requirements in land, buildings, livestock, and equipment for a new farm. For the farmer who wants to expand his size of business, the economic venture may be justified in many instances. However, the question is not alone how much is the total cost; it is also what are the alternatives and the probable benefits. The costs of *not making* necessary adjustments may exceed the actual costs of improvement.

In another study, improvement in land utilization is designated as the field of adjustments in Massachusetts agriculture which promises the most profitable results. Many farms are inadequate in land resources, both as to area and as to quality. Rough terrain, stony soils, presence of boulders and stone walls, small fields, and improper drainage have delayed the mechanization which has proved to be profitable in other parts of the country. As Dr. Rozman states, "The fundamental problem remains one of consolidating the scattered fields, and

Table 2.—Requirements for Adjusting 100-139 Acre Farm to Standard One-Man Dairy Farm.

Standard* Land Requirements One-man Family-Type Dairy Farm	Acres	Present Farm Land Uses	Acres	Types of Improvement Needed	Costs
Hay land	25	Hay land	19	Shift 6 acres crop land to hay—stone wall removal	$200
Crop land	10	Crop land	16		
Improved pasture	10	Plowable pasture	15	Boulder and stone wall removal—$20 per acre	300
Open pasture	25	Other land	24	Clearing and stoning 20 acres for improved pasture—$25 per acre	500
Wood land	50	Woods	46	Stand improvement	....
Farmstead	5	Farmstead	5		
Total acres	125	Total acres	125	Total cost	$1,000

* Standards for Massachusetts Dairy Farms—Dept. Agr. Econ. and Farm Mgt.. Massachusetts State College.

where necessary, increasing the total amount of arable land on farms in order to obtain an efficient and economic family unit capable of using modern mechanical methods."[4]

In order to demonstrate the economic significance of adjustments in farm land utilization through clearing and improvement, a dairy farm in the 100-139 acre size group of the agricultural census was adjusted to the standard requirement for a one-man dairy farm. The necessary adjustments and costs are shown in Table 2. Boulders and stone walls were removed from crop and hay land for about $500. Other open pasture was cleared of occasional bushes and boulders for another $500 to furnish more improved pasture for a larger herd.

Much the same type of comparison could be made with poultry farms, to indicate the amount of improvement needed to develop poultry ranges. Also, standards might be set up for fruit farms, showing the amount of renovation and enlargement necessary on apple orchards; or for vegetable farms, to show the probable extent of clearing and improvement work needed to build an economic unit. Selected cases are presented to illustrate the effects on size, organization, and farm income where improvement work has been done. The majority of farms on which heavy equipment has been used for land clearing and improvement in recent years are above the average in acreage, livestock numbers, and volume of business. Many of the units are 2- or 3-man farms. Likewise, in the future most of the improvement will probably be done on the larger than average farms, to enable more efficient operations and to expand the volume of business.

There is no reliable source of data for estimating the acreage of land in the State on which it would pay to perform improvement work. The decisions in this respect must be made on an individual basis, measuring probable costs against probable benefits and considering alternatives. In many cases, the only possibility for increasing the size of unit is through land improvement, because no suitable land can be purchased.

Costs of land improvement through use of heavy equipment will need to be compared in individual instances with costs of expanding size of business through purchase of additional land. If adjoining fields can be acquired at reasonable prices and if this available land is well adapted to the use intended, purchase rather than improvement may well be the choice. On the other hand, if additional land is available only at a distance or at high prices per acre then purchase is undoubtedly the more expensive. The persons interviewed in this study were usually of the opinion that it was cheaper to spend money on lands within the boundaries of their farms than to purchase additional crop, pasture, or orchard lands.

The choice will depend upon the particular situation. The small farm with limited acreage will not be able to make extensive additions to cropland or pasture through land reclamation. If the farm is to be enlarged, purchase of more land is the only possibility. The larger farm, with a woodlot, a sizable tract or two of unimproved pasture land, or a swampy area—any one of which is potential crop or pasture land—may be able to do the improvement work just as economically as to buy more land.

Costs and Returns

In a majority of cases the costs of land improvement on the farms studied were paid from current earnings and accumulated savings. Whether funds were on hand or were borrowed each activity has to meet the test of the return that may result from the improvement. Capital invested in land improvement work

[4]Massachusetts Agricultural Experiment Station Bulletin 430, page 7.

Figure 11.
Insufficient Grazing on Stump Land.

is no different from capital invested in land or buildings. What are the benefits that have been realized or may be expected? How much does land improvement work affect income per acre treated, or income per farm? The results vary with the type of work done, the kind of land, and the use to which the land is devoted after the work is done. Specific examples of benefits are given in the following cases.

Case A-1—Twenty acres of stumpland were cleared and pasture improved on a 30-cow dairy farm in Franklin County. The case is presented as an example of the way costs may be met through increased farm returns. The stumps were taken out, stones and roots were removed, and the low spots were filled and graded. A bulldozer was hired at $6 per hour to do the heavy work. The field was seeded in the fall of 1944 and was pastured in 1945. The soil, a heavy and

TABLE 3.—COMPARISON OF COSTS AND RETURNS FOR IMPROVING 20 ACRES OF STUMP LAND FOR PASTURE.

Land Use	Previous Acreage	Present Acreage	Type of Improvement	Cost	Returns per Year
Crop land	55	55	Removing stumps (with bulldozer)	$1,170	
Pasture	18	38			
Stump land	30	10	Picking roots and stones	60	Pasture for 30 cows
Farmstead and woods	15	15	Harrowing	40	for 5 months at $3 per month = $450
			Total costs	$1,270	
			Cost per acre	$63.50	Returns per acre $22.50

sandy loam, was well adapted to the use intended. Liming, fertilizing and seeding costs on the 20 acres of pasture are excluded, because these are operational rather than land improvement costs.

When good pasture land can be developed from stump land in this manner, the improvement costs soon pay for themselves in additional production per acre. The stump land undoubtedly produced some feed before it was cleared, so not all of the value of pasture can be counted as an increase. The differences in production between the stump land and the Ladino-clover pasture were about the same as those between native grass and clover-grass pasture in 1942[5]. On this basis the stumpland produced about one-fifth as much grazing valued at $4.50 per acre per year. The difference of $18.00 per acre per year was the increased return for land improvement and pasture seeding. Approximately 60 percent of the total cost of the pasture was for land improvement. Therefore the return is $10.80 per year per acre and the land improvement work would be paid for in six years of grazing.

Although number of cows has not been increased to expand the size of business, 20 acres of good pasture land have been added. The expenditure of $1270 is justified on this basis alone, because of the feed supply added to the farm. In addition, the improved pasture land can be used for crops or hay.

Case A-2—Stumps and stones were removed from three acres to provide additional pasture on a 30-acre dairy farm with 17 cows. The contrast with case A-1 is striking because of difference in type of soil. More work was done per acre on a smaller tract of land, at more than twice the cost, to provide none-too-good pasture. The additional acreage was not sufficient to furnish the necessary amount of land nor to decrease feed costs appreciably.

TABLE 4.—COMPARISON OF COSTS AND RETURNS FOR IMPROVING 3 ACRES OF STUMP LAND FOR PASTURE.

Land Use	Previous Acreage	Present Acreage	Type of Improvement	Cost	Returns per Year	
Hay	15	15	Remove stumps	$324		
Pasture	10	13	Level and fill	78	Pasture for 4 cows for	
Stump land	3	0	Bog harrow	10	4 months at 13 per	
Other	2	2	Pick stones	20	month	$48
			Total cost	$432		
			Cost per acre	$144	Returns per acre	$16

A power shovel and a bulldozer were hired by the hour. Some of the stumps were buried and others were burned. At $144 per acre the costs were high, considering the quality of the improved pasture that resulted. Seeding, liming, and fertilizing costs per acre were about the same as in Case A-1; therefore 80 percent of total pasture costs consisted of land improvement. On this basis pasture value per acre attributed to land improvement work amounted to about $13 per year.

Case B-1—Boulders were removed from a 10-acre field on a 60-cow dairy farm in 1940. The land has been used for five years, for both crops and pasture.

[5]Returns from Pasture Treatment. C. R. Creek. FM-13, April 1943, mimeo.

Figure 12.
High Yielding Ladino Clover Pasture on Land where Boulders Had Been Removed.

Power machinery could not be used before, because the stones were too many and too large. The work of removing boulders with a bulldozer and picking the stones cost $57 per acre. The stony loam soil is suitable for crops and produced yields of 15 tons of corn silage per acre. Crop land had been added to the farm at a cost of $57 per acre, at a time when good crop land in that community was selling at $100 per acre.

On the same farm, another 14-acre field was cleared of boulders in 1944. A small bulldozer was used, and many of the boulders were broken by blasting. Costs amounted to $188 per acre for all boulder removal work. Soil type, number and size of boulders, and general condition of the two fields were the same. The differences in cost are accounted for by size of bulldozer used. Returns per acre in crops and pasture showed little variation between the two fields.

Putting the two together, 24 acres were added to the farm, doubling the acreage of cropland and increasing pasture by 50 percent. The differences in costs of the two fields are extreme. The 10-acre field will easily pay for itself in a few years. The main justification for the second field at the higher cost is that the farm was overstocked and more crop and pasture land had to be added to help support the number of milk cows kept. It was to the economic advantage of the owner to add crop and hay land at $188 per acre rather than decrease the number of cows; but the same benefits from the work which was done at a cost of $57 per acre produced higher returns.

Case B-2—On another farm many large boulders were removed from 5 acres at a cost of $250 per acre and this tract of crop land was added to the farm in the place of poor pasture and unsightly boulders. Although cropland was increased by a third, and the new land was needed, only high yields of vegetables over a period of years will pay the costs of the improvement. The high cost per acre, plus the fact that the farm is a small business unit makes it questionable whether the benefits will justify the work that was done.

Case C-1—Brush, trees, and some stumps were cleared from a sandy loam soil for a total cost of $115 per acre which included the bulldozer charge of $100 per acre and $15 for burning brush and stumps. This land was well adapted to potatoes and produced 200 bags or over 300 bushels per acre. In the first year of cropping, a net profit of 75 cents per hundredweight was realized on potatoes. At this rate sales of 150 hundredweight or 250 bushels of potatoes per acre would pay for the cost of clearing in one year. Prices received for potatoes were high in this season and the margin of profit will be less in years of lower prices. Alternative uses may be needed for this land.

Case C-2—In several instances a similar type of cover was cleared and the land used for vegetable crops. In these cases the profits over cost of production in one year were more than equal to the clearing costs of about $100 per acre. For a vegetable crop with a net return of only 40 cents per box, only 250 boxes per acre were required to pay clearing costs. With lower prices for vegetables the margin of profit from land improvement will be decreased, but the cost of land clearing also may be lower with more efficient methods and machinery.

Case C-3—When woodland was cleared on stony loam soils on sloping land for new orchard plantings the clearing costs were also about $100 per acre. A less thorough job of removing stones and roots was performed because the land was not plowed. If interest and taxes were charged on this land for 12 years until the orchard came into production, a total cost of $200 per acre would be accumulated on the land exclusive of seeding costs and trees. At a net return of 50 cents per bushel of apples over costs of production it would require the profits from crops of two or three years to pay costs of the land. When the margin of profit is greater in a period of higher prices the land costs may be paid in one or two years. Probable returns are used here to demonstrate the ratio between benefits and costs because the orchards have not been in production long enough to give figures on actual returns.

Case D-1—Benefits from land improvement work through drainage depend somewhat upon amount and distribution of rainfall. In ordinary seasons these ditches which were blasted will carry surface water rapidly enough to prevent killing of crops or grass by standing water.

In one case a ditch about 500 yards long was blasted for a total cost of $120 for dynamite and labor. Three acres of land that had been too wet for harvesting during a rainy season were made suitable for hay. In addition, 12 acres of land were made suitable for pasture. An extra ton of hay per acre at $15 per ton amounted to $45 and three additional months of grazing on 12 acres at $7.50 per acre gave a total return of $135 on a drainage cost of $120. Drainage costs were only $8 per acre on this farm and two seasons of grazing would pay the total costs of reclamation and seeding.

Case E—The benefits of stone wall removal usually cannot be measured in terms of new land added to the farm. Stone walls were removed on most farms to combine several small lots into one larger field so that machinery could be used in crop production. This was true for hayland where tractor mowers, pick-up field balers, and field choppers were used and for cultivated crops such as potatoes where planters, sprayers, dusters, and diggers were used on long rows for more efficient production. Mechanized farming has been a powerful incentive to keep many young men on the home farm and the use of machinery has aided in obtaining and keeping a higher type of hired farm labor. An intangible benefit, but none-the-less important to many farmers was the satisfaction of seeing one large open field instead of small lots bounded by stone walls covered with vines, shrubs, and weeds plus occasional trees and bushes in the fence row. Other tangible benefits such as weed, rodent, and disease control were fully as difficult to evaluate as the saving in time and effort through the use of machinery. On the basis of total acreage in the fields which were combined by stone wall removal, the costs ranged from $15 to $30 per acre on different farms. On cropland where machinery was used this cost might be repaid in lower production costs over a period of years. On pasture land there is little economic justification for stone wall removal except to facilitate reseeding and to destroy weeds and shrubs.

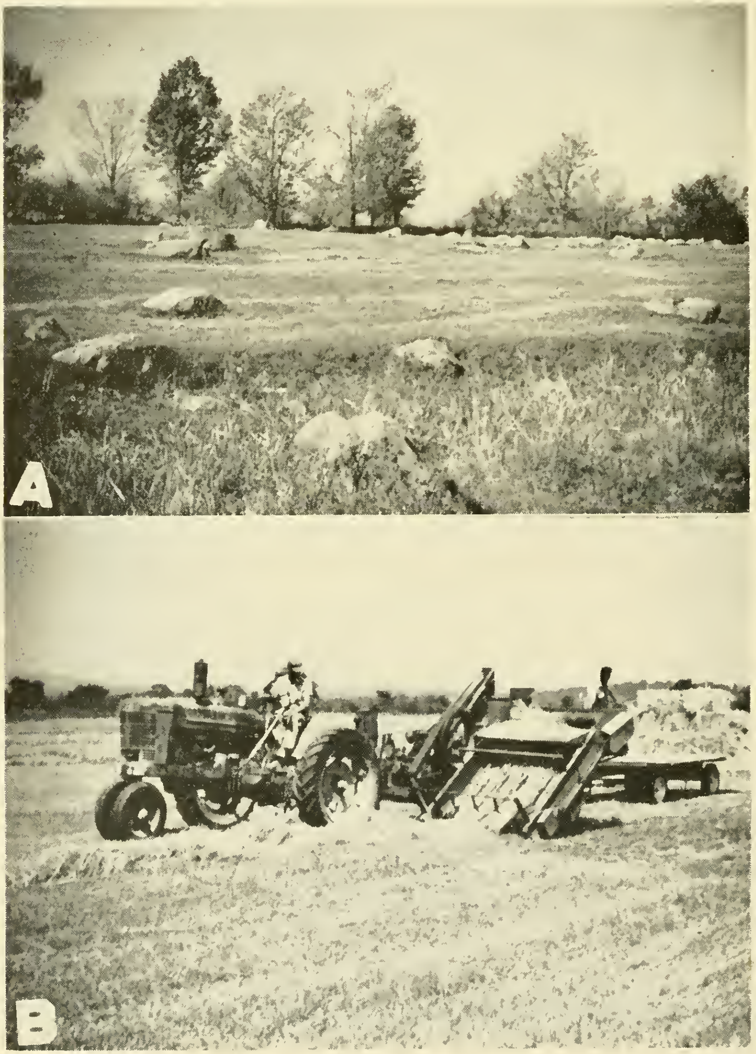

Figure 13.
A. Boulders in Hay Land Restrict the Use of Machinery such as Field Hay-Balers.
B. Labor Saving Machinery Can Be Used after Stone Walls and Boulders are Removed.

Other Benefits

All these types of land improvement work have resulted in economic benefits of some type whether measurable or not. The intangible or non-economic benefits were important to the farm living but did not assist in paying the cost of land improvement. For example, when the swamp was drained the mosquitoes disappeared and it was possible to make a road to a hay lot beyond the swamp after building a bridge over the ditch. In another instance a considerable sum over the value of the land was spent to clear large boulders from a field which was directly in view from the house. The owner knew that the cost was high but considered the satisfaction of an open field as partial payment. Where stone walls were removed, the satisfaction of no longer having the unsightly fence row in the field was a part of the benefits. In some cases stumpland was cleared chiefly because of the unsightly appearance of the field. Idle land which could be made productive was a challenge to many farm owners and considerable pride and satisfaction were gained when the work was completed. On many farms the crop plan and dairy feeding practices have been adjusted when a new pasture, or new area of silage corn or hay land was added to the farm unit through land improvement. Some poultrymen have grown replacements for the flock on new land which was cleared for range, when formerly pullets were purchased. Land improvement to increase the size of the farm unit as well as allow greater use of machinery has kept many people on the farm becau e a reasonable living without drudgery was in prospect.

The benefits accrue to the farm as a whole rather than to the reclaimed areas or farm enterprise in many cases of land improvement work. An improved pasture or hay field may result in significant adjustments in number of cows, growing of herd replacements, field organization, labor efficiency, and crop plans in addition to merely furnishing additional feed. The farm as a unit may produce a greater increase in income than the value of feed from the improved land.

Amortization of Land Improvement Costs

The amount of money which could be paid for land improvement for various crops and pasture may be determined by comparing the amortization costs per year with the yield of crops necessary to pay the costs. In Table 5, the costs of

TABLE 5.—ANNUAL CHARGE AND CROP YIELDS TO PAY LAND IMPROVEMENT COSTS

Cost of Land Improvement per Acre	Annual Carrying Charge*		Additional Yields per Acre Necessary to Pay Annual Costs**							
			Hay (tons) or		Pasture (cow days) or		Tobacco (pounds) or		Potatoes (bushels)	
	5 yrs.	10 yrs.	5 yrs.	10 yrs.	5 yrs.	10 yrs.	5 yrs.	10 yrs.	5 yrs.	10 yrs
$50	$11.80	$6.36	0.6	0.3	120	60	39	21	12	6
100	23.60	12.73	1.2	0.6	235	130	79	43	24	13
150	35.40	19.10	1.8	1.0	355	190	118	64	35	19
200	47.20	25.46	2.4	13.	470	255	158	85	47	25
250	59.00	31.82	3.0	1.6	590	320	197	106	59	32
300	70.80	38.19	3.5	1.9	710	380	236	128	71	38

*Interest for 5-year payment plan at 6% and for 10-year plan at 5% on unpaid balance.

**Hay at $20 per ton, pasture at $3 per cow per month, tobacco at 30 cents per pound, and potatoes at $1 per bushel.

the land improvement work are amortized over a 5-year and 10-year period on the basis that money was borrowed to pay the original costs. The crop and pasture yields per acre are the amounts necessary to meet the annual costs of land improvement expenses in the first column. They do not include the yields necessary to meet the annual costs of production and are in addition to these yields.

When crops were valued at 1935-39 average prices for Massachusetts, land improvement costs up to $100 per acre were paid with additional yields of hay on a 5-year payment plan. If hay is valued at $20 per ton, it would take a yield of 1.2 tons per acre for 5 years to pay for land improvement work costing $100 per acre. On a 10-year cost-spreading period 0.6 tons of hay were needed each year to pay this cost of land improvement. Likewise, it would take 25 bushels of potatoes per acre for 10 years to pay the cost of land improvement work at $200 per acre. Additional grazing from pasture would carry a $50 per acre land improvement cost over a 5-year period or a $100 per acre cost over 10 years. Additional yields of tobacco over production costs would pay for improvement costs in either a 5-year or a 10-year period. Physical limits on the total yields of crops and days of grazing on pasture were the determining factors for the cost of land improvement which could be justified on net returns. Costs of production were paid first and the remaining yield was applied to repay improvement costs.

The costs for land improvement work, especially when the charges per acre are high, should be spread over a long period. High costs per acre cannot be expected to be covered by increased returns over two or three crop years. The usual time period in paying for a farm, when income is derived only from the land, is from 20 to 40 years. A farm is expected to pay for itself and furnish a living to its owner in this period. Land reclamation on any extensive scale should be handled in the same manner. There is no difference between paying $50 an acre for land and another $50 for improvement work and paying $100 an acre for improved land. In either case, the charges should be spread over a number of years.

The spreading of costs over a period of years is one of the basic principles that must be remembered by the land owner when he is deciding whether or not to perform improvement work. The costs per year are to be compared to the additional returns per year. It is good farm practice to invest in land improvement that increases annual expenses by 10 percent, for example, if gross income is increased by more than 10 percent thereby.

In the case of a small amount of work or the improvement of only a few acres at moderate costs it is not necessary to spread the costs over a long period. The expenditure of $200 to improve four or five acres of pasture may be spread over a two or three year period, and may be charged as operational expense. Interest charges are then lower than when costs are amortized over a long period. The contrast between short and long time financing is greatest in terms of small and large expenditures. A total outlay of $200 usually can be carried in a year or two but a total outlay of $2000 or more may have to be spread over a number of years as illustrated above. The decision between short and long time cost spreading rests on the two main factors of available cash and the amount of the charges. Extensive operations, on which total costs are high, may be financed over a long time and small amounts over a short time.

Developing New Farms

In only limited instances will it be profitable to develop new farm units from land not in farms. In the past few years a few farms have been carved out of forest and brush land, but these have been specialized cases. New farms have been developed from abandoned dairy farms by clearing bushes and brush for growing potatoes. On the latter, improvement costs and land prices were low. Likewise, vegetable farms have been developed from raw land, but the soil types were favorable and savings from control of disease alone the first few years were calculated to pay for a good share of the improvement costs.

Land improvement has its greatest possibilities on land already in farms. Chief among the reasons for this is that when costs of land improvement are added to land costs, building costs, machinery, and livestock, the total will exceed considerably the amount for which a comparable farm can be purchased on the open market.

This study has concentrated upon cases in which a few acres per farm have been improved. No complete records have been obtained on whole farm developments, because the instances are few and specialized, and because in the future as in the past few years, the prospects are for most of the work to be done on land already in farms. The costs of whole farm development are too likely to be prohibitive. Undeveloped lands outside of farms may be improved and added to existing farms to better advantage than in making a whole new unit. Such addition not only will provide opportunity for enlarging non-economic units, but will require less expenditure for necessary buildings.

Future Work on Clearing and Improvement

The need for land improvement work is primarily on farms with limited crop and pasture acreage. The presence of boulders and stone walls as impediments to use of mechanical equipment, plus the small size of many of the farms, points to the desirability of reclamation. Land improvement which includes increasing the size of the farm and making present acreages suitable for use of power machinery is one of the main requirements to enable Massachusetts farmers to compete in agricultural production.

A high proportion of the persons on farms of less than $1000 total value of product are in the group that work more than 100 days off the farm. Many of the small or low-income farms would be suitable for improvement work to some extent. If the combination of non-farm employment and farming produces a satisfactory income, such arrangement probably offers more economic security than would increasing the farming activity through land improvement to replace the non-farm job. The economic desirability of land improvement on commercial farms that provide the whole family income is a different proposition. It is on these farms that land reclamation under proper conditions will be of greatest economic importance in agricultural production.

No estimate can be made of the acreage that would be suitable and economically feasible for development. Decisions in this respect will have to be made on an individual farm basis, with the operator estimating costs and comparing these costs with probable returns. Nor is there any reliable method of forecasting the probable demand for land improvement work. Land reclamation can be expected to continue during the next decade much as it has from 1940 to 1945. When the wartime level of farm incomes drops to "normal" levels, fewer land owners are going to be interested in high-cost land improvement. The more progressive land owners who desire to increase operating efficiency will continue to undertake improvement work that has any prospect of paying out. Road construction machinery is being adapted to land improvement work, and new types of equipment are being developed to increase the efficiency of the work. With the formation of Soil Conservation Districts, it is likely that more individuals will be interested in farm land improvement, particularly if costs can be reduced below present contract prices per hour and per acre.

Figure 14.
Bushes, Shrubs, and Weeds Are Chopped and Mixed with Soil by Rotary Tiller as First Step in Pasture Improvement.

The organization and operation of Soil Conservation Districts offer opportunities to devote more specific attention to land improvement problems in the future. The district supervisors can assist in making heavy equipment available to farmers at reasonable rates. Farmers who are interested in land improvement work and conservation can focus public attention on the problems. The land owners, the district supervisor, and the technicians working together should be able to outline and put into operation a program of land improvement and soil conservation.

Soil Conservation Districts in other states have provided technical assistance and have made arrangements for obtaining heavy equipment. The details of the arrangements have varied from state to state and from district to district. In some cases the district acquires the machinery and furnishes the machine operator; in others, the district supervisors make arrangements to hire county- or state-owned equipment. In all cases, the land owner pays the costs of the work, either by the hour or by the job. The costs are often lower than the charges by commercial operators.

SUMMARY AND CONCLUSIONS

The acreage of improved farm land in Massachusetts has decreased by 50 percent in the last century and many adjustments have been made in crop and livestock production. Poultry and dairy enterprises which are dependent upon western grain areas for feed have supplanted sheep and beef cattle production. Vegetable and fruit production does not meet local demand. Intensive crops with a high value per acre have been substituted for grain crops. Lower production costs in other agricultural areas have been responsible for these shifts and for abandonment of much farm land in Massachusetts. However, efficiency of production has increased in many farm enterprises.

Improvement of abandoned farm land has been possible in recent years as a result of higher prices for farm products and availability of heavy machinery. Higher profits and technological advances in agriculture have increased the interest of farmers in land improvement and soil conservation. Removal of physical obstacles to the use of modern farm machinery is a primary requirement for desirable land use adjustments. The trend towards larger and more efficient farms will continue with the clearing and improvement of land in farms. Land improvement will be of greatest value on the commercial type of farm.

The decision to improve land should be made only after careful study of the economic and physical factors involved, including probable costs, expected returns, total benefits to the farm, type of soil, topography and location of land, type of cover to be removed, possible changes in the farm plan, and alternative uses for the money to be paid for improvements. If the work is undertaken, methods of land improvement should be fitted to requirements of the individual case. Costs may be amortized over a period of years and should be met by additional yields of crops or grazing over yields required to meet annual production costs.

The following conclusions are based on analysis of records on land improvement work, on case studies of individual clearing projects, and on appraisal of other information on the subject.

1. Type of soil and typography of land to be cleared should be adapted to agricultural use. High-producing crop land cannot be made on steep slopes or stony, gravelly soil.

2. Size and type of machinery should be adapted to the conditions for each job. Small bulldozers at low cost per hour may be more expensive than larger machines for heavy work. Combinations of machinery are often used for stump and stone-wall removal.

3. High costs per acre may be justified if the returns are also high. Low costs may prove more expensive if returns are low.

4. Profitability of land improvement work should be calculated on additional yields, prices, and values expected over a period of years.

5. Land improvement, particularly stone-wall, boulder, and stump removal, provides for increased mechanization of farm operations, more efficient use of labor, and less breakage of machinery.

6. Wet land was reclaimed at low cost per acre by blasting ditches. Technical assistance from the Soil Conservation Districts and cooperation of neighbors in obtaining outlets for ditches were important factors in this method of land reclamation.

7. Costs of land improvement work were usually paid from farm earnings.

8. New types of heavy equipment such as grubber blades for bulldozers, power rotary tillers, and steel stoneboats may result in lower clearing costs and more efficient work.

9. Land improvement may be of greatest economic importance on commercial farms.

10. Development of new farms by land clearing will be justified only in unusual cases for production of specialized crops with a high acre value.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 440 AUGUST 1947

Apples as Food

By William B. Esselen, Jr., Carl R. Fellers,

and Marie S. Gutowska

Apples owe their widespread popularity to their attractiveness and palatability. Now with recognized food values assigned to them, apples also assume importance as a "protective food" in the American diet. This bulletin summarizes information on composition and nutritive value.

UNIVERSITY OF MASSACHUSETTS

AMHERST, MASS.

APPLES AS FOOD[1]

By William B. Esselen, Jr., Associate Research Professor of Food Technology, Carl R. Fellers, Head of the Department, and Marie S. Gutowska, Assistant Research Professor

INTRODUCTION

Since ancient times special curative powers have been attributed to the apple. We are all familiar with a modification of the old Devonshire rhyme (Manville, 1936a)—

"Ate an apfel avore gwain to bed,
Make the doctor beg his bread."

Apples have been widely used as a food from the earliest times and they hold a place of well-deserved popularity today. According to Todhunter (1937) there are many reasons why this fruit has received dietary recognition.

> It has "color appeal": green, red, russet or yellow, it catches the eye; it has "appetite appeal": cool, crisp, and raw it is most refreshing; and the thrifty like it because it has "variety appeal." No other fruit can be used in so many different ways. Raw or cooked, made into preserves and jellies, candied, dried, canned, prepared as fresh apple juice, made into cider or vinegar, and the peelings used for pectin making, no part of the apple need be wasted.

During the past ten years considerable effort has been expended in an attempt to make the public nutrition or vitamin conscious. Through scientific research the nutritive qualities of many foods have been evaluated and the results of such investigations have been applied to the improvement of the human diet. As an outgrowth of this development the nutritive value of a food has been used as a strong sales argument for its greater use in many cases. We hear such stories every day on the radio and read them in the newspapers and magazines. In spite of all this publicity, appetite appeal is still all-important to the individual in his choice of foods, and he is reluctant to choose a food on its nutritional merits alone if it lacks eye appeal and appetite appeal.

Apples have won their enviable position through their aesthetic and appetite appeal, but research has shown that they also possess definite nutritional and therapeutic properties.

This bulletin summarizes the results of eighteen years of research on the nutritive and therapeutic values of apples as carried on in this department, as well as the wealth of information reported by other investigators. Much interest has been shown in Massachusetts regarding the nutritive value of apples, both by the fruit grower and by the consume . This interest has gone so far that some people even appear to prefer to think of apples as a bottle of vitamin pills rather than as an attractive and flavorful fruit. However, in all probability, apples will continue to maintain their popularity on a basis of their flavorful and refreshing characteristics, with their nutritive value secondary in importance.

[1] Acknowledgment is due to the Massachusetts Society for Promoting Agriculture for their interest and assistance in the preparation of this bulletin.

HISTORY OF THE APPLE

The apple has been grown in Europe for more than two thousand years. The cultivated apple, *Malus Sylvestris* (*M. communis*), probably had its origin in mountain ranges of the Caucasus, between the Black and Caspian Seas. The wild forebears of the apple are also found in adjoining regions of Asia Minor and Persia (Varilow, 1930).

It is believed that the name "apple" originated in Abella, a town in Campania, where many fruit trees grow, and that Virgil conferred it upon a number of fruits to which the gardener gives the name apple; namely, the balsam apple, the rose apple, the pineapple, and the love apple (tomato) (King, 1946).

The apple was brought to North America by the earliest settlers, and was rapidly disseminated from coast to coast throughout the temperate zone of the United States (Magness, 1941). After 1800 when grafting became more generally known and practiced, the number of named varieties increased rapidly (Gourley and Howlett, 1941). For convenience of discussion, Shaw (1911) divided North America into seven apple belts, each having a fairly characteristic list of varieties. In the apple trade, however, apples are classed mainly as "Western" and "Eastern." The leading Western varieties are Winesap, Jonathan, Delicious, Yellow Newtown, Rome Beauty, and of the early apples—the Gravenstein (United States Department of Agriculture, 1935).

In New England no less than fifty varieties can be found in commercial orchards. Of these, McIntosh and Baldwin are the only two of real importance, and the latter is declining. Northern Spy, Rhode Island Greening, Cortland, Wealthy, and Delicious are among the more important minor varieties.

APPLE PRODUCTION AND CONSUMPTION

The total world's crop of apples exceeds 500 million bushels. This figure is based on reports from thirty-one countries for a six-year period (1931–36), and allowance is also made for the crops in such important countries as the U.S.S.R. and China, for which definite information is lacking (Gourley and Howlett, 1941).

However, with the greatly increased supplies of other fruits, apple consumption in the United States has apparently decreased during the past thirty years, and consequently, the number of apple trees has also decreased.

Figure 1 shows the per capita civilian consumption of apples in the United States for the period of 1909–43 (United States Department of Agriculture, 1944). Whereas the per capita consumption of apples decreased from approximately 60–70 pounds to 40–60 pounds from 1909 to 1920, it has declined from 62 to 36 pounds during the period 1920 to 1930, and from 51 to 25 pounds during the period 1930 to 1943.

Figure 2 shows the total United States production of apples from 1909 to 1938 and Figure 3 the number of trees and the average yield per tree from 1909 to 1934 (United States Department of Agriculture, 1938). Whereas the decrease in the number of trees of bearing age is about 45 percent; the yield per tree, owing to improved methods of culture, has increased about 70 percent.

There has been a rather steady decrease in the per capita consumption of apples from 1910 to date. Some persons have attributed this decrease to the increased availability of other fruits, particularly grapefruit and oranges. The substitution of these other fruits can probably be attributed to the desire for variety as well as other factors such as advertising and developments in the field

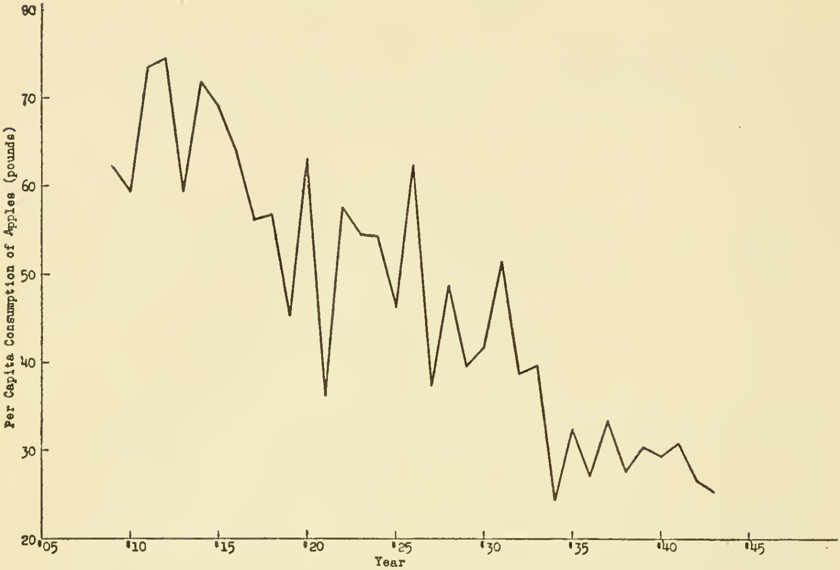

Figure 1. Per Capita Consumption of Apples in the United States, 1909-1943. (United States Department of Agriculture, 1944.)

of nutrition. The spectacular increase in the production of canned fruit juices since about 1930 may well have played a part in the decreased consumption of apples. During the past few years there has been a definite trend indicating that people prefer many fruits in a form that they can drink.

Figure 2. Apples: Total United States Production and Production with Average Growing Conditions, 1909-1937.
(United States Department of Agriculture, 1938.)

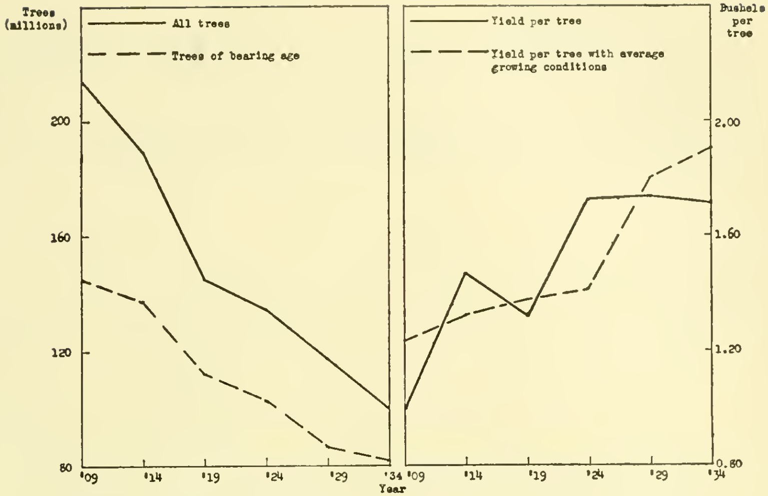

Figure 3. Apples: Number of Trees and Average Yield per Tree, 1909-1943. (United States Department of Agriculture, 1938.)

THE COMPOSITION OF APPLES

In a consideration of the nutritive value of a foodstuff its chemical composition is of primary importance. Information on the average chemical composition of the edible portion of fresh apples is presented in Table 1. Additional data on the composition of different varieties of Massachusetts-grown apples, as determined by Fellers (1928) and Holland and Ritchie (1941), are shown in Tables 2 and 3.

TABLE 1.—AVERAGE CHEMICAL COMPOSITION OF THE EDIBLE PORTION OF FRESH APPLES

(Chatfield and Adams, 1940)

Constituent	All	Early (summer)	Medium (fall)	Late (winter)
	percent	percent	percent	percent
Water	84.1	86.5	85.4	83.6
Protein	0.3	0.3	0.3	0.3
Fat	0.4	0.4	0.3	0.3
Ash	0.29	0.3	0.25	0.28
Carbohydrate (total)	14.9	12.5	13.8	15.5
Fiber	1.0	—	1.1	—
Sugars	11.1	9.4	10.4	11.2
Starch	—	—	—	—
Acid (as malic acid)	0.47	0.70	0.45	0.46
Fuel or energy value (In Calories)				
Per 100 grams	64.0	55.0	59.0	66.0
Per pound	290.0	250.0	270.0	300.0

Table 2.—Chemical Composition of Certain Varieties of Massachusetts Apples
(Fellers, 1928)

Variety	Year	Number of Samples	Total Solids	Soluble Solids	Total Sugars	Reducing Sugars	Sucrose	Starch	Pectin as Pectic Acid	pH	Acidity as Malic	Ash
			percent	percent	percent	percent	percent	percent	percent		percent	percent
Baldwin	1925	3	18.06	15.50	11.72	7.12	4.60	0.08	0.29	3.55	0.45	0.27
Baldwin	1926	2	16 79	14.12	9.93	6.22	3.71	trace	0.32	3.42	0.61	0.29
Baldwin	1927	2	15.90	13.60	11.01	7.58	3.43	0.11	0.37	3.47	0.53	0.33
Red Astrachan	1926	1	15.31	12.61	9.20	5.99	3.21	0.18	0.28	3.18	1.11	0.35
Rhode Island Greening	1926	2	15.70	12.91	10.00	7.80	3.20	0.10	0.34	3.37	0.51	0.31
Winesap	1926	2	18.61	15.79	13.52	10.03	3.49	trace	0.31	3.45	0.47	0.32
McIntosh	1926	3	15.70	13.28	12.09	9.13	2.96	0.0	0.27	3.60	0.38	0 28
Wealthy	1926	1	13.83	11.76	10 60	8.90	1.70	0.0	0.30	3.40	0.47	0.26
King David	1926	1	14.98	12.28	10.60	8.68	1.92	trace	0.47	3.25	0.91	0.28
Red Siberian Crab	1926	2	16.17	12.76	10.25	8.47	1.78	0.09	0.62	3.20	0.80	0.36

Table 3.—Composition of Apples
(Holland and Ritchie, 1941)

Variety	Original Moisture	Crude Protein*	Crude Fat*	Nitrogen Free Extract*	Crude Fiber*	Crude Ash* Soluble	Crude Ash* Insoluble	Iron*	Copper*	Manganese*	Calcium*	Phosphorus*
	percent	percent	percent	percent	percent	percent	percent	p.p.m	p.p.m.	p.p.m.	percent	p.p.m.
Baldwin, cored	85.0	1.60	1.62	89.46	5.62	1.70	0.00	35	12	none	0.024	790
McIntosh, cored	86 4	1.34	1.96	90.68	4.89	1.12	0.01	11	2	trace	0.043	510
Wealthy, cored and pared	87.4	0.98	2.00	90.55	4.61	1.84	0.02	54	9	none	—	630
Baldwin, cored and pared	85.7	1.11	0.73	92.78	4.05	1.32	0.01	21	5	trace	—	770
McIntosh, cored and pared	85.4	1.27	0.86	93.09	3.61	1.15	0.02	34	5	trace	—	690
Baldwin, skins	80.7	2.42	4.81	82.50	8.35	1.90	0.02	39	5	14	—	770
McIntosh, skins	81.8	1.65	4.81	85.79	6.70	1.03	0.02	30	11	trace	—	640

*Dry weight basis

There is some variation in the composition of apples according to variety and other factors. Ordinarily more than four-fifths (80 to 86 percent) of the apple consists of water. The total solids vary from approximately 14 to 19 percent, of which 12 to 15.5 percent is soluble solids. Sugars make up a large proportion of the solids (approximately 75 percent and approximately 12 percent of the total weight ot the apple). The chief organic acid of the apple is malic acid, which is found to the extent of from 0.5 to 1.0 percent. Citric acid has been found in only a few varieties.

Carbohydrates

From a nutritional standpoint carbohydrates can be divided into two groups: the so-called available carbohydrates such as starches and sugars; and the unavailable or fiber fraction consisting of pectin, cellulose, and hemicellulose, usually considered indigestible.

The young apple contains a relatively large amount of starch (3 to 4 percent), but as the fruit ripens the starch is converted into sugars. A fully ripe apple contains little or no starch.

The total available sugar content of the apple amounts to approximately 12 percent. The sugars consist of at least three distinct compounds; sucrose (from 0 to 6 percent), and a mixture of dextrose and levulose of which there may be from 5 to 10 percent. The excess of levulose over dextrose is rather unusual in fruits (Shaw, 1911). According to Manville (1936b) the excess of levulose in apples may account for the greater tolerance of diabetics for this fruit.

According to Sherman (1946) one good-sized apple will furnish 100 calories, which is equivalent to the energy provided by one fair-sized potato, one thick or two thin slices of bread, or two-thirds of a glass of milk (about five ounces). Apples may be considered a food of moderate energy value, comparing favorably in this respect with many of the other fruits such as apricots, blueberries, oranges, peaches, pears, plums, raspberries, and strawberries.

The caloric value of the apple is relatively well utilized in the body according to Ullmann (1933), who found that 88.3 percent of the caloric value of ingested apples was assimilated by the body.

Pectin

As a nutritive element in apples, pectin is particularly interesting. Pectin was discovered in 1825 by Braconnot, a French scientist, who first suggested that this material might be of value as an antidote for lead poisoning (Rooker, 1928). However, pectin was only a laboratory curiosity until 1909, nearly 100 years later. At that time investigators established the relationship between pectin, sugar, and acid. In 1913 the first patent for the commercial production of pectin was issued to Douglas. Since that time it has come into general use in jelly and preserve making.

The pectin content of fresh apples averages about 0.5 percent. Chemically, pectin is a polygalacturonate, containing 8 molecules of galacturonic acid. It was pointed out by Manville (1936b) that galacturonic acid plays a definite role in mucin formation and in this respect has a vitamin A-sparing action.

The uronic acid content of apples, as reported by Manville (1936b) and shown in Table 4, appears to vary with the variety of apple; but in all cases apples were considerably richer in this compound than such fruits as lemons, oranges, or tomatoes.

TABLE 4.—URONIC ACID VALUE OF SOME APPLE VARIETIES AND OTHER FRUITS (Manville, 1936b)

Variety	Uronic Acid per Gram of Fruit
	milligrams
Arkansas Black	10.6
Baldwin	9.8
Delicious	11.8
Gravenstein	7.3
Jonathan	8.5
Rome Beauty	13.3
Spitzenberg	12.1
Winesap	13.9
Winesap juice	5.4
Yellow Newtown	16.5
Lemon juice filtered	2.0
Orange juice filtered	4.0
Tomato juice filtered	2.0

Kobren, Fellers, and Esselen (1939) investigated the effect of adding pectin to the diet of vitamin A-deficient rats in order to observe its vitamin A-sparing action. It is generally recognized that xerophthalmia and the keratinization of the mucous epithelium of the body are due in part to a deficient synthesis of mucin, occurring as a result of dehydration of the mucous membranes. From this investigation, pectin appeared to be a beneficial supplement to a diet deficient in vitamin A only insofar as pathological changes due to avitaminosis A in the vagina, nares, and eyelids are concerned.

The effectiveness of raw apples in the treatment of diarrhea is attributed largely to their pectin content, as will be discussed more fully later.

Minerals

The apple contains approximately 0.25 to 0.36 percent of ash. The approximate composition of the ash of the edible portion of the apple as compared with other fruits is shown in Table 5. Although apples cannot be considered an important source of minerals, they are comparable to other fruits in this respect, and their liberal use in the diet does contribute definite amounts of these specific nutrients.

The iron, phosphorus, and calcium in the apple have been reported to be highly available and fully utilized by the human body. Moreover, the preponderance of base-forming elements makes the apple an efficient agent in reducing the acid output. The principal base-forming elements in apples are potassium, sodium, calcium, and magnesium, of which potassium occurs in the greatest quantity.

In addition, it is of interest to note that apples contain traces of iodine.[2] The

[2] The estimated daily requirement of humans for iodine is about 0.002 to 0.004 milligram a day for each kilogram of body weight. This amounts to about 0.15 to 0.30 milligram daily for the adult. Iodine is especially important in adolescence and pregnancy. (U.S. National Research Council, 1945.)

TABLE 5.—PERCENTAGES OF CERTAIN OF THE MINERAL ELEMENTS IN THE EDIBLE PORTION OF FRUITS

(Sherman, 1946)

Kind of Fruit	Calcium	Magnesium	Potassium	Sodium	Phosphorus	Chlorine	Sulfur	Iron	Copper	Manganese
	percent	percent	percent	percent	percent	percent	percent	percent	p.p m.	p.p.m.
Apples	.007	.006	.116	.010	.011	.004	.005	.0003	.71	.84
Apricots, fresh	.015	.009	.279	.030	.024	.002	.006	.0005	*	*
Blackberries	.032	.024	.181	.004	.032	.015	.017	.0009	*	*
Blueberries	.026	.010	.065	.016	.020	.008	.011	.0009	*	*
Orange (or juice)	.025	.010	.181	.010	.019	.004	.008	.0003	.76	.25
Peaches	.009	.011	.256	.015	.018	.005	.007	.0003	*	*
Pears	.013	.009	.129	.008	.016	.004	.007	.0003	1.34	.64
Pineapple, fresh	.016	.011	.214	.014	.011	.046	.007	.0003	*	*
Plums	.017	.011	.232	.004	.020	.002	.005	.0005	.80	.96
Raspberries, seed included	.0.40	.023	.190	.003	.037	.022	.018	.0009	*	*
Rhubarb	.051	.016	.358	.017	.025	.053	.008	.0005	*	*
Strawberries	.022	.012	.145	.007	.022	.011	.012	.0009	.75	2.13

*No figure available

iodine content of apples and applesauce has been determined by Nebraska and Ohio investigators, who found that dried Nebraska apples contain from 89 to 340 parts per billion of iodine. Dried apples in the Oregon goitrous region contained only 3 parts per billion; whereas Ohio applesauce showed 125 parts per billion of iodine (American Can Company.)

Acids

The chief organic acid of the apple is malic acid, which is found to the extent of from 0.5 to 1.0 percent. Citric acid has been found in only a few varieties. Crab apples may contain as much as 0.03 percent citric acid, Yellow Transparent 0.02 percent, and Winesap a trace. Apples also contain a small quantity of tannic acid (which contributes astringency to their flavor) and uronic acid. Uronic acid is closely related to pectin, as discussed previously. Ursolic acid, a complex organic acid, is one of the principal components of the waxy coating of the skin of the apple.

Apples as eaten have an acid reaction, but because of their buffering capacity they influence the acid–base balance of the body as an alkaline food. The organic acids of the apple are oxidized in the body to furnish energy and leave a basic residue in the blood. The preponderance of base-forming elements in the apple leads to the formation of a urine less acid than normal. The apple thus safeguards the body from reduction of the bicarbonate concentration or alkali reserve of the blood.

One of the first studies of the titrable acidity and hydrogen-ion concentration of New England apples was made by Fellers (1928), who found that the acidity of Massachusetts varieties of apples varied only in very narrow limits, namely from pH 3.6 to pH 3.2. The relation between total titratable acidity and hydrogen-ion concentration was reasonably constant; i.e., the higher the hydrogen-ion concentration the higher the acidity and vice versa. Some varieties appeared to contain more buffer substances than others. The titratable acidity of apple juice and jelly manufactured from these apples was also determined. The juice was slightly lower in hydrogen-ion concentration than the fruit itself; the second and third extracts were lower than the first. The total acidity of the finished jelly, calculated as malic acid, varied from 0.22 percent in McIntosh to 0.66 percent in Red Siberian Crab; while the pH value ranged from 3.2 in Red Astrachan to 3.6 in Baldwin.

The hydrogen-ion concentration and the titratable acidity of thirteen varieties of New York apples was determined by Pfund (1939). Nearly all had pH values between 3.0 and 4.0; and if all the titrable acid is considered to be malic, the molarity values are between 0.070 M and 0.013 M. Of all the apple fruits examined, approximately 86 percent had pH values between 3.1 and 3.7 and molarity values between 0.055 M and 0.18 M. The differences between the pH values of raw apple juice, baked apples, and applesauce were not significant; therefore, the pH value of the raw apple juice may be considered as representative for the acidity of the cooked product. The data are shown in Table 6.

The basic effect of apples on the alkali reserve of the blood and acidity of the urine was studied by Shea and Fellers (1942). The term "alkali reserve" refers to the amount of basic elements (such as calcium, magnesium, potassium, and sodium) combined as bicarbonates in the blood. These bicarbonates provide a readily available source of base for the neutralization of acids. Nine healthy men from 22 to 27 years of age were placed on two diets; one group received an acid-

Table 6.—Acidity and pH Values of Thirteen Varieties of Apples Grown in New York State
(based on 302 samples, 1930 to 1935)
(Pfund, 1939)

Variety	Average Acidity* and pH Values					
	October to January		February to April		October to April	
	Acidity*	pH	Acidity*	pH	Acidity*	pH
Baldwin	10.7	3.26	6.4	3.45	8.6	3.35
Cortland	7.0	3.33	5.1	3.56	6.6	3.46
Fameuse	6.1	3.38	4.6	3.56	5.6	3.45
Golden Delicious	7.0	3.44	3.7	3.83	5.0	3.67
Jonathan	9.0	3.29	6.6	3.45	7.8	3.37
McIntosh	6.5	3.31	4.5	3.56	5.6	3.42
Northern Spy	9.6	3.21	6.9	3.34	8.6	3.25
Red Canada	8.0	3.38	4.2	3.60	6.3	3.47
Rhode Island Greening	9.4	3.25	8.1	3.38	8.9	3.30
Rome Beauty	5.1	3.32	4.2	3.50	4.7	3.40
Twenty Ounce	8.6	3.22	5.3	3.45	7.6	3.29
Wealthy	7.6	3.20	6.6	3.32	7.2	3.26
Winter Banana	5.7	3.41	4.2	3.55	5.1	3.47
All Varieties	7.7	3.31	5.4	3.50	6.7	3.39

* Average milliliters of N/10 NaOH required to neutralize 10 milliliters of raw juice.

forming basal diet and the other an approximately neutral basal diet. The neutral diet was chosen because the effect of added apples on urinary acidity could not be forseen. The acid-forming basal diet was used because it was believed that if the ingested material increased the alkalinity of the urine, the results would be more evident. Baldwin and McIntosh apples were tested. Large quantities (800 and 1000 grams) of these were eaten daily by the men on the experiment. The alkali reserve was expressed as cubic centimeters of carbon dioxide per 100 cubic centimeters of blood plasma. The data are summarized in Table 7.

The ingestion of large quantities of Baldwin or McIntosh apples caused a slight reduction in the pH value of the urine but did not significantly affect the blood alkali reserve; also approximately 90 percent of the organic acids of apples was completely oxidized or otherwise transformed in the body on either acid-forming or neutral diets.

The fact that there was no significant increase in urinary acidity in human subjects as a result of eating large quantities of apples indicates the probable absence of benzoic and quinic acid in apples.

The European worker, Marynowska-Kaulbersz (1933), reported that an apple diet tended slightly toward alkalosis.

It may be of interest that Fellers, Redmon and Parrott (1932) investigated the effect of cranberries on urinary acidity and blood alkali reserve, and found that when eaten in normal quantities (2 to 5 ounces of cranberry sauce, equivalent to 22 to 54 grams of fresh cranberries) no demonstrable effect on blood alkali reserve could be observed. However, when large quantities of cranberries were eaten (100 to 300 grams) a mild to moderate acidosis resulted.

TABLE 7.—SUMMARY OF AVERAGED DATA ON pH, ORGANIC ACIDITY AND AMMONIA OF URINE AND PLASMA ALKALI RESERVE

(Shea and Fellers, 1942)

Diet	Subject*	pH		Organic Acidity		Ammonia		Alkali Reserve		Days Run (Urine sample taken daily)
		Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	
		pH		c c. of 0.1 N acid		grams		cc. of CO_2/100 cc. of plasma		
Basal	G & F	5.55	6.10	619	355	.430	.376	61	65	4
Basal	G & F**	5.52	6.36	569	379	.420	.281	64	70	4
McIntosh Apples, 800 grams	R & S	5.55	6.00	571	441	.380	.342	62	65	4
McIntosh Apples, 800 grams	R & S	5.40	5.89	608	437	.540	.327	63	58	4
Basal	D & C	5.77	6.00	355	351	.358	.284	64	67	4
Basal	D & C	6.04	6.29	330	308	.535	.322	65	68	4
Baldwin Apples, 1,000 grams	J & K	5.72	5.50	422	482	.505	.410	63	63.5	2
Baldwin Apples, 1.000 grams	J & K	5.50	5.70	433	350	.680	.346	61	63.5	2
Basal	D & C	5.81	5.98	577	489	.494	.308	61	65	4
Basal	D & C	5.92	6.13	608	518	.624	.398	60	66	4
Tomatoes, 1,000 grams	L & K	6.02	5.87	569	430	.474	.295	62	65.5	2
Tomatoes, 1,000 grams	L & K	5.95	6.07	735	591	.520	.566	60	63.5	2
Basal	D & C	5.75	6.05	537	552	.569	.279	60	64	4
Basal	D & C	5.75	6.12	688	609	.578	.414	60	60	4
Dates. 400 grams	L & K	5.63	6.22	730	625	.538	.278	60	65	2
Dates, 400 grams	L & K	5.44	5.96	709	591	.523	.378	61	61	2

*Subjects G, R, D, J, and L were on the acid-forming diet; subjects F, S, C, and K were on the neutral diet.
**The subjects were allowed two days on the basal diet in the first two experiments with apples before any urine samples were taken.

Protein

The apple contains a somewhat smaller percentage of protein than many of the other fruits. The proximate composition of the apple shows 0.3 percent of protein as compared with 0.6 percent in blueberries, 0.6 percent in cantaloupes, 0.5 percent in watermelon, 0.4 percent in pineapple (Sherman, 1946).

The few available studies on the amino-acids of the protein of apples indicate that it is composed mainly of arginine, histidine, and lysine, all of which belong to the group of "essential amino-acids," indispensable in mammalian nutrition. The proportion of the amino-acids remains fairly constant during the development of the apple. The amide nitrogen forms 24.8 percent, the amino-nitrogen 45.3 percent; the "rest" nitrogen, including imino-nitrogen, 20 percent; nitrogen formed from NH_3 6.3 percent; and basic nitrogen 3.6 percent (Hulme, 1936). Research on the nature of the protein of the apple is now in progress in this department.

Flavor

Shaw (1911) stated that the characteristic flavor and aroma of apples is due to certain esters or flavoring oils which are of great importance in determining the quality and value of the apple. Power and Chestnut (1920) analyzed the odorous constituents of several varieties of apples and found them to consist essentially of the amyl esters, acetic and caporic acids, with a very small amount of caprylate and a considerable portion of acetaldehyde. The essential oil possessed to a high degree the characteristic fragrant odor of fresh apples. The yield of oil from the peel of Ben Davis apples was 0.0035 percent and from that of crab apples 0.0043 percent, corresponding to about 0.0007 and 0.0013 percent, respectively, of the entire ripe fruit. In an examination of McIntosh apples, Power and Chestnut (1922) confirmed the results of their earlier investigations that the odorous constituents of the apple consist chiefly of amyl esters, and obtained further information respecting the substance that imparts a distinctly roselike odor to some apples. This substance, present in minute amounts, was found to be geraniol.

More recently Milleville and Eskew (1944) have described a commercial method for the recovery and utilization of natural apple flavors. The product is a colorless water solution of the volatile constituents of natural apple flavor concentrated from 100 to 150 fold. The actual proportion of flavoring constituents in the solution does not exceed a few tenths of one percent by weight. The odor of the concentrate was mildly pungent and no perceptible changes have been found to occur in the product during storage.

Oils and Waxes

Oils and waxes exist in the apple, particularly in the peel, in very small quantities. Sando (1923) investigated the constituents of the waxlike coating on the peel of the apple and isolated triacontane ($C_{30}H_{62}$), heptacosanol ($C_{27}H_{56}O$), and an alcohol, malol ($C_{30}H_{48}O_3$), as well as several other fractions apparently consisting of mixtures of hydrocarbons and alcohols. In further work Markley and Sando (1931) found that ursolic acid (a monohydroxytriterpene acid), oil fraction, and total ether extract in the peel of apples increased throughout the growing period and during storage. Larger quantities of ursolic acid and total ether extract were generally found on the shady side of apples than on the sunny side.

Chibnall et al. (1931), in a study of the wax constituents of the apple cuticle, identified nonacosane, heptacosane, d-10-nonacosanol, hexacosanol, octacosanol and triacontanol. Hulme (1937) determined the wax content of apples during different stages of storage and found that the fraction soluble in cold alcohol and the ether-soluble fraction increased during storage from 139.4 milligrams per 100 grams of fresh tissue to 175.5 milligrams. The fraction insoluble in alcohol but soluble in ether increased from 14.5 to 36.1 milligrams per 100 grams of fresh tissue.

Vitamins[3]

Apples have been found to contain at least small amounts of most of the known vitamins. The average vitamin values based on available information are summarized in Table 8. These data are only approximate because the vitamin content is subject to considerable variation depending upon the variety and other factors which will be discussed later.

Table 8.—Average Vitamin Content of Apples per 100 Grams Edible Portion

Vitamin A	50-100 International Units
B Vitamins	
Thiamin	.096 milligrams
Riboflavin	.05 milligrams
Nicotinic Acid	.50 milligrams
Pantothenic Acid	.030 milligrams
Pyridoxin	.026 milligrams
Biotin	.0009 milligrams
Inositol	24.0 milligrams
Folic Acid	.008 milligrams
Ascorbic Acid (Vitamin C)	1.0-20.0* milligrams
Vitamin D	none

* Varies greatly with variety and storage conditions. An average value for common varieties may be taken as 2.0 to 5.0 milligrams.

[3] The recommended daily allowance for the vitamins considered here is as follows*:

	Vitamin A	B Vitamins			Vitamin C (Ascorbic Acid)
	I. U.	Thiamin Mg.	Riboflavin Mg.	Niacin, Mg. (Nicotinic Acid)	Mg.
Men	5,000	1.2-2.0	1.6-2.6	12-20	75
Women	5,000	1.1-2.0	0.5-2.0	11-20	70-150
Pregnant	6,000				
Lactating	8,000				
Children (depending on age)	1,500-6,000	0.4-1.8	0.6-2.5	4-18	30-100

*U. S. National Research Council, 1945.

Table 9.—Vitamin Content of Apples as Compared With Other Fruits (per 100 grams) (Sherman, 1946)

Kind of Fruit	Vitamin A	Ascorbic Acid	Thiamin	Riboflavin
	I. U.	milligrams	micrograms	micrograms
Apples	40 – 100	4.0 – 8.0	21 – 46	5 – 26
Oranges (or juice)	50 – 400	50.0 – 56.0	66 – 96	15 – 90
Peaches, yellow (fresh)	1,000 – 2,000	6.0 – 9.0	20 – 70	45 – 50
Pears	10 – 20	3.0 – 5.0	30 – 95	20 – 150
Pineapple (fresh)	40 – 60	13.0 – 25.0	80 – 125	20 – 80
Plums	350	4.0 – 7.0	48 – 200	30 – 44
Raspberries	320	8.0 – 75.0	20 – 30	70
Rhubarb	30 – 100	9.0 – 24.0	10 – 25	—
Strawberries	60 – 90	49 – 60	30	30 – 70

Table 9 shows an evaluation of the apple as a vitamin carrier in comparison with some other fruits. Apples do not rank high as vitamin carriers. In this respect, they are similar in value to pears, plums, and rhubarb. However, the nutritional value of the apple would be greatly misrepresented if it were considered only as a source of vitamins.

Vitamin A

Potter (1933) found practically no difference in the vitamin A content of three varieties (McIntosh, Red Delicious, and Golden Delicious) of apples grown in Washington. The presence of yellow pigment in the apple was not related to vitamin A potency. Potter showed that apples are equal to orange juice in vitamin A content and that they compare favorably with other fruits as a source of vitamin A. Fraps and Treichler (1933) indicate that apples are rather an expensive source of vitamins as compared with many other foods.

Vitamin A occurs in apples and in all plants only as carotene. There is some question as to the equivalent potencies of vitamin A and carotene. Recent research seems to show equal or nearly equal potencies, although the usual conversion factor is 1.0 International Unit of vitamin A = 0.66 micrograms of carotene.

In compilation of data on the vitamin content of foods, Daniel and Munsell (1937) indicated that fresh apples contained from 58 to 147 I.U. of vitamin A per 100 grams. Todhunter (1937) reported that the peel of Richared apples was at least five times as rich in vitamin A as the flesh of the apple. Delicious apples contained approximately 102 I.U. per 100 grams of apple.

Thiamin

The thiamin content of apples is low, and they cannot be considered an important source of this vitamin. Lane, Johnson and Williams (1942) in a study of sources of thiamin in the American diet, used apples which contained .019 milligrams per 100 grams. When apples were made into applesauce, approximately 30 percent of the thiamin was destroyed during heating. Cheldelin and Williams (1942) analyzed apples that contained 0.096 milligrams of thiamin per 100 grams. In a compilation of information on the vitamin content of foods, American Can Company (1943) indicated that apples contained from 0.010 to 0.69 milligrams of thiamin per 100 grams. The thiamin content varied with the variety.

Other "B-Vitamins"

As may be seen in Table 8 apples contain only relatively small amounts of most of the "B-vitamins." Lanford, Finkelstein and Sherman (1941) found that the citrus fruits, bananas, and tomatoes were richer in riboflavin than the pome fruits as represented by apples and pears. Apples contained 4.3 micrograms of riboflavin per 100 grams. According to American Can Co. (1943) the riboflavin content of apples may range from 0.010 to 0.073 milligrams per 100 grams.

Tepley, Strong and Elvehjem (1942) reported that peeled apples contained 0.50 milligrams of niacin (nicotinic acid) per 100 grams and that the peel contained 1.13 milligrams. McVicar and Berryman (1942) reported similar figures.

According to Jukes (1941) apples are a poor source of pantothenic acid, containing less than .03 milligrams per 100 grams on a fresh basis. Likewise, apples are a poor source of pyridoxine according to Schneider, Ascham, Platz and Steenbock (1939).

In studies on the B-vitamin content of foods Cheldelin and Williams (1942) reported the following amounts in terms of milligrams per 100 grams of fresh apple: thiamin, 0.096; riboflavin, 0.018; nicotinic acid, 0.081; pantothenic acid, 0.060; pyridoxine, 0.026; biotin, 0.0009; inositol, 24.0; and folic acid, 0.008.

Ascorbic Acid

Considerable work has been reported concerning the ascorbic acid content of apples and factors influencing it. One of the first studies on the ascorbic acid content of different varieties of apples grown in the United States was reported by Fellers, Cleveland and Clague (1933) and Smith and Fellers (1934). These workers investigated 21 varieties of Massachusetts-grown apples, which were classified as to their vitamin C potency as follows:

Very Good	*Good*	*Fair*	*Poor*
Baldwin	Esopus (Spitzenberg)	Arkansas	Jonathan
Northern Spy	Rome Beauty	Gravenstein	Delicious
Ben Davis	Red Astrachan	Wealthy	Tolman
Winesap	King	Cortland	McIntosh
	Roxbury Russet	King David	
	Rhode Island Greening	Golden Delicious	
	Stayman		

In a more recent investigation Fellers and Dunker (1940) evaluated 69 varieties of Massachusetts apples as to their ascorbic acid content, which was found to range from 0.7 to 11.6 milligrams per 100 grams of fresh fruit as shown in Table 10. Other workers have found that the ascorbic acid content of apples ranged from 1.0 to 20.8 milligrams per 100 grams.

Fellers, Isham, and Smith (1932) reported that the epidermis of Baldwin apples contains about four times as much vitamin C as the flesh immediately beneath it, and six to ten times as much as the flesh near the core. McIntosh apples also contain much more vitamin C in the peel than in the flesh.

FACTORS AFFECTING COMPOSITION OF APPLES

As is the case with other agricultural crops, there are a number of factors that may exert an influence on the composition of apples. Because of the extensive

TABLE 10.—THE ASCORBIC ACID CONTENT IN SIXTY-NINE VARIETIES OF APPLES GROWN IN MASSACHUSETTS.
(Original data*)

Variety	Ascorbic Acid (Fresh Basis) Bioassay Results	Ascorbic Acid (Fresh Basis) Dye Titration	Variety	Ascorbic Acid (Fresh Basis) Bioassay Results	Ascorbic Acid (Fresh Basis) Dye Titration
	mg. per 100 gm.			mg. per 100 gm.	
Arkansas	4.7	2.1	Montreal	—	1.3
Arkansas Black	—	2.9	Mother	—	1.9
Baldwin	12.5	5.8	Newell	—	5.0
Bailey Sweet	—	2.4	Northern Spy	10.0	7.5
Ben Davis	8.3	—	Northwestern Greening	—	4.5
Bietigheimer	—	0.9	Patricia	—	1.7
Bismark	—	1.9	Pedro	—	2.6
Blenheim	—	3.8	Pewaukee	—	2.1
Brock	—	1.2	Porter	—	1.4
Canada Baldwin	—	4.1	Pumpkin Sweet	—	1.3
Carlton	—	1.4	Ranier	—	3.8
Coopers' Early Seedling	—	1.2	Rambo	—	2.7
Cortland	4.2	3.7	Red Astrachan	6.2	—
Delicious	2.0	4.9	Red Sauce	—	2.5
Esopus Spitzenberg	—	6.0	Rhode Island Greening	5.8	2.3
Fall Pippin	—	0.7	Ribston	—	4.0
Fameuse	—	2.1	Rome Beauty	6.6	—
Gano	—	2.4	Roxbury Russet	5.8	—
Golden Delicious	3.3	1.7	Stark	—	3.6
Gravenstein	4.5	1.2	Starking	—	4.6
Grimes Golden	—	1.2	Stayman	5.8	—
Helm	—	1.2	Stimson	—	4.0
Hurlburt	—	3.1	Summer Extra	—	0.9
Jonathan	3.1	3.3	Tolman	2.5	—
Joyce	—	2.6	Tolman Sweet	—	2.9
King	5.8	3.9	Tompkins King	—	3.4
King David	3.3	7.4	Twenty Ounce	—	7.8
Lawver	—	11.6	Wagener	—	4.8
Limberturg	—	3.5	Washington Red Gravenstein	—	1.5
MacMahon	—	1.8			
Maiden Blush	—	1.3	Wealthy	4.2	3.2
Mann	—	3.8	Winesap	7.7	6.6
McIntosh	2.0	3.1	Winter Banana	—	4.6
Milton	—	3.2	Winter St. Lawrence	—	2.6
			Wolf River	—	0.8
			Yellow Belleflower	—	3.8

* Dr. C. F. Dunker carried out the dye titrations for ascorbic acid.

amount of work that has been reported on the subject it is impossible to review all of it here. The present discussion will be confined to pointing out some of the factors concerned and their effect on apples.

Variety

There is evidence that each variety of apples has a characteristic chemical composition that is fairly constant when maturity is attained. Shaw (1911) stated that many of the differences found in various samples of a single variety could be attributed to a difference in the stage of maturity. Chatfield and Adams (1940) summarized data on the composition of summer, fall, and winter apples as shown in Table 1. According to this information the early varieties tend to contain slightly more water than the later varieties. The protein, fat, and ash content were fairly constant. The total carbohydrate content was slightly higher in the later varieties, whereas the acidity was highest in the early varieties.

Smith and Fellers (1934), Manville, McMinis and Chuinard (1936), Todhunter (1939), and others have discussed the differences in vitamin A, B, and C content in different varieties of apples. Some investigators have indicated that the vitamin C content of apples tends to increase as the chromosome number in the cells of vegetative tissues increases, but Smith and Fellers (1934) did not observe any such correlation.

Environment and Climate

Besides genetic factors the composition of the apple may also be significantly influenced by environmental factors. The effect of climatic conditions on the composition of apples has been studied extensively by Shaw (1911) and Caldwell (1928a, 1928b). According to Caldwell it would appear that the annual crop of fruit upon a perennial plant is an integrated expression of the climatic factors for the season in which it is produced in the same degree to which the growth of an annual plant is integrated with these factors. He further indicated that the mean summer temperature as a separate factor has little influence in determining the composition of apples.

Murneck (1945) compared the composition of apples during development to harvesting maturity on the outside portion of the tree with better exposure to light, and that of apples developed on shaded branches. The apples on branches with better light were almost invariably higher in ascorbic acid content than those grown on shaded branches. This was not merely "skin-deep," but extended within the flesh of the fruit. The smaller apples were somewhat higher in ascorbic acid than the larger ones. Moreover, if a limb carried a relatively light crop, the vitamin content of the apple was apt to be somewhat higher than where the yield was heavy. It was also reported that the ascorbic acid concentration in fruit borne on weak trees, was higher than in fruit on trees of high vegetative vigor. The ratio of the leaf area to fruit in relation to the vitamin C content of Delicious and Winesap apples was studied by Batchelder and Overholser (1936). The Winesap seemed to show higher vitamin C values when the ratio was low, but the Delicious apples showed no differences. The leaf–fruit ratio seemed not to affect the vitamin C content directly.

Soil and Fertilizer Treatment

Wilder (1909) of Massachusetts Experiment Station determined the soil adaptations of various varieties of apple trees and indicated that different varieties have decided preferences as to soil. However, Shaw (1911) states that "not enough is known regarding this question to make any very definite generalization on the subject."

The effect of fertilizers was investigated by Aldrich (1931), who applied sodium nitrate (Chili saltpeter) during the months of August and September and then studied the quality of the apple fruit. This treatment decreased the color, increased the nitrogen content and had no measurable effect on keeping quality.

Magness and Overley (1930) studied the keeping quality of apples from untreated and from nitrate- or potash-treated trees, but found no significant differences.

Todhunter (1937) reported results of studies of apples from unfertilized, normally fertilized, and heavily fertilized soil. No differences were found, either in the vitamin C content or in the nitrogen content of the apples. In general the beneficial effect of sunlight on color and flavor is well known. The quality and size of fruit is improved by good pruning and soil fertility practices. Good moisture conditions are also required.

After reviewing the "spray residue" problem, Clague and Fellers (1936) stated that "arsenic and lead residues often persist on apples after picking. Only a small part of these toxic substances is removed by ordinary fruit washing methods. Commercially, apples are often washed in solutions containing from 0.5 to 1 percent hydrochloric acid. This treatment is effective in residue removal." In the East the normal rainfall removes most of the spray before harvest. Furthermore, orchardists are refraining from using lead or arsenic sprays during the latter part of the season. It is not believed that spray residue on apples constitutes a health hazard in the non-irrigated sections of the United States.

Water Supply

The dessert and keeping qualities of the apple are not adversely affected when the moisture supply varies enough to permit it to fall temporarily to the wilting point, according to Gourley and Howlett (1941). They point out, however, that extremes of moisture are undesirable. Pressure tests indicated that fruits growing under a higher degree of moisture were softer and more susceptible to soft scald. Drier plots produced fruits more acid and better flavored. The general consensus of opinion is that excessive irrigation may have a detrimental effect. Apple trees, as a result of their deeper rooting system, have access to a much larger water reserve than herbaceous plants, and therefore any moisture changes are not quickly apparent in the fruit.

Storage

Gunness, Cole and Roberts (1939) have described the effect of storage on apples as follows:

> An apple grows as a part of a living organism—the tree. Before harvest it continues to receive materials from the tree and the net result of these life processes is growth and increased weight. After removal from the tree, life must be sustained on food stored in the apple. Life processes are destructive, and when they have run their course, the apple dies. This natural breakdown of the apple is marked by a gradual darkening of the flesh beginning at the core, and may occur without rotting. Frequently, decay organisms attack the apple and it rots before its food reserves are completely exhausted.
>
> The changes that take place within the apple are the result of chemical reactions. The important constituents affecting the quality of an apple are starch, sugars, acids, tannins, pectins, and esters which are compounds responsible for the characteristic odor and flavor of a particular variety. Quality in an apple depends chiefly upon the proportions of sugars and acids. Prior to harvest, an apple contains a relatively large quantity of starches. In the process of ripening, the starches change to sugars and the acids and tannins diminish, thus making the apple more agreeable to eat. Changes in the character of the pectins are believed to be responsible for the "mealy" or granular condition of the flesh as apples become overripe. Chemical changes within the apple are accompanied by the utilization of oxygen and the evolution of carbon dioxide. This process is known as respiration and is a measure of the speed of ripening. These chemical changes are hastened by heat and retarded by cold. If left in the orchard, an apple may reach its maximum quality for human consumption in early autumn. If exposed to low temperatures before that maximum is reached, development may be retarded and a condition of prime eating quality reached in February or March instead of September or October.

> This is the function of storage. No method has yet been discovered by which life processes in an apple may be stopped and the apple held indefinitely at one stage of development without killing it. The progression must go on, but efficient storage slows it down to a marked degree.

There is ample evidence that storage brings marked changes in apples. The factors influencing the storage qualities of apples, according to Wallace (1930) can be summarized as follows:

(a) Material — variety and age of tree.

(b) Environmental. These may be further divided into two subgroups:

1. Natural conditions — including the climatic factors, soil, pests, fungi, etc.
2. Artificial factors introduced by the grower — including soil treatment, other operations, picking, and handling.

Carlsen (1946) reported that a gradual reduction of temperature from 45° to 36° to 31° F. will keep Delicious apples in better condition than any other practice, except immediate storage at 31° F. The age of the apple after picking can be measured by the structural changes within the apple as shown by increases in the soluble pectin content determined by chemical analyses. The softening of the flesh which accompanies ripening or maturity is due to gradual increase in the soluble pectin content. These changes take place much more rapidly and completely in so-called early and summer varieties such as Yellow Transparent, Red Astrachan, Williams, etc. The rate of softening is closely related to temperature of storage.

Fellers, Cleveland and Clague (1933) found that apples tend to decrease in ascorbic acid content during storage. This change varies to some degree with the variety and takes place more rapidly at warm storage temperatures. Baldwin apples had lost about 20 percent of their vitamin C content after 4 to 6 months' storage at 36°F., and after 8 to 10 months the loss had reached nearly 40 percent. At a storage temperature close to 32°F. there is but little loss of ascorbic acid. At warmer storage temperatures the loss may be as much as 50 percent after 6 to 8 months. According to Thornton (1938) no loss of ascorbic acid occurred in apples stored in an atmosphere of carbon dioxide. Todhunter (1937) found that Delicious apples kept for one year at 45°F. retained approximately only half of their original vitamin C content. Other investigators have reported similar findings in respect to changes in the ascorbic acid content of apples during storage.

EFFECT OF PROCESSING AND COOKING ON COMPOSITION AND NUTRITIVE VALUE

Cooking

Apples tend to lose certain of their nutrients during cooking as do other foods. So far as the apple is concerned, ascorbic acid (vitamin C) is probably the nutritive element that shows the greatest change during cooking. The other nutrients can be expected to be quite stable with the exception that some water-soluble materials may be leached from the apple if it is cooked in an excess of water or syrup. However, ordinarily apples are not cooked by methods which would lead to an excessive leaching of nutrients.

Fellers, Isham, and Smith (1933) and Todhunter (1935) found that a considerable amount of the original ascorbic acid of fresh apples was retained when they were made into applesauce or baked in pie. Baked apples were found to retain a much higher percentage of their original ascorbic acid. Curran, Tressler and King (1937) reported a 20 to 30 percent loss of ascorbic acid when Northern Spy apples were made into applesauce and 80 percent loss when these apples were baked or made into pies. After 48 hours at room temperature the vitamin C content of apple pie filling had been reduced to 12 percent of the original. They concluded that the factors influencing the loss of ascorbic acid were the length of the cooking period, the relatively slow rate of heat penetration with corresponding delayed effect on oxidase enzymes, and the presence of atmospheric oxygen. Kohman (1937) indicated that ascorbic acid would be better retained if apples were immersed in a salt solution before processing.

According to Pfund (1939) good flavor in cooked apples is associated with relatively high acidity (pH 3.1 to 3.4), firmness of the raw fruit, short storage periods, aromatic and spicy qualities, retention of natural flavor of the raw fruit, pleasant texture, and, for applesauce, a lack of thickness in consistency. The flavor of apples cooked after January was considered unsatisfactory if the flavor procurable before and during January was used as a criterion. Pleasant texture in cooked apples was associated with relatively high acidity (pH less than 3.3), short storage periods, tenderness in the raw fruit, juiciness, fineness, mealiness, and, for applesauce, a lack of thickness in consistency. Coarseness was more undesirable in applesauce than in baked apples, but dryness of applesauce was masked by the addition of water during preparation. Texture in cooked apples, like flavor, was less agreeable after January; but, unlike flavor, it may be comparatively satisfactory for some varieties through March.

The food value of certain cooked apple products, as reported by Taylor (1942) is shown in Table 11.

Apple Products

Cider

Clague and Fellers (1936) determined the more important physical and chemical characteristics of cider made from different varieties of apples grown in Massachusetts. Their data are shown in Table 12. In a discussion of the nutritive value of cider they pointed out that apple cider should be sold on its merits as a pleasant, refreshing beverage and not primarily because of its nutritional properties. The vitamin C content of cider was found to be quite low.

Apple Juice

Apple juice (a term usually applied to clarified and bottled or canned cider) has essentially the same composition and food value as the cider from which it was made. Esselen (1945) reviewed methods used in the production of apple juice and made suggestions for the improvement of this product, particularly as regards the use of McIntosh apples grown in this locality. The results of this work were summarized as follows:

> The flash-heating method of clarification has been found to be particularly effective for apple juice. Apple juice clarified by this method showed no tendency to throw down a sediment during storage and was superior in flavor to juices clarified by other methods.
>
> The temperature of extracting apple juice and the speed with which it is flash-heated after extraction influence the rate of oxidation and subsequent flavor of the finished product. By taking these factors into consideration

Table 11.—Food Value of Cooked or Prepared Apple Products

(Taylor, 1942)

Product	Weight		Approximate Measure	Calories	Protein	Calcium	Iron	Vitamin A	Thiamin	Ascorbic Acid	Riboflavin
	grams	ounces			grams	mg.	mg.	I.U.	mg.	mg.	mg.
Baked Apple	132	4.6	1 medium apple	160	0 5	10.0	0.45	90	.034	2.0	.038
Apple Juice	235	8.3	1 cup	118	0.2	15.0	0.66	135	047	12.0	.071
Applesauce	126	4.4	½ cup	135	0.5	10.0	0.45	90	.034	5.0	.038
Applesauce cake	23	0.8	1 piece, 1½" x 3¾" x 1½"	100	1.1	3.0	—	50	.012	—	.009
Cider, sweet	170	6.0	1 glass	85	0.2	—	—	—	—	8.0	—
Apple fritters	24	0.8	1 slice apple, 2¾" in diameter, ½" thick	50	0.5	5.0	0.16	35	.012	1.0	.018
Apple pie	157	5.5	4½" sector	300	3.2	12.0	0.60	150	.029	1.0	.027
Apple pie	100	3.5	3½" sector	230	2.3	9.0	0.46	115	.022	1.0	.021
Salad, apple and carrot*	82	2.9	½ cup	100	0.6	22.0	0.40	1,335	.072	5.0	.081
Salad, apple and cabbage*	125	4.4	½ cup cabbage ¼ large apple	150	1.4	41.0	0.80	165	.090	40.0	.099
Salad, Waldorf*	114	4.0	½ cup	185	1.9	49.0	0.76	165	.078	8.0	.063

*With mayonnaise

Table 12.—Composition of Juices Made From Several Varieties of Massachusetts Apples

(Clague and Fellers, 1936)

Variety	Specific Gravity		Degrees Brix		pH		Viscosity		Pectin, Percent		Tannin, Percent		Total Acid, Percent		Ash, Percent	
	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934
Baldwin	1.055	1.041	14.1	11.8	3.2	3.5	3.8	3.2	.10	.10	.08	.06	.56	.48	.16	.19
Ben Davis	1.045	1.045	10.9	11.5	4.0	3.7	4.2	3.8	.08	.31	.05	.06	.33	.43	.20	.16
King	1.055	1.050	12.5	12.9	4.0	3.6	5.1	7.3	.18	.26	.04	.07	.40	.53	.16	.17
McIntosh	1.045	1.040	12.2	11.5	3.1	3.5	4.3	4.6	.18	.11	..	.08	.41	.48	.24	.15
Northern Spy	1.045	1.045	11.8	12.0	3.2	3.4	4.0	2.2	.08	.09	.08	.08	.48	.49	.18	.13
Rhode Island Greening	1.045	1.045	11.2	12.0	3.2	3.5	4.7	5.6	.16	.30	.04	07	.44	.47	.14	.12
Roxbury Russet	1.065	1.065	15.5	16.0	3.9	3.3	5.1	4.7	.18	.32	.07	.06	.61	.67	.15	.15
Wealthy	1.040	1.045	9.8	11.5	3.6	3.3	4.7	4.2	.15	.28	.05	.05	.57	.61	.23	.19
Crab	1.065	....	16.0	...	...	...	...	...	.09	...	.25	...	.75	...	.38	...
Average	1.051	1.047	12.7	12.4	3.5	3.5	4.5	4.5	.13	.22	.08	.07	51	.52	.20	.16

> it may be possible to control to some extent the intensity of fresh apple flavor and cider flavor in processed apple juice. It is possible that other methods of controlling oxidation such as the use of antioxidants or the extraction and handling of the juice in an oxygen-free atmosphere might also be of value in producing an apple juice of light color and fresh apple flavor.
>
> In Massachusetts and New England the McIntosh is the most important commercial apple crop. Unfortunately, the juice of the McIntosh, grown in this area, has a rather insipid flavor and must be blended with the juice of other apple varieties for the manufacture of palatable processed apple juice. Tests have been made to determine the optimum amount of McIntosh apples that can be blended with Baldwin or Delicious varieties to yield a good commercial product. It was found that blends of Baldwins containing up to 60 per cent of McIntosh apples yielded a pleasing product. In such blends it is not recommended that over 25 per cent of Red Delicious apples be used owing to their strong aromatic flavor.

In a recent paper Esselen, Powers and Fellers (1946) reported on the fortification of fruit juices, such as apple juice, with ascorbic acid. It would appear that apple juice deserves consideration, in this respect, because of its increased use as a breakfast juice. Added ascorbic acid in fortified apple juice was well retained during processing and storage. The addition of 195 grams of l-ascorbic acid per 100 gallons of apple juice before pasteurization was adequate to provide a finished product that contained at least 35 milligrams of ascorbic acid per 100 milliliters. Such a fortified apple juice is comparable to orange and grapefruit juices as a source of vitamin C. The addition of ascorbic acid to bottled apple juice also had a marked effect in lightening the color of the juice and in retarding darkening during storage. In the opinion of many people the lighter color in apple juice produced by added ascorbic acid improves its appearance. Added ascorbic acid also had a flavorable effect on flavor retention in most cases.

Canned Baked Apples

Ruffley, Clague and Fellers (1939) found that canned glazed apples retained more vitamin C than did canned baked apples. The average loss of vitamin C for five varieties of canned baked apples was 65 percent, and in the canned glazed apples 44 percent. The percentage composition of canned baked Northern Spy apples is shown in Table 13.

Varieties of apples found suitable for canning after baking or glazing were those relatively high in pectin and acid content such as Baldwin, York, Rhode Island Greening, Gravenstein, and Northern Spy.

Table 13.—Composition of Canned Baked Northern Spy Apples

(Ruffly, Clague, and Fellers, 1939)

Water	72.31 percent
Protein (N x 6.25)	0.20 percent
Crude Fat	0.26 percent
Ash	0.19 percent
Crude Fiber	0.65 percent
Total Carbohydrates	27.04 percent
Acid (as Malic)	0.31 percent
Fuel Value per 100 Grams	113.10 calories

TABLE 14.—AVERAGE COMPOSITION OF CANNED APPLE PRODUCTS

(American Can Company, 1943)

Product	Type of Pack*	Number of Analyses	Moisture	Total Solids	Ash	Fat (Ether Extract)	Protein (N x 6.25)	Crude Fiber	Carbohydrates by Difference	Calories Per Gram	Calories Per Pound
			percent	percent	percent	percent	percent	percent	percent		
Apples, baked	AS	1	67.1	32.9	0.3	0.4	0.7	0.7	30.8	1.3	588
Apple juice	NS	2	88.5	11.5	0.2	0.1	0.1	trace	11.2	0.5	206
Apple rings	NS	1	87.4	12.6	0.2	0.3	0.1	1.0	11.0	0.5	213
Applesauce	NS	3	88.1	11.9	0.2	0.2	0.3	0.6	10.2	0.4	197
Applesauce	AS	2	75.7	24.3	0.2	0.1	0.2	0.5	23.1	1.0	426
Applesauce	JP	–	87.3	12.7	0.3	0.2	0.2	0.6	11.4	0.5	230
Applesauce, chopped	AS	1	85.8	14.2	0.4	0.7	0.1	2.1	10.9	0.5	228
Applesauce, strained	NS, NSA	2	87.9	12.1	0.3	0.2	0.2	0.6	10.8	0.5	207
Applesauce, strained	NS, SA	1	87.9	12.1	0.2	trace	0.3	0.5	11.1	0.5	209
Applesauce, strained	AS	3	85.2	14.8	0.3	0.4	0.2	1.1	13.0	0.6	251
Applesauce, strained	AS, SA	1	79.2	20.8	0.8	0.8	0.2	1.0	17.5	0.8	354

* AS — added sugar
JP — juice packed
NS — no added sugar
SA — salt added

Canned Apples and Applesauce

In general the composition of canned apples or applesauce is essentially the same as that of the apples from which they are made. The addition of sugar, syrup, or water in the preparation or canning of these products will alter their composition accordingly. Except for ascorbic acid, the other nutrients of the apple can be expected to be reasonably stable in the canned product. The composition of several canned apple products, as summarized by American Can Company (1943), is shown in Table 14.

Dried Apples

Dried apples are a much more concentrated source of nutrients than are raw apples, owing to the removal of moisture. However, in actual use they are usually rehydrated and so tend to resemble the fresh product in composition. The average proximate composition of dried apples, as reported by Chatfield and Adams (1940) is shown in Table 15. The composition of dried apple powder as reported by the American Medical Association (1939) may be seen in Table 16.

Table 15.—Proximate Composition of Dried Apples

(Chatfield and Adams, 1940)

Moisture		23.0 percent
Protein		1.4 percent
Fat		1.0 percent
Ash		1.4 percent
Carbohydrates, Total		73.2 percent
Fiber	4.6 percent	
Sugars	54.0 percent	
Acid (as Malic)		2.3 percent
Fuel Value		
Per 100 grams		307.0 calories
Per pound		1,395.0 calories

PHYSIOLOGICAL AND THERAPEUTIC PROPERTIES OF APPLES

Calcium Retention

Mindell, Esselen and Fellers (1939) found that the addition of apples or cranberries to the diet of albino rats appeared to increase the amount of calcium absorbed by the animals. It was suggested that the increased calcium retention resulting from fruit diets might be due to an increased acidity of the intestinal tract as had been reported by Esselen (1937) and Sullivan and Manville (1938). Another possibility suggested was that the calcium of the diet might have reacted with the acid of the fruit to form more soluble calcium compounds.

TABLE 16.—COMPOSITION OF APPLE POWDER

(American Medical Association, 1939)

Moisture	2.0	percent
Total solids	98.0	percent
Ash	1.8	percent
Fat (ether extract)	2.5	percent
Protein (N x 6.25)	1.5	percent
Crude fiber	6.7	percent
Reducing sugars (before inversion..)	52.0	percent
Sucrose	17.1	percent
Pectin (alcohol precipitate)	5.2	percent
Uronic acids	9.2	percent
Total carbohydrates (by difference)	84.1	percent
Tannin and coloring matter	1.4	percent
Total sulfurous acid	0.01	percent
Total acidity (as malic)	2.9	percent
pH	3.5	
Alkalinity of ash, equivalent to 240 cc. of 0.1 N acid/100 gm. powder.		
Sodium	0.11	percent
Potassium	0.87	percent
Calcium	0.015	percent
Magnesium	0.029	percent
Copper	0.0008	percent
Iron	0.0125	percent
Phosphorus	0.0014	percent
Chloride	0.216	percent
Total sulfur	0.137	percent
Silica (SiO_2)	0.01	percent
Sulfur dioxide	0.0004	percent
Calories 95.0 per ounce	3.7	per gram

Treatment of Intestinal Disturbances

According to Manville, Bradway and McMinis (1937), it is in the German folk customs that the idea of using the apple in specific ailments originated. The suggestion of treating the acute digestive disturbances accompanied by diarrhea, which are so frequent in childhood, with bananas, orange juice, or raw apple, either alone or all together, was made by Fanconi (1930). About this time Moro (1929) and Heisler (1930) promulgated their raw-apple therapy for diarrhea of young children, based on the old custom among German peasants of using raw apple for this disorder.

A review of the literature indicates at least five factors which have been suggested as being responsible for the beneficial action of such fruit diets.

1. Tannic acid and astringency.
2. Cellulose and pectin, which act to scour out the intestines, effectively removing bacteria which are basic causes of difficulty.
3. Effect on the pH (acidity) of the intestinal tract, which may be such as to discourage the growth of bacteria.
4. Carbohydrate content of some fruits, which may act to bring about a change in the intestinal bacterial flora through promoting growth of organ-

isms whose presence creates an unfavorable medium for other types of bacteria.

5. Increased calcium excretion through the mucosa. The increased calcium may inhibit intestinal inflammation and detoxicate amines and phenols by salt formation.

In order to study the beneficial action of fruit diets for intestinal disorders, Esselen (1937) investigated the effect of cranberry, blueberry, and apple diets on the intestinal bacterial flora, intestinal putrefaction, and intestinal acidity of the albino rat. A 20 percent cranberry diet was found effective in reducing the numbers of fecal gas-producing and *Escherichia coli* bacteria. There was also evidence that 20 percent apple, blueberry, and cranberry diets materially decreased intestinal putrefaction. A study of the hydrogen-ion concentrations of the intestinal contents showed that diets of 10 and 20 percent raw cranberry and of 100 percent raw apple significantly increased the acidity of the contents ot the cecum and large intestine.

Manville and Sullivan (1940) found that the feeding of a dehydrated apple supplement to rabbits increased the hydrogen-ion concentration of the intestinal contents and changed the intestinal flora from one in which *Escherichia coli* predominated to one in which the acidophilic type of organisms was dominant.

Bergeim, Hanszen and Arnold (1936) referred to the presence of definite communities of bacterial life residing within the lumen of the alimentary canal. A fruit meal of apple or banana was found to bring about a condition in the stomach and intestine that is inimical to the presence of bacteria. Feeding the pulp of one apple, or 70 grams of dried banana to human subjects, prior to the introduction into the stomach of a large number of bacteria, caused a condition in the intestine that resulted in the destruction of all, or nearly all, of the organisms ingested. The *Escherichia coli* were also greatly reduced in the subjects fed fruit pre-meals. The meal of fruit, aside from its acid content was considered to be inimical to bacteria because of the butyric acid derived from it. The authors stated further that a fruit pre-meal also reduces the irritating properties of foods to which an individual may be sensitive.

The use of apple powder in the treatment of diarrhea has been reviewed in some detail by Manville, Bradway, and McMinis (1936b, 1937), and the history of the apple in ancient and modern nutrition has been described by Manville (1936a).

Kertesz, Walker and McCay (1941) observed the effect of feeding applesauce on induced diarrhea in rats in order to determine further how an apple diet acts in this respect. The feeding of commercial canned applesauce resulted in a rapid curing of diarrhea. The experimental results confirmed the opinion held by many investigators that pectin is an effective constituent of the apple diet; but, contrary to the opinion of some investigators, it appeared that pectins were not the sole agents in the apple responsible for the curative effect. It was pointed out that, while the important role of the "fiber" content of various foods has often been emphasized and in turn also enlisted as a possible active principle in the apple diet, this was the first case where its important role in curing diarrhea had been demonstrated. An evaluation of the results indicated that the curative effect of the applesauce depended on the pectins and fibrous materials responsible for its colliodal properties. There was no indication that the presence of uronic acids or tannins had any role in curing the induced diarrhea in rats.

From an investigation of pectin as a detoxication mechanism in the body, Manville, Bradway, and McMinis (1936a) demonstrated that galacturonic acid (a breakdown product of pectin) is capable of forming conjugation products with toxic materials in the same manner as glucuronic acid. Evidence was also obtained that pectin may exert a protein-sparing action. Foods containing hemicellulose and pectin, such as apples, were considered to have a value separate and distinct from caloric considerations. Manville, Reithel, Yamada, Spencer and Richardson (1940), in further studies on pectin and the detoxication mechanism in rats, guinea pigs, and rabbits, found that apple included in the diet is capable of affording protection against the toxic effects of ingested lead.

From further studies on the relationship of organic acids and pectin to the body's self-regulation defense mechanism, Manville and Sullivan (1940) indicated that the bactericidal effect of such food mater als as the apple in the intestine is not so much due to substances contained in them as to factors derived from them by enzymic action.

The American Medical Association (1939) have reviewed the question of the therapeutic value of apples in the light of available information and have pointed out that much more evidence is needed before the precise mechanisms involved are made clear. It was concluded by their Council on Foods that the apple is useful as a therapeutic agent in the dietary management of diarrhea but that the mechanism responsible for the reported success of this diet is not clear. It was further emphasized that the use of the fresh or dried apple does not obviate the necessity for other measures, including parenteral administration of fluids when indicated, the careful selection of a suitable transition diet, and competent pediatric supervision.

SUMMARY

Apples have been widely used as a food from earliest times. In addition to their aesthetic and appetite appeal they have also a definite food value. Chemical analyses show that the edible portion of the apple is in general similar in composition to many of the other fruits. Although the apple cannot be considered an important source of minerals, its liberal use in the diet does contribute definite amounts of the mineral elements needed by the body.

During the process of digestion the acids of the apple are oxidized, and for this reason apples are considered an alkaline food. Tests with human subjects have shown that a person can eat large amounts of apples with no effect on the alkali reserve of the blood.

The use of raw apple in the treatment of diarrhea dates back many years in Germany and other European countries. Recent scientific evidence points to pectin as one of the substances in the apple which is important in bringing about the beneficial effect. Pectin is thought to exert its effect by removal of toxic substances because of its colloidal properties and buffering action. It may also serve as a source of galacturonic acid. The tannin and acid contents of the apple have also been suggested as an aid in maintaining intestinal tone and motility.

The Council on Foods of the American Medical Association has concluded that the apple is useful as a therapeutic agent in the dietary management of diarrhea.

In addition to their other properties apples also contain their share of the vitamins. When eaten fresh, apples can constitute an important source of ascorbic acid (vitamin C) in the diet. They also contain vitamin A, thiamin, and the other "B-vitamins" in small amounts.

We have always eaten apples for their zest, attractiveness, and flavor. Now with a recognized food value assigned to them we can appreciate apples for their nutritive as well as their aesthetic value.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 441 SEPTEMBER 1947

Annual Report

For the Fiscal Year Ending June 30, 1947

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1946-47

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Development of Statistical Data as Controls to Livestock Production Program. (A. A. Brown and Elaine M. Roberson.) The 6 percent areal sample proved satisfactory for estimating the total number of farms. The estimate was within one half of one percent of the map count. Errors of estimate ranged from a low of 3.97 percent for number of farms to 19.47 percent for the number of chickens on commercial poultry farms. The estimates differed substantially from census data or crop reporting service data. The usefulness of the method to Massachusetts could be improved by type-of-farm maps, improved sample design, and improvements in field procedure.

It is not the intention, however, to carry the work any further. The Crop Reporting Service has recently begun to use the areal method for selected items; and, until the results of this experience become available, this project will be held in abeyance.

The Effect of Public Regulation of Milk Marketing Upon the Organization of the Milksheds of Massachusetts Markets. (A. A. Brown.) Attention was given during the past year to the movement of supplemental milk supplies from the North Central States to eastern markets, especially Boston. Data were assembled covering routes, rates, and service.

Normally milk cars are handled as head-end tonnage on scheduled passenger trains; the rule being to put them into the first available connection. During the fall months, in recent years of heavy shipment, several of the carriers have set up a "Milk-Extra" so as to better handle the traffic.

Through rates exist between many shipping points in Illinois, Iowa, Minnesota, and Wisconsin and principal eastern markets. Commodity tariffs applicable to milk and cream moving in Passenger Train Service are effective. Most of the rates are on a ten-gallon can basis. Only a few special gallon rates are published for movement in tank cars. When milk moves in tank cars between points having only the can rate, the amount to be charged is based on the rate per gallon of the ten-gallon can rate.

Among several selected shipping points in the dairy states, there was a range of 20 cents per can in the rate on a carload minimum of 2500 gallons (250 forty-quart cans). Madison, Wisconsin, had the lowest rate to Boston of $1.39 per can, and Minneapolis the highest at $1.59 per can; both rates before tax.

This short study will become part of a more inclusive one dealing with price and volumes as well as transportation of the supplemental supplies.

A Study of Farm Real Estate Taxation, Methods of Taxation Reform, and the Effect of Such Measures on Farm Income. (A. A. Brown and Judith E. Rosenthal.) Farmers would get a greater return on their curiosity if in addition to scrutinizing their property taxes they studied their valuations. The differences among farms in land, building, livestock, and machinery valuation are substantial. These differences may be interpreted as logically reflecting the assessors' application of the principle of "fair market value" on the grounds that no two properties are ever identical; or contrariwise, that the differences are greater than actually exist for purposes of taxation. Valuation by owners, i.e., market value, is largely influenced by subjective considerations. This element, despite supervisory safeguards, affects assessors' valuations. Subjective consideration cannot be entirely removed even if we wished to do so. Nor is its complete elimination necessary for improvements in the valuation process. This can be achieved for land by applying a system of classification based on broad capability uses. The valuation of cattle would be more equitable if it were reduced to a salvage basis. The difficulties in properly evaluating breeds and grade and mixed herds would be partially overcome if beef values were applied; these values to be determined by the Commissioner of Corporations and Taxation and announced as of November for the succeeding valuation period.

Improving Land on Massachusetts Farms. (C. R. Creek.) The benefits and economic justification of land improvement activities have been appraised on a number of farms where additional land has been brought into production. Power machines such as bulldozers and gas shovels, plus heavy equipment such as brush-breaker plows and bog harrows, have been used to improve farm lands where hand tools and the usual farm machinery were inadequate. Land improvement work in most cases has been limited to a few acres of suitable types of soil on established farms, but in some cases whole farms have been developed on abandoned land. Woodland and brush have been cleared, shrubs and weeds plowed under or harrowed, boulders and stone walls removed from fields, and lowlands drained by dynamited ditches to increase the acreage in orchards, cropland, pasture, and poultry range on farms.

Land improvement work that formerly was costly in terms of man labor now requires only a few hours with power equipment. High income in recent years from land brought into production has paid for the use of machinery in addition to the saving of labor in improvement work. Speed and timeliness were most important where land was cleared for cash crops. Pasture and range improvement aided in lower costs on dairy and poultry farms. Net profits for one or two years often met the total costs of land improvement for certain crops. In extreme cases of high costs and low returns there was no economic justification for land reclamation.

The cost of land improvement work has been amortized for a five-year and a ten-year period to show the annual carrying charge (including interest); and the yields of pasture and crops that would be necessary to pay these annual costs have been calculated on the basis of prewar prices. Normal returns over costs of production would pay the land improvement charges for tobacco in one year, and for potatoes in one to three years for different types of reclamation work. For hay, a longer period was needed to repay costs that were generally lower per acre, because value of the product was less. Generally, five to ten years were required to pay the cost of land improvement. Normal values of pasture would meet improvement costs of $75 to $100 per acre in seven to twelve years. Physical limits on the total yields of crops or pasture and the margin of return over cost of production were determining factors for the cost of land improvement which could be justified on net returns. The indirect effect on the management of the farm by increased size of business and more efficient production was also important in the final decision on this type of work.

Organization and Management of Poultry Farms. (C. R. Creek.) Summaries of poultry accounts for six years showed that the one-third most profitable farms had higher net returns than the one-third least profitable group because of these factors in the farm business: (a) Larger size of business—1200 hens per farm contrasted with 300 hens; (b) Diversification within the poultry business—more sales of hatching eggs and chicks instead of market eggs; (c) Higher egg production—one to four dozen more eggs per hen; (d) Lower cost of feed—two to six cents less per dozen; (e) More favorable feed-egg ratio—one dozen less eggs needed to pay for 100 pounds of feed; (f) More efficient labor—85 more productive work units per man; (g) Higher price received for eggs—one to seven cents more per dozen.

The type of poultry business was an important factor in obtaining high returns as illustrated by the market egg-hatching egg combination. These flocks were of larger size in order to supply a sufficient volume of hatching eggs, egg production was high because of superior breeding and extra care, average egg prices were high because of the premium for hatching eggs, feeding efficiency was high because of high egg production, and labor efficiency was high because these farms were large one-man units and labor-saving practices and equipment were used to advantage.

Many of the family-type poultry farms were started on a part-time basis with a small flock as a minor farm enterprise or while the operator was engaged in a non-farm occupation. Eggs and poultry were sold at retail prices to overcome the disadvantages of small size, low production, high feed costs, and low labor utilization. As experience was gained, the flock was expanded and the type of business developed through the market egg to the hatching egg-market egg combination for greatest profits and most efficient operation. Another adjustment in farm organization was the short-time change to broiler production in 1942 and 1943 in combination with market egg production. Many market egg farms that were operated efficiently showed average returns over a period of years, but were likely to show low returns if one or two measures of the farm business were unfavorable in any one year.

More Efficient Labor Practices on Vegetable Farms. (C. R. Creek.) Variations in organization of the packing crew and the use of a packing table accounted for a range of four to twelve man-minutes of labor per sack to unload, grade, and pack cabbage. Use of a conveyor belt made the packing operation easier with less mechanical damage to heads but about six man-minutes of labor were required per sack.

Various methods of harvesting and packing iceberg lettuce were observed to determine a combination of practices and equipment for efficient, labor-saving, and low-cost harvesting. Preliminary results indicate that bulk hauling of field-harvested heads which are trimmed and packed from a conveyor belt in the packing shed is preferable to field packing of market crates. More specialization and skill is possible with the packing shed system and lettuce can be graded to obtain more uniform packages. Other advantages are cleanliness, less fatigue, and less wilting of heads after packing.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Evaluation of Additions of Sodium Nitrate and Ammonium Sulfate when Applied to the Soil during the Late Summer Preceding the Spring when Tobacco Is Planted. (Walter S. Eisenmenger and Karol J. Kucinski.) It is known that tobacco when planted after such crops as corn, clover, or timothy will not thrive well and will show mild or malignant symptoms of brown rootrot. These plants —corn, clover, and grasses—are comparatively high in lignin at maturity. Many other plants besides tobacco do not thrive well if lignin is present in large amounts.

It is believed that the physiology of plants during the early growing period is not normal under these conditions. The postulate has often been made that micro-organisms instrumental in decomposing tissues containing much lignin need an abundance of nitrogen and consequently rob the seed plant temporarily of this element.

Nitrogen at the rate of 0, 50, 100, 200, 300, and 500 pounds per acre in the form of nitrate of soda was applied to some hay plots in the early fall and to others in the spring before the plots were plowed. Tobacco was grown on these plots. An improvement in the crop index was found in nearly all cases; but the higher rates of 300 and 500 pounds of nitrogen did not greatly increase the yield of tobacco over the lower rates of 100 or 200 pounds. A greater effect due to the nitrogen was noted on those plots that were plowed in the early fall than on those which were similarly treated but plowed in the spring. The warm early fall days apparently gave the micro-organisms an opportunity to act more fully upon the fiber plowed under in the mature grass. Where lime was applied, the response was greater than where no lime was added. It may be concluded, therefore, that the limed land served as a better medium for the decomposing micro-organisms than the unlimed land.

In a similar experiment where corn was plowed under after the ears were removed and nitrate of soda was applied, there was an increase in the yield of tobacco of 100 to 200 pounds per acre.

On plots treated similarly in every respect except that sulfate of ammonia was the form of nitrogen applied, results were not so favorable as where nitrate of soda was applied.

The Absorption of Chemical Elements by Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) In the field, copper ions at the rate of 225 parts per million, calcium carbonate at the rate of 5,000 pounds per acre, and magnesium sulfate at the rate of 225 parts of magnesium per million were added to soil in which rye, barley, and buckwheat were grown. There was no pronounced lowering of the magnesium in the plants where copper was applied. However, when copper and calcium were used together, in every case there was a pronounced increase of calcium intake in all three species of plants as compared with plants which grew where calcium and magnesium were applied singly or together; where copper was applied alone; where magnesium and copper were applied together; or where there was no treatment. There would seem to be no doubt that calcium and copper together augment the intake of calcium for these three species.

Magnesium Requirements of Certain Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Magnesium deficiency is conditioned by factors other than the amount available for plants. During dry growing seasons, magnesium deficiency is not nearly so evident as during wet periods. In the experimental field, one of the deficient areas has received lime every year and the other has not received either lime or magnesium. The symptoms of magnesium deficiency are invariably more pronounced on the plot receiving no lime than on the area where lime was applied. On the magnesium-deficient areas, the pH is about 4.4 where no lime has been applied and about 6.9 where lime has been applied.

In the orchards, it has been found that applications of magnesium are often of no great aid in correcting magnesium deficiency. In the magnesium plots it has been well demonstrated by chemical analysis that very frequently no increase in magnesium or only very small increases occur in the plant tissue of perennials grown on land where magnesium has been applied. This is unlike the usual behavior of annuals.

Plants frequently found as weeds in the garden, such as grasses, members of the aster family, isolated cases of members of the Boraginaceae and Convolvulaceae families, and other well-developed plants, grow seemingly as well on the magnesium-deficient soil as they do on plots supplied with magnesium. On the other hand, such weeds as purslane (*Portulaca oleracea*) and the chickweeds grow abundantly where magnesium has been applied but their presence on land not receiving magnesium is negligible.

Magnesium Deficiency. (Walter S. Eisenmenger and Dale A. Hinkle.) It has been noted that chlorosis of the older leaves and lack of normal growth are symptoms of magnesium deficiency in plants. An attempt is being made to determine the relative fate of chlorophyll, carotene, and xanthophyll in the process of tissue deterioration as well as to determine the comparative supplies of magnesium in the more common agricultural soils in Massachusetts. The latter involves the base exchange capacity, the magnesium involved in the base exchange, and the total magnesium.

It has also been a part of the project to determine whether or not mass action of large quantities of magnesium when applied to apple orchards would influence magnesium intake as compared with normal applications, which in the past have proved futile. Results to date have not been encouraging. It was found that most of the apple leaves had the same magnesium content although the applications of this ion to the soil areas around different trees varied greatly in amount. This indicates that old apple trees may be adjusted physiologically to the intake of a somewhat definite amount of the magnesium ion so that mass action would be unlikely to have much effect on magnesium intake.

The relative yields of common vegetable crops are being observed to determine the economic significance of magnesium applications.

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) The Canadian varieties of sunflower, which have considerably shorter stalk and smaller head than the Russian Mammoth, are being tested. This shorter variety will withstand breakage of the stalks due to windstorms, and this merits consideration. At the Experiment Station, acre yields for the Canadian type sunflower ranged from 2,000 to 2,400 pounds; the Russian sunflower averaged 2,525 pounds per acre; and a black hulled sunflower of medium height, which has been selected at the Station, produced an average of approximately 2,800 pounds per acre.

Long Time Fertility Tests. (Karol J. Kucinski and Walter S. Eisenmenger.) About sixty years ago a series of test plots was established to study the effects on the soil of a long-time fertilizer program. For the last three years, hay has been grown on these plots. As in the two previous years, yields of hay indicate that in the case of plots treated singly with either nitrogen, potash or phosphorus, the nitrogen plots showed the greatest response. Liming alone produced approximately twice as much hay as no treatment. The greatest response to lime occurred on plots treated with both potassium and phosphorus. On the unlimed plots, the heaviest yield was obtained where a complete fertilizer was used.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

Use of Snow Fencing in Controlling Wind Erosion. The heavy cover of snow during the winter of 1946-47 prevented any drastic dust storms. For several years, snow fencing has been satisfactorily anchored when held with iron pipes 4½ to 5 feet long, driven 18 inches into the ground and spaced about a rod apart. It has been found that where one snow fence is placed only at the head of a "blow-out" area, perpendicular to the prevailing winds, a deposition of soil occurs when the wind blows from the opposite direction. It is suggested therefore, that in large "blow-out" areas, parallel fences be placed perpendicular to the prevailing wind, one at each end of the "blow-out."

Farm Fish Ponds. Considerable interest has been shown by farmers who are adopting soil conservation practices in building fish ponds on their farms. In the South and West, farm fish ponds are common and successful. In New England this is a new venture and studies are being made to determine the kinds of fish and rate and type of fertilization that should be recommended for the various types of farm ponds constructed. Very little is known about the yield and rate of growth of self-propagating fish in this vicinity. Information of this nature is greatly desired, especially in regard to species of trout.

Investigation of Beach Grass. The American or native beach grass (*Ammophila breviligulata*) found commonly on Cape Cod has been used with various degrees of success in the stabilization of beach areas and coastal sand dunes. Recently machinery has been developed for the rapid transplanting of beach grass plants, and this has made it of economic importance to obtain transplants in sufficient quantity. Studies are in progress to determine what response beach grass will make to fertilization, in the natural state and when propagated; and to find feasible methods of encouraging the growth and increasing the rate of propagation of natural stands in order that they may eventually be used commercially as transplants.

Black Root Rot of Tobacco. (C. V. Kightlinger.) The purpose of this project is to improve Havana Seed tobacco by breeding new strains that will produce tobacco leaf of better type and quality in more profitable amounts than existing strains of Havana Seed. Special emphasis is being placed on breeding new strains that are highly resistant to black root rot and capable of producing tobacco of acceptable type and quality in profitable amounts on black root-rot infested land.

Havana 211, Havana K1, Havana K2, and Havana K2-24 seem to be the best of the new strains produced so far. They yield well under most black root-rot conditions, as well as under more favorable growing conditions, and are acceptable to most growers for yielding capacity. However, owing to their larger size, these strains require greater care than many farmers are accustomed to use in preparing tobacco for harvesting and in harvesting and curing it; consequently they are sometimes not fully acceptable to the tobacco trade for quality. Better preparation for harvesting, more careful harvesting, and better curing of tobacco, regardless of whether it be the new strains or common Havana Seed, would produce tobacco of better type and quality and often of greater weight, thus resulting in more profit to both the tobacco trade and the producer, especially the latter.

Some differences exist among these new strains. Havana 211 will usually outyield the others under similar growing conditions, especially under favorable conditions. Havana K1 and K2 usually outyield Havana K2-24, especially under favorable growing conditions. Havana K2 and Havana K2-24, usually sort out in approximately the same percentage of weights per grade as does well-grown and well-cured common Havana Seed; while Havana 211 and Havana K1 usually sort out a higher percentage weight of light wrappers and seconds grades. One part of the tobacco trade seems to prefer Havana K2 and Havana K2-24 because they produce tobacco that resembles common Havana Seed so closely in type and quality. The other part of the trade seems to prefer Havana 211 and Havana K1 because they produce the greater amounts of so-called light tobacco. Further trials are needed to ascertain just how acceptable these strains may become with the tobacco trade and which of the strains may gain general preference. Better curing practices on the part of many farmers who grow these new strains may change present tendencies for preference of strains on the part of the trade.

The most desirable plants within the existing strains are being selected and propagated to improve habits of growth in general and type and quality in particular. Still other strains are being produced by crossing plants that embody the desirable properties of the different strains in highest degree.

Potato Seed Treatments. (C. V. Kightlinger and H. M. Yegian.) Seven varieties of potatoes (Green Mountain, Irish Cobbler, Russet Rural, Katahdin, Chippewa, Sebago, and Earlaine) and eight seed treatments were used to ascertain the comparative tolerance of common varieties of potatoes to the treatments and also their effectiveness in controlling rhizoctoniose and scab. The materials used were corrosive sublimate, corrosive sublimate plus acid, cold formaldehyde plus acid, Semesan Bel, Sanoseed, Spergon, Fermate, and Thiosan, all prepared and used according to recommendations. The potatoes were dormant or only slightly sprouted at the time of treatment.

The inorganic materials caused little if any noticeable injury to tubers or reduction in stands of Green Mountain, Irish Cobbler, and Russet Rural; slight injury to tubers and moderate reduction in stands of Katahdin, Sebago, and Earlaine; moderate injury to tubers and heavy reduction in stand of Chippewa. The organic materials caused no noticeable injury to tubers of any variety and no reduction in stands of Green Mountain, Irish Cobbler, and Russet Rural; little reduction in stands of Katahdin, Sebago, and Earlaine; and moderate reduction in stand of Chippewa. Injury to tubers consisted not only of injury to eyes and sprouts but also of pitting of the tubers. The treated and untreated potatoes of each variety were taken from the same lot; therefore, it seems reasonable to conclude that the reductions in stand were caused by the treatments and not by rhizoctoniose on the sprouts before they emerged from the ground.

None of the seed treatments seemed to increase the vigor of the plants. On the contrary, there seemed to be some retardation in the emergence of plants from the treated seed of some of the varieties. There were no consistent differences in the amounts of infection of rhizoctoniose, either on the growing plants when about a foot tall or on the tubers grown from treated and untreated seed. Although these experiments yielded no specific information on the effectiveness of disinfecting treatments to prevent injury by Rhizoctonia to the young sprouts before they emerge from the ground; nevertheless, on the basis of the results obtained, it seems reasonable to conclude that the use of disinfecting seed treatments is of doubtful value in preventing the development of rhizoctoniose on the stems and tubers of potatoes.

Little or no scab developed on any of the potatoes at any time in these experiments, so they yielded no information regarding the effectiveness of these disinfecting seed treatments for controlling scab. However, owing to the widespread occurrence of the scab-causing organism (like the rhizoctoniose-causing organism) in most cultivated land, and the fact that the scab disease develops late in the growth of potatoes, the use of disinfecting seed treatments would seem to be of doubtful value for controlling scab. Satisfactory control of both rhizoctoniose and scab of potatoes must be sought by other means than the use of disinfecting seed treatments.

Fertilizer Placement for Potatoes. (C. V. Kightlinger and H. M. Yegian.) Green Mountain potatoes were grown on one-twentieth acre plots, replicated four times. Approximately one ton per acre of 5-8-7 fertilizer was applied in four different ways: all banded, two-thirds banded and one-third broadcast, one-third banded and two-thirds broadcast, and all broadcast. The broadcast fertilizer was applied and harrowed into the soil before the potatoes were planted. The potatoes were planted on May 20; sprayed with Bordeaux mixture at weekly intervals throughout the season, beginning June 26, and with DDT and nicotine sulfate as needed; and harvested October 19 and 21.

There was no striking difference in the yields of potatoes of any class or size obtained from the different ways of using fertilizer this season.

Potato Variety Trials. (Karol J. Kucinski, Ralph W. Donaldson, Walter S. Eisenmenger.) The 1946 season was considered an exceptionally good potato year. The yields obtained in the variety tests ranged from 474 bushels per acre for Sequoia to 190 bushels per acre for USDA 46952. Based on yields of marketable size, the potato varieties in the Experiment Station plots ranked as follows: Sequoia, Green Mountain, Pontiac, Mohawk, Chippewa, Teton, Houma, Sebago, Irish Cobbler, Warba, USDA 627-103, Katahdin, and USDA 46952. The Houma variety produced 347 bushels per acre, but approximately 23 percent of these were "B" size or smaller.

Pasture Renovation Experiments. (Wm. G. Colby.) Work with pasture renovation was begun in 1943 in cooperation with the U. S. Department of Agriculture Regional Pasture Laboratory at State College, Pennsylvania. The nature and scope of the project was given in last year's report (Mass. Agr. Exp. Sta. Bul. 436: 13-14, 1946.)

Herbage Yields. Yield data from all of the different trials thus far conducted, indicate that untreated sods yielded from practically nothing for very poor sods up to one ton of dry matter per acre for the better ones. Good Kentucky bluegrass and natural white clover sods liberally topdressed with lime and a complete fertilizer produced up to two tons of dry matter per acre, while areas which had been tilled and re-seeded in addition to being limed and fertilized, yielded three tons of dry matter and in several cases three and one-half tons. The reseeded areas, in addition to giving greater total yields, maintained more uniform production throughout the grazing season. A mixture of Ladino clover, red clover, and alsike was used on all areas. Smooth brome grass (*Bromus inermis*) was the grass most frequently used, with smaller plots of orchard grass (Finnish late hay strain), timothy, and meadow fescue also included for comparative purposes. Although it is sometimes difficult to secure good stands of brome grass, this grass seems to show the most promise.

Land Drainage. Some of the best potential pasture land in the State is now practically useless because of poor drainage. Therefore, the first step in any renovation program is to provide adequate drainage. Many such areas can be satisfactorily and economically drained by dynamiting; others may require the use of a dry land dredge of some sort.

Reclaiming Newly Drained Land. The surface of newly drained land is usually so rough and uneven that considerable difficulty may be experienced in seedbed preparation even with the aid of a heavy brush and bog harrow. Observations were made on the use of a large machine using the "roto-tiller" principle for tilling rough, recently drained areas. In one operation this machine not only leveled off but broke up and cut to pieces the many tough fibrous tussocks or hummocks which were present. Where the land is not stony this machine shows real promise.

Time of Seeding. Comment was made last year that late summer seeding had been more satisfactory than spring seedings. It was pointed out that weather conditions were usually more favorable for summer than for spring seedings and that this was probably the most satisfactory explanation. It now appears that weather is not the only factor involved. In several instances where the land had been long out of cultivation, difficulty was experienced in establishing a new seeding when the seeding operation followed immediately after tilling, liming, and fertilizing. If seeding was delayed for several weeks, little difficulty was experienced. Apparently, therefore, the late summer seedings were more successful, not only because weather conditions were more favorable, but also because a period of time had elapsed between tilling, liming and fertilizing, and seeding. In bringing under cultivation land which has long been idle, farmers are advised to apply lime and fertilizing materials some weeks ahead of seeding or planting.

Red Clover Variety Trials. (Wm. G. Colby.) This project, carried on in cooperation with the U. S. Department of Agriculture Bureau of Plant Industry, is concerned with the resistance of some of the newer strains of red clover to certain diseases. Northern anthracnose (caused by *Kabatiella caulivora*), a disease which is becoming increasingly serious in other sections of the country, was prevalent on some of the more susceptible varieties included in this year's test. The variety Midland, for example, was seriously damaged. It remains to be seen whether or not this disease will become a serious hazard to red clover in Massachusetts. It may be that weather conditions this year were peculiarly favorable for its development.

Trials with Sorghum and Sudan Grass Strains. (Wm. G. Colby.) Notwithstanding the superior performance of a well-established, well-managed Ladino clover–brome grass pasture during July and August, the need for additional grazing is frequently felt, particularly during dry, hot seasons. One of the best crops available for providing supplementary grazing at this time is sudan grass or possibly sweet sorghum. Both produce heavy crops of palatable nutritious feed. If a reasonable amount of care is exercised in seedbed preparation, fertilizing, and seeding, crop failures are rare. Thus far, however, dairymen have been cautious about growing either of these species largely because of the possible danger of hydrocyanic acid poisoning.

Last season several strains of sudan grass and one of sweet sorghum were grown. In addition to obtaining yield data, tests were made of the cyanide content of the herbage at two growth stages. The Rancher strain of sweet sorghum was obtained from South Dakota where it was bred for low hydrocyanic acid content.

Samples were first taken for hydrocyanic acid determination on July 22 when most strains were in full head. All plots were then cut, the hay removed and an application of ammonium nitrate made to supply elemental nitrogen at the rate of 65 pounds to the acre.

Samples for a second test were taken on September 12. All chemical determinations were made by Professor Emmett Bennett of the Department of Chemistry.

Although Rancher Sorghum and Tift sudan grass ran considerably higher in hydrocyanic acid content at the first cutting than commercial sudan or sweet sudan, a cow would have had to consume from 50 to 60 pounds of green material at one time of either of these strains before there would have been any danger of poisoning. She would have had to consume 300 pounds of sweet sudan grass before being poisoned.

All strains ran much higher in hydrocyanic acid at the second cutting, with only small differences between strains. A cow would have had to consume from 20 to 25 pounds of green material of the second cutting at one time before danger of poisoning. Heavy fertilization with a nitrogen fertilizer was no doubt an important factor in the production of the relatively high content of hydrocyanic acid of the second cutting.

It would appear from these results that all of the four strains tested could be grown for midsummer pasture in Massachusetts without serious hazard of causing hydrocyanic poisoning.

Corn Improvement Program. (Hrant M. Yegian.)

Uniform Double Cross Tests. Twenty-five commercial hybrids of the U. S.-13 maturity group were tested, with five northeastern experiment stations cooperating. An experimental hybrid, (B164 x WF9) x (40B x L317), gave the highest yield—134.3 bushels of shelled corn per acre, calculated at 15.5 percent moisture, and 21.1 tons of silage per acre, calculated at 70 percent moisture. Ohio 3143, Pioneer 300, Funk G-94, Iowa 4059, and Conn 830 were also high producers. The hybrids which performed well at this station were also consistently high in yield in the other four tests.

None of the predicted double crosses in the early maturity group produced as much grain as the Mass. 62. New experimental double crosses are being tested this year in an effort to find one which will outyield Mass. 62.

Single Cross Test. A set of 45 single crosses involving all possible combinations of ten selected inbred lines in the early maturity group and another set of 45 single crosses in the midseason maturity group were tested cooperatively. On the basis of these tests a few of the promising predicted double crosses are being made for testing during the 1948 season.

Last year a new set of 45 early maturing single crosses was made here. They are being tested for their general adaptability in the Northeastern region.

Date and Rate of Planting. The results of further yield tests with four hybrids ranging in maturity from early to late, planted on three different dates (May 10, 20, and 30) and at three rates (3, 4, and 5 plants per hill), were again not very reliable. Excessive rainfall in the spring and poor drainage of the field caused wide discrepancies among the replicates. Although early planting hastened maturity from 7 to 10 days, in was very difficult to prepare a deep mellow seedbed, control the weeds, and secure a good stand, because of cold and wet soil conditions which favored poor germination and seed rot.

Onion Breeding. (Hrant M. Yegian.) *Hybrid Onions.* In 1946 a number of bulbs of male-sterile lines supplied by Dr. H. A. Jones of the U. S. Department of Agriculture were pollinated with selected strains of our Ebenezer lines to determine their relative combining ability. The resulting hybrid seeds from these crosses are being used for set production and will be distributed to interested local farmers for experimental testing.

Pre-harvest Spraying. Further tests for the control of storage rot of onions by spraying with Fermate, Puratized N5E, Isothan Q-15, Wettable No. 604, Wettable Spergon, and Dithane D-14 did not give any control of rot in storage. The various fungicidal chemicals were applied three times at weekly intervals before the onions were pulled.

In most instances infection of the bulbs takes place through wounds at the neck of the topped onions or through damaged roots, which may account for the ineffectiveness of the fungicides to control storage rot. Immature onions, big fleshy bulbs, or thicknecked bulbs are especially susceptible to infections. The most practical method known for reducing loss is to store only sound, properly cured onions in cold storage under controlled conditions at 32°–35° F. and low humidity.

Fertilizer Application. It is a generally accepted practice in the Valley to apply from 2000 to 2500 pounds per acre of a complete commercial fertilizer such as 5-8-7 to onion fields. Although the fertilizer is broadcast and disked in to a depth of 3 to 4 inches about a week prior to planting the sets, there have been cases, nevertheless, where serious fertilizer injuries have occurred on light sandy soils under adverse weather conditions. Furthermore, most of the growers have found it necessary to make an additional application of 500 to 700 pounds of a complete fertilizer during late May to replace excessive leaching losses by spring rains and to supply readily available plant food to the crop during a time when it is making a steady and rapid growth.

The results of last year's trial indicate that more efficient use of commercial fertilizer could be made by split application, consisting of 1000 pounds per acre of 5-8-7, broadcast and disked in prior to planting; 500 to 700 pounds per acre about the middle of May; and 500 pounds more about the first part of June. This would insure a steady supply of abundant plant food with a minimum loss through leaching and should entail no extra labor inasmuch as there are available fertilizer distributers which can be attached to powered onion cultivators.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald.) The work with cobalt has been completed, at least insofar as the present development of the project is concerned; and the results have been published in the *Journal of Dairy Science* Vol. 30, No. 5, May 1947. The following is quoted from the article:

> Cobaltous acetate was fed as a supplement (500 mg. daily) to the rations of eight cows for a period of two months by the double reversal method and the milk was analyzed for cobalt. The results revealed that feeding the supplement consistently raised the amount of cobalt in the milk. The average increase was four-fold. The milk from cows receiving the supplement averaged 2.4 micrograms of cobalt per liter in contrast with 0.6 micrograms per liter when the cows were on the control ration.
>
> The obvious possible significance of these results lies in their application to calf nutrition. In our experience, young stock have showed greater susceptibility to the nutritional anemia which is characteristic of cobalt deficiency than older cattle have. In the light of these results, it would seem that in areas where cobalt deficiency is common, the requirements of calves for this element might most naturally and logically be supplied through the milk of cows whose rations have been fortified with supplemental cobalt.

Interest in this work has been shown recently on the part of the indusrial processors of milk. One firm states that in connection with their "use of milk products as fermentation media, . . . very small concentrations of the so-called trace elements are of great importance." Cobalt is stressed by them as one of the principal elements in this connection.

The element nickel will be investigated during the winter of 1947-48.

A Study of Quality in Roughage: Composition, Palatability, and Nutritive Value of Hays as Affected by Curing, Harvesting, and Storing Procedures. (J. G. Archibald, M. L. Blaisdell, and H. N. Stapleton.) Preliminary studies with the 1945 and 1946 hay crop indicate marked differences in the composition of different lots of hay, especially with respect to their content of protein, sugar, and carotene. These differences are thought to be due to such variables as weather during the growing period and at curing time, kind of crop, and methods of harvesting and storing. Their significance with regard to palatability and nutritive value of the hay produced is, in our present state of knowledge, pretty largely a matter of conjecture. Existing knowledge on the subject is fragmentary, inconclusive, and even contradictory. It is the aim of this project to obtain authentic information. Work has just been begun and results are not as yet available.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Septic Tank Studies. (James E. Fuller.) This is a continuation of work previously reported (Mass. Expt. Sta. Bul. 436, p. 17, 1946). This study was concerned with the penetration of sewage-type coliform bacteria into the soil of disposal fields receiving sewage effluents from three septic tanks which represented three retention periods for raw sewage: 8, 12, and 24 hours. The soil samples were examined to determine their coliform indices by the conventional procedure of gas production in lactose broth, as outlined in the Standard Methods of Water Analysis (American Public Health Assn.). Organisms isolated from positive fermentation tests were studied to determine their relationship to sewage-type coliform bacteria (*Escherichia coli*). Results showed almost no sewage-type organisms in the soil, in spite of the fact that the flow from the 8-hour retention tank was so rapid that soil surrounding the disposal line was frequently saturated with moisture. Organisms isolated were, for the most part, the same as those isolated from soil (of the same type) that did not receive septic-tank effluent. Two conclusions resulted from the study: (1) the length of retention of sewage in the tanks did not influence the results obtained from the soil, and (2) the sewage-type coliform bacteria isolated from the raw effluent either did not penetrate into the soil or did not survive. Further study is planned to investigate the survival of sewage-type coliform bacteria in soil under different conditions.

Bactericidal Properties of Surface-active Agents. (James E. Fuller.) It was reported previously (Mass. Expt. Sta. Bul. 436, p. 17, 1946) that preliminary tests had been made on 42 surface-active agents to determine their germicidal efficiency. Several of these agents, representing three chemical groups, were chosen for further study of their germicidal properties, in different concentrations, against two representative types of bacteria, *Escherichia coli* and *Staphylococcus aureus*. The chemical groups represented were quaternary ammonium compounds, phosphonium compounds, and aliphatic sulphonates. Usually a certain concentration is recommended for the use of an agent. Results of the experiments indicated that the effectiveness of the agents varied for the different bacterial species, and that a formula could be derived for each agent showing the relationship of concentration of the agent and dosage time for any given bacterial species. The results of the experiments indicated that the agents could be made more widely useful if directions for their application were made more flexible, and economy of materials might result if weaker concentrations were employed where speed of disinfecting action is not important or necessary.

Microbiological Fixation of Copper in Soil. (Charles Hurwitz.) This study was undertaken to determine the effect of the soil microorganisms on the availability of the soil supply of copper to higher plants. Copper leached from the soil by neutral, normal ammonium acetate is considered available. Leachable copper was found to be greatly increased by an unknown soluble component of oat straw and alfalfa meal when either sodium chloride or ammonium acetate was used as the leaching solution, the effect being found in both Merrimac sandy loam and Dunkirk silty clay loam. This unknown soluble component is decomposed by soil microorganisms in about 14 days at 29° C., 37° C., and 45° C., no marked differences being observed at any of these temperatures. At 2° C., no decomposition of the soluble component occurred in 21 days, but when this soil was placed at 29° C., decomposition proceeded as before. Work is in progress now to characterize this unknown soluble component and to determine its agricultural significance.

Laboratory Service, July 1, 1946 to October, 1946. (James E. Fuller.)
Water samples, bacteriological tests........................ 22
This service was discontinued in October, 1946.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. In 1941 the Dutch elm disease, caused by the fungus *Ceratostomella ulmi* (Schwarz) Buisman, was discovered in Massachusetts. One diseased tree was found in Alford, Berkshire County, just over the line from New York State. As of July 8, 1947, the disease has been isolated from 502 trees of 52 municipalities in 8 counties of Massachusetts. The spread of the disease from year to year is shown by the following table:

Year	Cumulative Totals		
	Trees	Towns	Counties
1941	1	1	1
1942	7	5	2
1943	11	6	2
1944	43	15	2
1945	85	24	3
1946	381	47	8
1947 (July 8)	502	52	8

Until 1946, occurrence of the disease in Massachusetts was limited to the Connecticut Valley and the area between this boundary and the New York State line. Currently, however, affected trees were discovered in Quincy and more recently in nearby towns in Norfolk County as well as in Plymouth and Bristol Counties. Since the principal known vector of the causal fungus is a bark beetle, *Scolytus multistriatus*, which has been known to be present in eastern Massachusetts from about 1900, the diseased trees in that section of the State may be regarded as more than individual isolated cases such as sometimes occur independently of the major area of disease and beetle vector infestation. On the basis of experience, increase in the number of diseased trees locally parallels closely the build-up of beetle population if the causal fungus is present.

An important part of the work is now, and must continue to be, the exploration of possible further spread of the disease in Massachusetts, as well as obtaining additional data in areas where trees are known to be affected. Detailed reports are furnished to the Massachusetts Department of Agriculture, to local officials, and to private citizens involved, regarding findings in individual municipalities, with special reference to need for action in retarding the spread of the disease.

Experiments are in progress in cooperation with the Department of Entomology on the use of spray materials for the control of carrier beetles.

The investigation of disease resistance deserves further attention. Thus far, however, other commitments have precluded studies to determine evidence of possible resistance to disease in elms of Massachusetts.

Other Tree Problems. Fifty-three diseases of twenty-nine species of trees, including eight diseases of elm, were identified from approximately 450 specimens and inquiries received during the year. The *Cephalosporium* wilt of elm was reported from two additional municipalities in the State. *Verticillium* sp. was isolated from several species of woody plants.

Anthracnose of maples and oaks, black spot of elms, and other leaf diseases caused by fungi are prevalent on trees currently. In some instances premature defoliation is traceable to this type of fungus infection.

A needle blight of Colorado fir (*Abies concolor*) was found on specimens collected at Newburyport, Mass. This disease is caused by the fungus *Rehmiellopsis balsameae*. Under suitable conditions the resultant disease may become epiphytotic in plantations. Accordingly, the growth of the current season may be rather uniformly scorched in appearance, resembling damage by late frosts to which cause this fungus disease was formerly often attributed. Although the disease was first known in Massachusetts on Colorado fir, later the causal fungus was found on balsam fir (*Abies balsamea*) in Maine. It seems assured that the fungus is native in eastern United States on balsam fir and may have spread to ornamental plantings of Colorado fir introduced into the vicinity. The disease has not been found in the Western States, native range of the Colorado fir.

Neglect of general maintenance work on street trees is increasingly important as a cause of tree injury. The rising cost of this work to municipalities is the primary factor involved. The result of the accumulation of weakened parts of trees may be seen widely in the State following ordinary storms. Inevitable accidents involving such trees may serve to direct needed action toward necessary, constructive tree improvement and protection programs.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Work on the vegetative propagation of the Kudzu vine was continued and a paper on the subject prepared for publication. Best results with this species were obtained when cuttings, each made to consist of one node, its leaf and a young axillary branch, were taken in mid-July, given a powder-dip treatment with indolebutyric acid, and set in sand-peat. The rooted cuttings were wintered in the greenhouse and, in cooperation with the Department of Agronomy, set in the field in spring for later observations as to hardiness and growth.

Work on the vegetative propagation of hemlock and of white pine was continued and a bulletin written and published about the latter.[1]

Different clones of hemlock, like different clones of white pine, were found to respond very differently to treatments with the same root-inducing substance, the best rooting being from more than 80 percent with some clones to less than 10 percent with other clones. Indolebutyric acid 150 to 200 mg./l., 20 to 18 hr., often improved the rooting of cuttings of hemlock taken in early winter; but the rooting of cuttings taken in October was more improved by naphthaleneacetic acid 50 mg./l., 18 hr.

Continued attention was given to the use of fungicides in combination with root-inducing substances for the treatment of cuttings, and it was found that a given fungicide when added to Hormodin No. 3, in the proportion of 15 percent fungicide, does not have the same effect on cuttings of all species. Fungicides which improved the rooting of summer cuttings when thus used were zinc ethylene bisdithiocarbamate (HE178E), ferric dimethyldithiocarbamate (Fermate), and zinc mercaptobenzothiazole with (leaf-bud) cuttings of a *Rhododendron catawbiense* hybrid; diphenyl guanidine phthalate (Gauntal) with cuttings of *Viburnum Carlesii*; Fermate with flame azalea; 2, 3-dichlor-1, 4-naphthoquinone (Phygon) with *Cotoneaster adpressa*, and HE178E with red cedar. Phygon was also safe with *Viburnum Burkwoodii*.

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[1]Doran, W. L. Vegetative propagation of white pine. Mass. Agr. Expt. Sta. Bul. 435, 16 pp. illus. July 1946.

Tetramethyl thiuram disulfide (Tuads), zinc trichlorophenate (Dow Seed Protectant No. 9) and Guantal were apparently injurious to the leaf-bud cuttings of Rhododendron, and Dow Seed Protectant No. 9 had a similar unfavorable effect on cuttings of red cedar and Japan quince.

The effects of solution-immersion treatment applied in the usual manner with only the bases of the cuttings being immersed, were compared with the effects of immersion of the entire cuttings in solutions of a root-inducing substance. Rooting of fall cuttings of two yews was more hastened or improved by complete immersion in indolebutyric acid 150 mg./l. or naphthaleneacetic acid 25 mg./l., 18 hr. than by basal treatment only and this was true also of fall cuttings of Hinoki cypress in indolebutyric acid 50 mg./l., 18 hr. But the rooting of fall cuttings of arbor-vitae and two species of Juniper was as much improved by one method as by the other, and the rooting of cuttings of five hemlocks taken between October and January was more improved by immersing only the bases of the cuttings than by immersing the cuttings entirely.

Some work was done with potassium nitrate in solution, used with or without a root-inducing substance. Rooting of December cuttings of Norway spruce was improved by potassium nitrate 100 mg./l., 23 hr., used alone. Rooting of fall cuttings of red cedar, oriental bitter-sweet, and inkberry was more improved by potassium nitrate 50 mg./l. used with indolebutyric acid than by the latter used alone.

Powder-dip treatment of December cuttings of Norway spruce with 2, 4, 5-trichlorophenoxyacetic acid 0.5 mg./gm. resulted in improved rooting if the carrier was activated charcoal but not if it was talc.

Arasan (tetramethyl thiuram disulfide), used as a seed treatment, protected seedlings of *Pinus Mugo* var. *Mughus* against damping-off better than did either Phygon or Spergon (tetrachloro-parabenzoquinone) similarly used.

Applied as a soil treatment immediately before seeding, Arasan 0.5 gm. per square foot improved the stands of Carolina Rhododendron and a *Rhododendron catawbiense* hybrid.

Diseases of Plants Caused by Soil-infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) The application of soil fungicides in fertilizer used as a carrier was found to be a simple and effective method for the control of certain soil-borne fungus diseases of plants. It is especially useful in the case of such light applications (per acre) that the fungicide could hardly be distributed except in some carrier. A liquid carrier would mean more labor and, as is stated below, the results with water may be inferior to those with fertilizer.

Especial attention was given to the control of clubroot of cabbage, smut of onion, and damping-off of certain vegetables by some organic fungicides applied to the soil in a 5-8-7 fertilizer (15.6 gm. per square foot) immediately before seeding. The effectiveness and safety of some of the fungicides thus applied were compared with their effectiveness and safety when applied in water to soil immediately after seeding. Observations were meanwhile made as to which soil fungicide applied in fertilizer is better and safer with one species of plant, which with another.

Dithane D14 (disodium ethylene bisdithiocarbamate), Dow Seed Protectant No. 9 (zinc salt of 2, 4-trichlorophenol), Fermate (ferric dimethyldithiocarbamate), Arasan or Tuads (tetramethyl thiuram disulfide) gave better and safer control of damping-off of all vegetables when applied in fertilizer to soil before seeding rather than in water after seeding.

Phygon (2, 3-dichloro-1, 4 naphthoquinone), Tuads, and Dithane applied in fertilizer gave better control of damping-off in limed soils than in the same soils not limed. But there were also good results with these and other fungicides applied in fertilizer to unlimed soils.

The fungicide, in fertilizer, which gave the best results with one kind of vegetable did not necessarily, however, give the best results with all others. Damping-off of cabbage, onion, pepper, tomato, beet, and cucumber was well and safely prevented by Tuads 0.5 gm. (Rates of application are expressed in grams per square foot in all cases.) Dithane D14, 2.5 cc., gave good results with all of these except cucumber. Dow Seed Protectant No. 9, 0.45 to 0.75 gm., gave good results with beet, cabbage, and cucumber but not with onion, pepper, or tomato; Phygon only with pepper and tomato.

Fermate and Tuads applied to soil in fertilizer immediately before seeding gave better control of onion smut than when applied in water to soil immediately after seeding. Best control of onion smut was by Dithane D14, 3.0 cc.; Phygon 0.6 gm.; or Tuads, 0.55 or 0.65 gm. With 53 percent smut in an untreated soil, there was no smut in this soil when Phygon 0.65 gm. or Tuads 0.65 gm. had been applied in the fertilizer.

Tuads 0.55 gm. or 0.65 gm. thus applied gave good control of cabbage clubroot in seedbeds and these treatments were followed by improved growth of plants.[1]

Fungicidal treatments of the seeds of *Lilium regale* were continued, tetramethyl thiuram disulfide giving the best results, and a paper was written.[2]

It was found that, lacking all fungicides, fair control of damping-off is possible by merely delaying the first watering for a few days after seeding, and the abstract of a paper read on the subject was published.[3]

Tomato Leaf Mold Caused by the Fungus *Cladosporium fulvum* Cke. (E. F. Guba, Waltham.) Tomato types developed for resistance to *Cladosporium fulvum* Cke. have been generally accepted by the greenhouse forcing industry. The most satisfactory type has been designated Improved Bay State. The resistance of Improved Bay State to tomato leaf mold was derived from a "pimpinellifolium" wild type from Ecuador designated U.S.D.A. Plant Introduction No. 112,215. The utility and resistance of Improved Bay State to Cladosporium leaf mold has been substantiated by other station workers. Confirmation of this fact by B. S. Crandall, Office of Foreign Agricultural Relations, U.S.D.A., working at Estacion Experimentale Agricola de Tingo Maria, Peru, South America, is especially significant.

Similar resistance was bred into Marglobe but the finished type lacks firm fruits and a high yielding habit. The hybrid of *L. esculentum* var. Prince Borghese X *L. peruvianum* outcrossed to Pan America, and submitted by W. S. Porte of the U.S.D.A. as No. 44B292, is being pure-lined for resistance to leaf mold and further study.

Supervision of seed production of Improved Bay State is planned, to preserve the desirable characters of the tomato for the industry. Seed samples have been distributed to interested workers in many countries.

This study, in progress since 1925, and since 1933 concerned with breeding for resistance to the disease, is nearing completion.

Causes and Control of Decay of Squash in Storage. (E. F. Guba, Waltham.) Study was made of the effect of field applications of fungicides on disease control and yield of Butternut squash. The plots were 16 x 210 feet in dimension. They were sprayed five times from August 5 to September 10.

The diseases involved were powdery and downy mildews (*Erysiphe cichoracearum* DC and *Pseudoperonospora cubensis* (B & C) Rost.) respectively, and black rot (*Mycosphaerella citrullina* (Smith) Gross.).

[1] The writer read a paper on "Fungicides applied in fertilizer for the control of cabbage clubroot and damping-off" at the Annual Meeting of the Northeastern Division of the American Phytopathological Society on November 26, 1946. An abstract will appear in Phytopathology.

[2] Doran, W. L. The protection of lilies against damping-off. National Horticultural Magazine 25:4:385-386. 1946.

[3] Doran, W. L. Control of damping-off by a delay in first watering after seeding. Phytopathology 36:8:679. August 1946.

Comparisons were made of Fermate 1½, Phygon 1, Zerlate 2, pounds in water, 100 gallons, Bordeaux 4-4-100, tribasic copper sulfate 4, and no treatment. The percentage of infected fruits in the unsprayed plots at harvest was 18.5 percent and 22.7 percent of the total. The percentage of infected fruits in the sprayed plots varied from 3.5 to 9.1 percent. The best control was obtained with Phygon.

The plots sprayed with Phygon and with copper showed the least foliage disease. The total yield and the average weight of the squash fruits were the least in the Phygon-sprayed plots.

Like numbers of squash from the sprayed plots were dipped in fungicide and combined fungicide and wax emulsions at harvest and then stored until mid-January. The least loss from black rot occurred in lots of squash from the Phygon-sprayed plots immersed in Phygon or in combined Phygon and wax emulsion, and from the Zerlate-sprayed plots immersed in Zerlate or Formalin solution. Control of rot in storage was not significant when the squash fruits from the sprayed plots were not immersed before storage. The least shrinkage from evaporation of moisture occurred among the lots of squash immersed at harvest in combined fungicide and wax emulsion.

Interrelation of Wettable Sulfur, Lead Arsenate and Lime in Apple Spraying. (E. F. Guba, Waltham.) Except for drought conditions from June 25 to July 24, the growing season was marked by continuous rains which contributed to the worst scab epidemic on record. Severe frosts caused a great reduction in the set of fruit of some varieties. Premature defoliation and discoloration of McIntosh trees from scab was prevalent.

Scab was controlled best on Delicious with Phygon and Puratized in a throughout schedule of six applications, and with a schedule of three sprays of Flotation Sulfur Paste alternating with three sprays of Puratized. Fermate gave significant control, and lime added to Flotation Sulfur Paste and lead arsenate controlled scab as well as the same mixture without lime. On McIntosh the best scab control was obtained with Phygon, Puratized, and Fermate, and significant control with Flotation Sulfur Paste and Puratized alternating. Eradication of foliage scab was best accomplished with Puratized. The action of liquid lime sulfur on the fungus was less satisfactory. Phygon and Fermate exert a marked fungistatic or inactivating action on the scab spores in foliage infections. Wettable sulfurs are not fungistatic in this respect. Fermate and wettable sulfur combined offer advantages over either fungicide alone in the control of scab.

The least amount of russeted Delicious fruit was associated with Phygon and Fermate, each combined with lead arsenate, and with wettable sulfur alone and with lead arsenate alone. Frost russeting was prevalent on Baldwin fruit among all treatments; russet ranged from 25 percent with Phygon to 70 percent with Puratized, indicating a significant influence of the spray chemical on the incidence of injury. The Phygon-sprayed trees showed abnormally colored foliage and depreciated weight of the harvested fruit.

Analysis of the sulfur residue before and after applications of sulfur indicates that the addition of lime increases the loss of sulfur from weathering. Paste sulfurs or the finest particle sulfurs weather off less than coarse sulfur.

Tobacco Frenching Induced by High Soil Temperature. (L. H. Jones and M. A. Tio.) Two varieties of tobacco—Havana Seed, a cigar tobacco, and Yellow Mammoth, a cigarette tobacco—were grown in a compost soil at two soil temperatures, a high of 95° F. and a low of 70° F. Frenching symptoms in the most extreme forms appeared on both varieties at the high soil temperature in 8 days. In 21 days terminal growth stopped, and rosetting or polyphylly was the main characteristic symptom. No frenching symptoms developed at the low soil temperature.

Parallel with the soil cultures was a series of solution cultures, at the same temperatures and with the same varieties of tobacco. The solution, Shive's R_5S_2 at 1.75 atm., consisted of KH_2PO_4, $Ca(NO_3)_2$, $MgSO_4$, with $FeSO_4$ as a source of iron. Frenching did not appear at either the high or the low solution temperature. The failure to induce frenching at the high solution temperature precludes the suggestion that root metabolism at a high temperature could be a cause of frenching. The nutrient solution was altered in several ways and various forms of iron were used in an effort to induce frenching, all with negative results. Soil extracts were obtained from frenching soils by mixing soil with distilled water and filtering. These were added to nutrient solutions but caused no symptoms of frenching.

Frenching has always been obtainable with a compost soil. To test a field soil, two tobacco field soils taken in the autumn were used for culture media parallel to the compost soil. At 95° F. the compost soil produced frenching in 14 days; field soil No. 1 in 20 days; and field soil No. 2 in 58 days in one plant of four. The field soils had been stored until February and were quite dry. Subsequent tests showed that air-drying of soil eliminated the ability to cause frenching. Autoclaving the soil for one hour at 15 pounds steam pressure also prevented frenching.

Tests made on frenched leaves showed a large amount of nitrates when it was known that there was an ample supply of nitrogen in the soil. Tests for major and minor elements, made by the floating disc method, showed a response to iron. Leaf analyses of frenched leaves showed a low amount of iron compared with normal leaves. It appears that a lack of iron in the plant seriously interfered with a proper utilization of nitrates. The osmotic concentration of the cell sap of leaf tissue of frenched leaves was above normal; 14 atmospheres for frenched leaves and 9 atmospheres for normal leaves. A histological examination of leaf tissue showed a lack of palisade tissue and spongy parenchyma in the frenched leaves.

Experiments in which iron was mixed with the soil in the forms of $FeSO_4$ mixed with peat and $FePO_4$ mixed with peat resulted in the complete prevention of frenching with the $FeSO_4$–peat mixture. Results were not so good with the $FePO_4$–peat mixture, and practically no control was obtained when either of these chemicals and peat were used separately.

When a little soil that had caused frenching was mixed with an autoclaved soil frenching was induced at 95° F. but not at 70° F. No frenching occurred in an uninoculated autoclaved soil.

The evidence now at hand indicates that at a soil temperature of 95° F. there is an effect on the soil flora which causes oxidation of iron to an unavailable form, and this oxidation takes place more rapidly than the reducing reactions which would normally maintain some iron in a ferrous form available for intake by the plants. Frenching results from a deficiency of available iron and may be prevented by supplying an excess of iron in the form of a ferrous humate made by mixing $FeSO_4$ with peat.

Resistance to Fusarium dianthi Prill. et Del., the Cause of a Serious Carnation Wilt Disease. (E. F. Guba, Waltham.) The following varieties of carnations have been crossed and self pollinated in the long effort to develop desirable commercial types resistant to Fusarium Branch Rot:

Dorothy Napier	Helen Hussey	Millers Yellow
Puritan	John Briry	Woburn
Maine Sunshine	Elizabeth Rowe	Paragon
My Love	Georgina	Hazel Draper
Eleanor	King Cardinal	Tom Knipe

These varieties were selected for selfing and crossing because of their inherent resistance to *Fusarium dianthi*. A large number of seedlings are being studied for their reaction to the disease and other characters. Two additional wilt diseases, Verticillium wilt (*Verticillium cinerescens* Wr.) and bacterial wilt (*Phytomonas caryophylli* Burkh.), have been found in eastern Massachusetts.

Toxic Effect of Wood Preservatives on Plants. (L. H. Jones.) Pentachlorphenol as a wood preservative is frequently used with range oil as a diluent. It may be easily and rapidly applied to lumber with a paint brush. When such treated lumber was covered with soil, no injury to plants was observed, even when their roots were in contact with the wood. However, when such treated lumber is used above ground, grave injury to seedlings may result from volatilization of the oil by high light intensity and high temperature coupled with poor ventilation. The injury is in the nature of a scorching due to the dissolving action of the oil on the epidermis. The injury is most severe where the treated sides of flats are higher than emerging seedlings. If the plants can grow higher than this source of the volatile substances, they are not affected by the gases.

Veneer wood plant bands strongly impregnated with range oil caused grave injury to plants when no ventilation was provided.

Miscellaneous Studies. (E. F. Guba, Waltham.)

Control of Seed Decay and Damping-off of Vegetable Seedlings by Seed-borne Chemicals. Studies have been continued to provide the vegetable growing industry with the latest information on the subject. During the year, zinc oxide, Semesan, Phygon, cuprous oxide, Arasan, Fermate, and Spergon were tested in comparison with no treatment. No one material was satisfactory with all vegetables; but for all the vegetables tested, one or more materials gave good results.

Celery Dermatitis. Many celery growers are poisoned from handling celery, especially by contact with spoiled celery caused by *Erwinia carotovora* (Jones) Comm. s.a.b. The relationship of other spoilage organisms is being investigated. A clinic was conducted by Dr. Francis M. Rackemann of Boston and his staff, in cooperation with the plant pathologist, which was attended by several celery growers. Studies are in progress in cooperation with Dr. Rackemann to learn the answers to various aspects of the problem.

Resistance to Potato Late Blight. Potato seedlings resistant to late blight, originated by Dr. F. J. Stevenson of the U. S. Department of Agriculture, were compared with standard susceptible varieties. Mohawk and Green Mountain vines were completely destroyed before September 1. The vine growth of all seedlings remained free of late blight up to October 2, when the tubers were dug. Seedlings B 69-16, B 70-5, and B 61-3 showed a trace of late blight tuber rot, and tuber infection was severe with seedling B 76-43. Seedling B 69-16 performed the best of the entire lot in every respect.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Factors Affecting the Vitamin Content of Milk and Milk Products. (Arthur D. Holmes.) During the past year three studies conducted under this project have been completed. All the products studied were produced locally, the ice cream and mare's milk being produced at the University. The various samples of goat's milk were obtained from prominent goat dairies located at widely scattered points in the State.

Goat's Milk as a Source of Bone-Building Materials for Infant Feeding. (Arthur D. Holmes, John W. Kuzmeski, Harry G. Lindquist, and Henry B. Rodman.) In previous studies of goat's milk attention was given to the vitamin content of commercial winter goat's milk and to the variation which occurred in the fat, ascorbic acid, and riboflavin content of individual samples of milk. Inasmuch as goat's milk is frequently used as an infant's food, it is obviously desirable to have data concerning its reliability as a source of the minerals required for the satisfactory development of an infant's skeleton. Twenty-four samples of fresh, raw goat's milk were collected at various localities in Massachusetts and southern New Hampshire. The milk was produced by four breeds of goats most common in this area; French Alpine, Nubian, Saanen, and Toggenburg. The samples were shipped to the laboratory packed in ice, and were about 24 hours old upon arrival. Average values obtained by analysis were calcium 137 mg. per 100 gm.; magnesium 17 mg.; potassium 170 mg.; phosphorus 112 mg.; fat 4.4 percent; and protein 3.4 percent. These data show that average goat's milk is a rich source of minerals and is therefore a valuable product for infant feeding. However, a final appraisal of its true value as a source of bone-building materials for infant feeding must await data regarding the extent to which infants can utilize the minerals supplied by goat's milk.

Stability of Vitamins in Stored Ice Cream. (Arthur D. Holmes, John W. Kuzmeski, and Frank T. Canavan). Ice cream has become an important component of the human dietary, about 3 gallons being consumed per capita per year. This volume of ice cream contains significant amounts of proteins, fats, carbohydrates, minerals, and vitamins. Since the proteins in ice cream are of animal origin, they have superior biological value. Only a relatively small amount of commercial ice cream is consumed at the time of its manufacture, and a question naturally arose regarding the stability of the vitamin content of ice cream during storage. Accordingly several samples of ice cream manufactured on a commercial scale in the dairy laboratory by the formula included in last year's Annual Report were stored at $-10°$ F. for seven months. Determination of the riboflavin, carotene, and ascorbic acid content of samples of ice cream before and after storage showed a 5.4 percent loss of riboflavin and a 15.7 percent loss of carotene during storage. These data indicate that the riboflavin and carotene in ice cream stored at $-10°$ F. for seven months are fully as stable as these vitamins present in a variety of canned vegetables stored for a corresponding period of time. Thirty samples of freshly made ice cream were assayed for reduced ascorbic acid, and none was detected. It is assumed that the ascorbic acid in the fresh, whole, raw milk was rapidly oxidized by the occluded air which constituted about half the volume of the ice cream.

Enhancing the Riboflavin Content of Mare's Milk. (Arthur D. Holmes.) Cow's milk is generally recognized as one of the best natural sources of riboflavin. On the other hand, as noted in last year's Annual Report, milk produced by mares that grazed in the same pastures and consumed hay grown in the same or adjacent fields as that provided for the cows, contained only about one-tenth as much riboflavin as the cow's milk. This raised the question of the comparative riboflavin content of the two types of milk and whether it would be possible to significantly increase the riboflavin content of mare's milk by feeding crystalline riboflavin as a supplement to the normal ration. Finely pulverized riboflavin crystals were diluted with a large amount of sugar pulverized to the same fineness. The homogeneous mixture was placed in No. 2 hard gelatin capsules, which are smaller than a kernel of corn but larger than an oat kernel. These were mixed with the crushed oats and readily eaten by the mares—all horses are particularly fond of sugar. A total of 5.26 gm. of riboflavin was administered to each mare during a 22-day feeding period. The riboflavin content of the milk was significantly increased, but the increase was of short duration and the riboflavin content soon returned to pre-experimental levels. While it is possible to materially increase the riboflavin content of mare's milk, it is evidently more efficient to administer riboflavin to the foal directly rather than through the mare's milk.

A Study of the Changes in Vitamin Content Coincident with Different Stages and Rates of Maturity of Vegetables Used for Home Consumption. (Arthur D. Holmes and Carleton P. Jones.) Two studies were completed during the fiscal year. Both produced data concerning the vitamin content of vegetables—winter squash and winter tomatoes—produced locally.

Composition of Squashes after Winter Storage. (Arthur D. Holmes and Albert F. Spelman.) Squashes have been an important article of diet in this locality since early colonial times. In this study four varieties, Blue Hubbard, Butternut, Golden Cushaw, and Delicious, were secured about the middle of February from chain and independent grocery stores, private homes, and the University dining hall storage house. This represented a wide variety of storage conditions which were believed to be similar to those in general use for squashes consumed in this locality. The four varieties of squashes contained about the same amount of riboflavin. The Butternut squash had higher calcium, iron, magnesium and phosphorus content than the other varieties. The squashes contained less calcium, iron, and magnesium but considerably more riboflavin and phosphorus than was found in lettuce and kale grown on the University farm. The values for carotene, riboflavin, calcium, iron, magnesium, and phosphorus varied with the different varieties and with individual squashes within the varieties; but the results show that all four varieties, after four-month's winter storage, were good sources of food ingredients essential for the human diet. The most striking values obtained were for carotene in Butternut and Golden Cushaw squashes, for they were unusually rich in this essential food constituent.

Food Value of Hormone-Treated Tomatoes. (Arthur D. Holmes, Albert F. Spelman, John W. Kuzmeski, and William H. Lachman.) According to agricultural statistics, the commercial crop of tomatoes in 1944 was 4,051,000 pounds, which is equivalent to over 31 pounds for each man, woman, and child in this country. During recent years numerous investigators have studied the effect of spraying tomato blossoms with various plant hormones to increase the number of fruits and to produce seedless tomatoes. It is generally believed that tomato seeds have very little human food value. Accordingly, a question arose concerning the relative food value of normal and seedless tomatoes. In the present study, tomato seeds of the Waltham Forcing variety were planted December 1, and the seedlings transplanted to the greenhouse February 1. Fertilizer was applied at the rate of 20 tons of horse manure and one ton of commercial 5-8-7 fertilizer per acre. A solution of 0.075 gm. of beta-naphthoxyacetic acid per liter was sprayed directly into the center of fully opened tomato blossoms with a small atomizer until droplets of the solution could be observed inside the flower. During the interval between planting the seeds and harvesting the tomatoes, the greenhouse was exposed to 1000 hours of bright sunshine. Very little difference was found in the water content or the magnesium content of the hormone-treated and control tomatoes. The hormone-treated tomatoes averaged slightly more nitrogen, phosphorus, potassium, and calcium; but the controls contained an average of 18.2 mg. of ascorbic acid per 100 grams as compared with 14.4 mg. for the hormone-treated.

The Investigation of Agricultural Waste Products. 1. The Chemical Investigation of Lignin. (Emmett Bennett.) Continued attempts have been made to increase the nitrogen content of lignin. Oxidations with nitric acid were not particularly fruitful and have been discontinued. Attempts also have been made to unite urea and lignin. With the means at our disposal, the reaction was not successful.

The most promising procedure tried was the ammonification and simultaneous oxidation of lignin in a medium of concentrated ammonium hydroxide and oxygen at atmospheric pressure. This reaction was improved by previously subjecting the lignin to a mild hydrolysis with citric acid. Chlorinated lignin ammoniated in the above manner yielded the highest percentage of total nitrogen. The maximum content of total nitrogen obtained was about 3.9 percent.

Studies on the Quantitative Estimation of Hemicelluloses. (Emmett Bennett.) Procedures relating to the development of a method for the quantitative estimation of polyuronide hemicelluloses have been continued. The technique adopted is based on the action of sodium chlorite on plant tissue. After certain preliminary extractions, this reagent removes the lignin to almost any desired extent, leaving behind the hemicelluloses. This group of substances may in turn be removed by extraction with relatively dilute solutions of strong alkali. The extracts are then oxidized in a solution of chromate in sulfuric acid. The reduced chromate is measured spectrophotometrically. By referring to a curve which relates reduced chromate to anhydropentose, the content of hemicellulose as anhydropentose may be ascertained.

In the case of cornstalks, extractions were found to be most efficient when the tissue was mercerized with 14 percent sodium hydroxide at 20° C. for ten minutes, then an equal volume of water added and allowed to stand for a total of 90 minutes. Approximately 85 percent of the furfuraldehyde-yielding substances may be removed in this way. It is also quite probable that such a partition separates the polyuronide from the cellulosan hemicellulose. It is felt that more drastic treatment is undesirable since some pentose units might be removed from the cellulose chains. It seems more desirable to consider such units as constituents of cellulose.

Pectic compounds and ether-soluble substances should be removed prior to treatment with sodium chlorite. Starch, to some extent at least, is solubilized by the action of this reagent. Protein is not removed completely during the production of holocellulose, but is extracted almost completely by the alkaline medium; hence corrections must be applied in obtaining the final figure for hemicelluloses.

The procedure has been applied to six different plant tissues with a hemicellulose content ranging from about 7 to 25 percent. Consistent results can usually be obtained and variations between samples usually do not exceed 5 percent. It is believed that the simplicity, rapidity, and consistency of the procedure will make it of value.

The Chemical Investigations of Hemicelluloses. (Emmett Bennett.) Investigations dealing with the chemistry of hemicelluloses have been continued. Special attention has been given the hemicelluloses of cornstalks. This fraction was obtained from holocellulose prepared according to a previous report (Jour. Ind. Eng. Chem. Anal. Ed. 19, 215, 1947). To date solubility studies have been made and some of the fractions characterized by certain determinations. All solvents used extracted some hemicellulose, but the bulk was freed by the action of 4 percent sodium hydroxide at room temperature. All fractions tested were optically active and ranged from about $-60°$ to $-85°$. The more negative rotations were associated with the higher content of pentosans. Methoxyl and uronic acids were present and decreased in amount as the content of pentosans increased. The magnitude of the alkali lability numbers would indicate that there is little difference in the chain length of the fractions obtained by use of the stronger reagents. Further interpretations are not in order at this time.

The Influence of Base Exchange Capacity and of Exchangeable Ions in Massachusetts Soils on the Availability of Potassium. (Dale H. Sieling.) Tobacco plants grown on soils of varying base exchange capacities (B.E.C.) and available potassium levels in 1942 were analyzed for calcium (Ca), magnesium (Mg), and potassium (K). Tobacco was grown on these same soils in 1946 to further exhaust the soils of cations and to determine the influence of B.E.C. on the availability of these residual bases. The plants produced were analyzed for Ca, Mg, and K.

From 50 to 60 percent of the available K was absorbed by the growing crop during the first season. The amount of K absorbed was closely proportional to the K present in the soil, and not related to the available Ca or the B.E.C. The dry weight production closely paralleled the K availability. In the second year the plants developed severe potash-deficiency symptoms and absorbed very much less K. In general, the second crop absorbed greater amounts of K from those cultures of high B.E.C.

Ca was absorbed in greater quantities from soils of high B.E.C. than from soils of low B.E.C. The relative amount of Ca to total bases absorbed was greater during the second year than during the first year. In all instances, an increase in K uptake resulted in a decrease in Ca uptake and a greater dry weight production.

The proportion of Mg to total bases utilized decreased significantly as the uptake of K increased. No significant effect on Mg uptake was shown by variations in the Ca level of the soil or the B.E.C.

There was a general tendency for the total phosphorus content of the plant material to decrease as the Mg/total cation ratio decreased.

In general, cation uptake and maximum growth was associated with soils of high B.E.C., and in turn less bases were lost by leaching from soils of high B.E.C. Therefore agronomic practices tending to increase the B.E.C. should be practical. Increase in available K in soils definitely favored the uptake of K by the plants with the subsequent decrease in the uptake of Ca and Mg. Increase of Ca, on the other hand, did not decrease the uptake of K but resulted in a higher total base uptake. The greatest dry weight production was associated with the widest K/Ca, K/Mg, and Ca/Mg ratios in the dried plant material. It therefore seems reasonable to suggest that the use of fertilizers high in K should be supplemented with liberal applications of Ca and Mg to prevent the induction of deficiencies of either of these elements as a result of luxury consumption of K.

The Fixation of Arsenic in Soils and the Influence of Arsenic Compounds on the Liberation of Fixed Phosphorus in Soils. (Dale H. Sieling.) Kaolin is a widely distributed soil mineral which has been said to have ability to fix phosphates in large quantities, especially after it has been reduced to a fine state by grinding or other means. It was found that kaolin could be activated to adsorb large quantities of either phosphate or arsenate by ball-milling it or heating it with an alkali metal hydroxide. The longer the time of ball-milling or the greater the amount of alkali hydroxide used per unit of kaolin, the greater was the sorption capacity of the activated kaolin.

The active constituent of ball-milled and alkali-activated kaolin could be removed by extracting the materials with 0.1N HCl, 0.1M tartaric acid, or 10 percent HCl. This active constituent was believed to be a hydrous alumina such as gamma —AlOOH which is known to be present in freshly precipitated alumina and to exhibit properties similar to the ball-milled kaolin.

The alumina of ball-milled kaolin sorbed phosphate and arsenate in practically equivalent amounts from the more dilute solutions of these ions; however, from the more concentrated solutions the sorption of arsenate far exceeded that of phosphate. The amount of either anion sorbed was dependent upon the reaction of the equilibrium solution and the initial concentration of the solution. The lower the pH within the range of pH 3.0 to pH 7.0, the greater the sorption; and the higher the concentration at any fixed pH, the more of the anion was sorbed per unit of alumina.

Freshly precipitated hydrous alumina sorbed phosphate and arsenate in greater quantities than an equivalent quantity of alumina contained in ball-milled kaolin. Freshly prepared anhydrous alumina was much less active in anion sorption than the alumina of ball-milled kaolin. Aged commercial "aluminum hydroxide" had no anion sorption activity unless it had been activated by alkali and heat.

Phosphates were effective in replacing sorbed arsenate from the alumina of ball-milled kaolin, but the reaction was not an equivalent one. Arsenates replaced only a very small percentage of the sorbed phosphates from the alumina of the ball-milled kaolin even when the concentration of the arsenate was five times that of the sorbed phosphate. Therefore, the use of arsenate as an analytical reagent for measuring the anion sorption of soils or for determining the exchangeable phosphorus in soils is not recommended. It follows also that soils which have received large quantities of arsenates as a result of measures used in pest control might release quantities of arsenates toxic to plants if they were heavily fertilized with phosphatic materials.

The Effect of Orchard Mulches on Plant Nutrient Elements in the Soil. (Dale H. Sieling and Jacob K. Shaw.) Six mature McIntosh apple trees whch had been managed by the cultivation–complete fertilizer system from 1931 through 1940 were selected for this study in June 1941. Six separate plots, each with an area of 1600 square feet and containing one tree at its center, were treated as follows: Duplicate plots received an application of 290 pounds, 417 pounds, 350 pounds, and 400 pounds of dry mixed-hay mulch in 1941, 1942, 1943 ,and 1944 respectively; duplicate plots received a mulch of fiber glass wool 2–3 inches in thickness in 1941; and two plots were cultivated and kept fallow. No commercial fertilizer was applied to any of the plots during the six years the investigation has been in operation.

Soil samples were taken at two systematically located positions under each tree before the mulch was applied. At each sampling location four samples were taken at the following depths: 1–3 inches, 6–8 inches, 12–14 inches, and 22–24 inches. This sampling procedure was repeated in 1942, 1943, 1944, and 1947 from newly selected positions not far removed from those of the previous year but far enough to insure the obtaining of the samples from soil which had not been disturbed by previous samplings. The mulch was removed from the sampling areas before sampling time to prevent its incorporation in the surface soil samples. The samples were stored in sealed containers and were analyzed for exchangeable calcium, magnesium, and potassium to find whether the mulching systems employed were effecting the movement of these cations into soil.

The hay used for mulching was analyzed for calcium, magnesium, and potassium and was found to vary considerably from year to year. In total, 34.3 pounds of calcium, 2.7 pounds of magnesium, and 21.7 pounds of potassium were added as mulch to each plot of 1600 square feet or at the rate of 933 pounds, 73.4 pounds, and 590 pounds of these elements per acre respectively.

The amount of these elements added as the mulch should, when the hay was mineralized, have had a significant effect upon the amounts in the upper zones of the soil beneath the mulch, provided the tree had not effectively removed the major portions of them as the mineralization took place.

Analysis of the soils for these elements revealed that the variations between the duplicate samples obtained from the various plots during any sampling period were much greater than the variations caused by the elements added in the mulch. Therefore it is not possible to say that the mulching procedure was effective in mobilizing or increasing the exchangeable calcium, magnesium, or potassium, although trees under hay mulch were superior in performance and appearance to the trees receiving the other two treatments.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Administration. Pursuant to providing acts of the legislature, considerable office changes were made in the main building of the station to accommodate increased personnel, an oil-burning plant was installed in the basement for heating the laboratory and offices, much new laboratory equipment was added, and a new full-time clerk was employed. These provisions should greatly increase the efficiency of the station and make it possible to finish in reasonable time some important lines of work that have long been in process.

General. An unusual combination of circumstances produced a large crop of cranberries in Massachusetts and the country as a whole in 1946, and there was a remarkable market demand for the fruit at record high prices. The state bog crop was the largest since that of 1923 and is returning nearly 32,000 dollars to the State Treasury.

Notable features of the 1946 cranberry season in Massachusetts were a very unseasonable frost on July 16-17 which destroyed over 1200 barrels of berries, mostly in Holliston, Plymouth, Waquoit, Santuit, Wakeby, and Brewster; and excessive rain in August (12.61 inches at East Wareham) that caused bogs to be flooded to such an extent that, as estimated, 15,000 barrels of berries were ruined. The berries of the Massachusetts crop proved to have very good keeping quality in spite of this rain.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.) Bulletin 239 was revised and amplified and presented for republication.

DDT. Investigations made in 1946 indicated that this insecticide is effective against the cranberry tipworm and the cranberry weevil, and it was advocated as a control for these insects as well as for the gypsy moth and the black-headed fireworm in the 1947 Cranberry Insect and Disease Control Chart.

Chlordane ($C_{10}H_6Cl_8$) used both as a dust and in a spray was not nearly so effective as DDT as a control for gypsy moth caterpillars and blunt-nosed leafhoppers (*Ophiola*).

Helicopters. Observations of these machines in commercial operations against cranberry pests in the spring and early summer of 1947 lead to the conclusion that they are likely to soon come into general use on Massachusetts bogs.

Prevalance of Cranberry Insects in the Season of 1946:

1. Gypsy moth infestation moderate in Plymouth County and inland; very light in Barnstable County.
2. Leafhoppers (*Ophiola*) not very abundant.
3. Fruitworm infestation very light, rather lighter than in 1945.
4. Black-headed fireworm not very troublesome.
5. Very few fire beetles (*Cryptocephalus*) found.
6. Spotted fireworms (*Cacoecia*) very few.
7. Spanworms, both green and brown, about as usual.
8. False armyworm infestation about normal.
9. Cranberry girdler (*Crambus*) still much more troublesome than before the war, owing to neglect of bog resanding.
10. Spittle insect about as usual.
11. Tipworm apparently very much more prevalent generally than usual. Probably partly as a result of this, the average terminal budding of the vines for the 1947 crop on the bogs in this State was the poorest observed by the writer in his forty years of cranberry experience.
12. Bumblebees and honeybees were unusually abundant on the bogs everywhere throughout the cranberry flowering. A very remarkable and possibly very instructive incident relative to bee abundance was observed. The winter flowage was removed from a bog of two and a half acres in East Carver on June 20. This bog reached full bloom about August 8. Bumblebee workers and males came to this bog in astonishing numbers whenever the weather was fair throughout the blooming. It was estimated that a third of a million of these bees were there much of the time. Watching them at work, as they rose from the cranberry vines and went back to them here and then there, gave one the strange feeling that he was looking out on a bumblebee sea. Honeybees seemed to be entirely absent. The fruit, about 180 barrels of Early Black berries of fair size and color, was gathered from this bog early in October.

Frost Forecasts. These are continued as a special service, with the 1947 charges for the telephone service increased materially over those of previous years to meet the larger costs caused partly by improvements. About 7200 acres of bog in the hands of 204 subscribers are covered by the telephone warnings, this being about three-fourths of the entire Massachusetts cranberry acreage with fair to full flowage protection. The accessory warning service by radio is cooperating as heretofore with the United States Weather Bureau office at Logan Airport, the warnings being given mainly through station WEEI at Boston.

Control of Cranberry Bog Weeds. (C. E. Cross.) A large number of experiments have been set out on the State bog and other bogs since May 1, 1946, the results of which have not been previously reported.

1. In the belief that one of the greatest weed problems faced by cranberry growers is that of controlling grasses and sedges which begin their season's growth after the cranberry vines have started, many tests were made in July and August, 1946, with kerosene oils, Stoddard solvent, insecticide base oils, and a large number of strictly experimental oils known only by numerical designation. None of these oils has, as yet, proved satisfactory as a selective weed killer during the summer season.

2. Stoddard solvent, sprayed at 400 gallons per acre during the first two weeks of May has been found an excellent selective killer of asters. Kerosene at 1000 gallons per acre will not kill asters nearly as effectively, though neither treatment injured cranberry vines or buds when applied before May 15. The Stoddard solvent treatment is more effective, more easily applied, less injurious to vines,

and less expensive than the previously recommended control of asters with ferrous sulfate.

3. Paradichlorobenzene, scattered at 7½ pounds per square rod and covered immediately with an inch of sand, has previously been recommended for controlling poison ivy, chokeberry, loosestrife, and white violets. Experiments now show this treatment to be effective against wild bean (Apios) and three-square grass (Scirpus), and occasionally against the small bramble (Rubus). In addition, this treatment was found effective against poison ivy and wild bean when applied early in April while ivy and bean were still dormant.

4. Ferrous sulfate can be spread at the rate of 50 pounds per square rod without injuring cranberry vines. This heavy application, made in June, July, or August, killed all white violets, asters, and needle grass. However, serious injury to cranberry vines resulted when this treatment was applied to bogs sanded within a year. Tender cranberry roots near the surface in the new sand were apparently severely burned.

Some study and experimental work has been done toward protecting cranberry bogs from winterkilling and frost by means other than flooding. This work looks promising but is still in its preliminary stages and will not be described more fully now.

Cranberry Breeding. (F. B. Chandler, Collaborator; H. F. Bergman, U.S.D.A.) One hundred and fourteen selections from the 10,685 cranberry seedlings produced by the U.S.D.A. have been set in Massachusetts for further testing: some in four bogs, and the others in two or three bogs. From these selections, it is hoped that some new varieties will be developed which will be resistant to false blossom and fungous diseases and will give good yields of desirable fruit.

The results of the breeding work and some of the information about these selections were published in *Cranberries* for May and June, 1947.

Fertilizer Requirements of Cranberry Plants. (F. B. Chandler and Wm. G. Colby.) Plots have been laid out and fertilizer applied to study nitrate vs. ammonia as a source of nitrogen for cranberries. The rate of application of nitrogen in the treated plots has varied from 10 to 80 pounds per acre. Fertilizer applications are being made before bloom (June), before fruit-bud formation (late July), late in the fall, and early in the spring. These plots have not been established long enough to give information on yield, but vines on fertilized plots have much better vigor and bloom and are much heavier than vines on unfertilized plots on both hard-bottom and peat-bottom bogs.

DEPARTMENT OF DAIRY INDUSTRY

H. G. Lindquist in Charge

Sanitizing Agents for Dairy Use. (W. S. Mueller.) Since the last war many new sanitizing products are available for dairy use. In general these new products, both liquids and powders, have in common a quaternary ammonium salt of one form or another, which is the active bactericidal material. The effectiveness of these new sanitizing agents for dairy use is being investigated and the following progress has been made:

1. *Bactericidal Properties of Some Surface-Active Agents.* (W. S. Mueller with the cooperation of Emmett Bennett of the Chemistry Department and J. E. Fuller of the Bacteriology Department.) Results of this study were published in the *Journal of Dairy Science* 29, November 1946. It was concluded that out

of 42 surface-active agents investigated, only the quaternary ammonium salts showed considerable promise of making a good sanitizing agent for dairy use.

2. *A Method for Evaluating the Sanitizing Efficiency of Quaternary Ammonium Compounds.* (W. S. Mueller and E. P. Larkin.) A method has been developed for evaluating the sanitizing properties of quaternary ammonium compounds. While the method is not new, it involves the use of some new procedures and some refinements of older techniques. In brief, the method consists of the addition of a standardized inoculum to a germicide, and the results are simply reported as percentage survival or kill for definite periods of contact time. The usefulness of this method depends largely upon the efficiency of the inactivator. A hand homogenizer and spectrophotometer are used in preparing the inoculum, and sodium naphthuride is used as the inactivator for the quaternaries. This method appears to give a truer picture of the germicidal potency under actual working conditions than is given by the phenol coefficient values as determined by the Food and Drug Administration method.

3. *The Use of Quaternary Ammonium Compounds in Dairy Sanitation.* (W. S. Mueller and D. B. Seeley.) Organisms like *E. coli*, *S. aureus*, thermophilic types, and the vegetative cells of *B. cereus* were readily killed by quaternaries. While quaternaries appeared to have no greater germicidal effect on spores of *B. cereus* and thermodurics than older types of germicides, they were highly bacteriostatic to sporeformers.

Approximately 0.3 percent of either cow manure or non-fat milk solids produced the first significant decrease in germicidal potency of a 200 p.p.m. quaternary solution. When this concentration of quaternary was used as an udder wash under normal conditions, approximately 30 to 40 cows could be washed before the germicidal potency of the solution decreased to a point where a fresh solution was needed. No chapping or cracking of udders, teats, or milkers' hands was noted when this concentration of quaternary was used.

Metal parts of dairy equipment, when properly washed, were effectively sanitized by the use of 200 p.p.m. of quaternary. However, as much as 400 p.p.m. was not effective in sanitizing the rubber inflation tubes of teat cups after each cow milked when the cups were dipped rapidly in and out of the solution.

A quaternary spray treatment for milk cans showed a significant reduction in counts.

Dual-purpose powders such as cleaner-sanitizer combinations appear to have considerable merit.

4. *The Effect of Quaternary Ammonium Compounds on Molds.* (W. S. Mueller and R. S. McKenzie.) Considerably less work has been done with quaternary ammonium compounds in connection with molds than with bacteria. The chief purpose of this study is to determine what effect quaternary ammonium salts have on some molds commonly found in milk, cream, butter, sweetened condensed milk, and cheese. While work on this study has not progressed far enough for definite conclusions to be drawn, it is evident that not all molds are destroyed after five-minute contact with a 200 p.p.m. quaternary solution at room temperature.

Antioxidants from Cacao. (W. S. Mueller.) Improvements have been made in the extraction of certain tannin-like antioxidants from cacao, thus making it possible to obtain antioxidants of greater purity. The refined products obtained were found to be more effective than the earlier extracts in improving the stability of butter oil, according to peroxide value, color, taste, and odor tests. The refined antioxidants also were more effective in retarding the destruction of vitamin

A and in neutralizing the pro-oxidant effect of copper. If the stability data which have been obtained on butter oil by accelerated tests can be applied to food products containing butter fat, then the food value, flavor, and keeping properties of such products should be greatly improved by the use of the antioxidant in question.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Effects of the War and Readjustments in Massachusetts Agriculture. (David Rozman.) Further studies were made of wartime changes in the pattern of agricultural production and their effect on the needed readjustment in the coming years. Analysis of the AAA records together with other supplementary material, provided a valuable basis for determining the changes in farming enterprises on individual farms. In the light of the investigations made under this project the 1947 production program was worked out for Massachusetts agriculture.

In connection with the problems of postwar adjustment in agricultural production, an analysis has been made of the changes in major farming enterprises in the period from 1942 to 1945 inclusive. On 2374 operating farms analyzed in five counties, the following changes in livestock numbers and crop acreages occurred: All cattle and calves increased 4.9 percent; hens and pullets for laying increased 53.7 percent; corn acreage declined 8.2 percent; vegetable acreage declined 0.5 percent; potato acreage increased 16.5 percent; tobacco acreage increased 20.8 percent. This presents the situation on the farms remaining in continuous operation through the war period. To the extent that a certain number of other farms in the State might have discontinued their operation on account of difficulties in production or for some other reason, indicated changes in various lines would need some adjustment to reflect the situation on a statewide basis.

Transfer of Ownership and its Effect on Agricultural Land Utilization. (David Rozman.) Work on this project commenced at the beginning of 1947 and is yet in preliminary stages. The main objective is to appraise the effect of changing ownership on land utilization and the future trend of farming in the State. From the preliminary evidence already obtained it appears that the rate of transfer of agricultural land during the war and immediately following has been accelerated by an increased demand from various sources. The character of new ownership will have a direct bearing on the size and kind of farms and their variations from the recognized standards of an efficient economic unit. Its ultimate effect will be to determine the pattern of agricultural production as it will emerge in the State in the coming years.

To obtain a representative sample of localities for investigation, a number of towns have been considered as to their suitability. In Hampshire County, Amherst and Hatfield have been selected. From the Registry of Deeds and from assessors' records complete information was obtained as to the transfer of land ownership in agricultural areas of these towns from the beginning of 1940 to the end of 1946. In addition to land areas and names of the parties in the transactions, the information obtained includes detailed classification and valuation of property; prices paid, if given; mortgages; and the numbers and kinds of livestock maintained on the land.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb.) Work in connection with the cooperative project with the Dow Chemical Company was continued in 1946, both at Amherst and Waltham.

Dormant applications of the experimental compounds D-608, D-610, D-542, D-289 and D-2 on apples, all gave excellent kill of overwintering eggs of apple plant lice. Aphids on sprayed trees averaged two or less per bud as contrasted with 50 per bud on unsprayed checks. There was also measurable reduction of European red mites on sprayed trees.

Pear psylla was very satisfactorily checked by D-542 and D-2. Eggs deposited on sprayed trees averaged less than 3 per fruit spur as contrasted with 80-85 on unsprayed trees. No further control measures were necessary on most of the pear orchard throughout the balance of the season.

D-542 on Viburnum prevented appearance of aphids on this ornamental shrub and for the first time in many years the specimens which received this spray produced a full bloom, and the unsightly appearance of distorted leaves and twigs was avoided.

At Waltham applications of experimental dinitro formulations prepared by the Dow Chemical Company were applied to 20-year-old apple trees when buds were in the silver-tip stage. The formulae were known as D-608, D-610, and D-289; and were diluted for spraying at 2 percent, 2 percent, and 2 quarts per 100 gallons respectively. Examinations on May 2 when the center bud was open showed no rosy aphis, green aphis, or newly hatched European red mite on any of the trees, including those unsprayed. Where D-610 at 2 percent was used, very slight but insignificant injury to the most advanced fruit buds was found. No injury was observed from the other formulae.

Orchard tests of a miticidal DDT containing 20 percent hydroxy penta methyl flavan were made at Waltham and in cooperation with orchardists at Bolton, Groton, and Westford, Massachusetts. When this material was used at the rate of 5 pounds in 100 gallons of spray, careful leaf counts showed a reduction in the mite population varying from 60 to 80 percent after two applications. However, red mite eggs were not killed and there was no toxic residue to prevent a serious reinfestation in two or three weeks.

DDT for Control of Black Scale on Gardenias in a Commercial Greenhouse. (A. I. Bourne.) The black scale (*Saissetia oleae*), a native of tropical and subtropical regions, occurs on many types of trees and shrubs and is one of the most serious insect pests of citrus fruits. In Massachusetts and other northern areas, it is almost entirely a pest of greenhouse plants. This scale is so prolific and has such a wide range of plants upon which it will thrive, that it is always a dangerous pest and, when well established, has proved very difficult to control. Aside from the direct damage from its feeding, the honeydew excreted by the scales serves as an excellent medium for the growth of sooty fungus. On many greenhouse crops such accumulation of black, sooty fungus on the foliage constitutes a depreciation in value second only to that caused by reduction of bloom. All these factors combine to make this species one to be dreaded by all commercial growers who encounter it in their houses.

On September 16, attention was called to a serious outbreak of black scale on Gardenias in a commercial greenhouse. The infestation occurred in both sections of one range, comprising a total of 60,000 square feet. The plants were in their second year of growth and were coming into their first season of full production. Scale was present throughout both houses but the heaviest attack was centered in the three south benches of the east house. On many plants both buds and leaves were heavily infested and much of the foliage was coated with sooty fungus. Examination of sample leaves from the house showed an average of 56.5 crawling young and 54.8 older stage scales per leaf, or a total of 111.3 scales per leaf.

On this same date a 25-foot section of one bench in the area of heaviest infestation was given a spray of a 25 percent DDT emulsion at 1:250 dilution. The rest of the eastern half of the house was sprayed with nicotine sulfate 1:500 + fish oil soap 4 pounds per 100 gallons, on September 17, 24, and at 7 to 10 day intervals thereafter.

One application of the DDT emulsion reduced the number of scales from an average of 111 per leaf to 2, within two days, and held it at approximately the same figure for three months. In the meantime weekly applications of nicotine sulfate failed to prevent an increase in the number of scales so that by late October it was necessary to make an application of DDT emulsion to the whole house to prevent serious damage to the plants. By this time, in this area, leaves and buds had become heavily infested (average 150 scales per leaf). The small number of scales in the section sprayed with DDT (average 1.6 scales per leaf) indicated how completely the pest had been controlled in that section. Both leaves and buds were practically clear of scales. The new, terminal growth was noticeably greater and the plants were in much more vigorous condition. Moreover, the DDT emulsion left no white deposit on the foliage, an objectionable feature of the use of DDT in the form of wettable powder.

The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts. (A. I. Bourne, in cooperation with the Departments of Pomology and Plant Pathology.) Injury from frost so reduced the set of fruit that it was necessary to rearrange the location of the spray tests.

In the orchard where the lead arsenate tests were made, the set of fruit was very light on the unsprayed check trees. They were in an exposed section of the orchard and suffered greatly from frost damage. There was also a heavy drop from disease and insect attack. All of the apples on these trees were blemished by scab; 50 percent were scarred by curculio; 67 percent were damaged by codling moth (blossom end and side worm "stings"); and about 33 percent showed scarring by minor pests and were infested by apple maggot.

The regular schedule, with lead arsenate the insecticide, held codling moth to 16 percent injury and curculio to 6½ percent, and reduced scab to 19 percent damage. When the emergency codling moth spray was interposed between the 2d and 3d cover spray, codling moth and minor insect pest damage was cut down to a mere trace, and this extra application reduced scab to 11 percent blemished fruit in a season of unusually heavy attack. The application of a mid-August spray did not give any measurable additional reduction of codling moth.

Results would indicate that if the emergency spray is carefully timed on codling moth development, no other additional spray is required, and that the increased protection from scab afforded by this spray would also justify its use.

In the orchard to which the tests with DDT were transferred, the test blocks received the regular schedule up through the calyx and first cover spray. In the

2d cover spray, all the sprayed rows received lead arsenate 2 pounds + fungicide. In addition row 1 received DDT ½ pound (actual); row 2 received DDT 1 pound; and row 7 received DDT 2 pounds. Row 5 was left as a check. In the emergency A spray and the 3d cover, the sprayed rows received the DDT as in the 2d cover, but lead arsenate was omitted. In the 4th cover, lead arsenate 2 pounds + fungicide was used, but no DDT.

Because of frost damage, the yield on the check row of McIntosh was too light to be worth considering, so that the fruit on Cortland variety was checked.

Codling moth was not as severe a pest as usual in many of the orchards in 1946, but in the DDT blocks it was practically nil (about 3 apples in 500). The heavy dosage of DDT (2 pounds actual) + lead arsenate (2 pounds) in the 2d cover spray evidently cut curculio damage materially. This conformed with results of tests in other orchards. The effectiveness of DDT was also reflected in the protection against apple maggot and miscellaneous apple pests, all of which were reduced to a mere trace; actually only a matter of an occasional apple per bushel. It was also encouraging that in a season of unusual severity of scab, the combination of DDT with wettable sulfur fungicide not only proved compatible but gave excellent protection of the fruit from scab.

Insecticides for the Control of the European Corn Borer. (A. I. Bourne.) The first brood, corn borer infestation in Massachusetts was very light in 1946 and occurred somewhat later than usual.

Cold, windy weather which prevailed through most of May appeared to be very unfavorable for moth activity. Early plantings of corn developed rather slowly, and without doubt many moths in the field emerged before corn was up or was of attractive size. This was certainly true of material in the emergence cages. Probably many moths died without depositing eggs, which seems to be borne out by the insignificant infestation on early sweet corn since there was a moderately heavy carryover and almost no winter mortality.

Throughout most of the State damage by first-brood larvae was negligible even in untreated fields. Severe drought from mid-June to late July may have contributed one factor, since considerable rolling of the leaves occurred in many fields and egg masses are easily dislodged, especially when rolling is accompanied by hot, drying winds, such as occurred in 1946. The growth of corn was slowed down and early plantings were late in maturing. Many fields planted by mid-April or earlier, and breaking ground by late April, did not mature until early August.

The second brood was also somewhat delayed and in general was not serious. In the field tests, applications were made at 7-day intervals. Evidently this was too far apart for securing best results from derris, although it appeared to be satisfactory for the other materials. Ryanex both as a spray and as a dust gave very satisfactory control and caused no injury. Applications of DDT and DDD were followed by slight burning.

Of the sprays, Ryanex, DDT (1 pound actual), and DDD (1 pound actual) gave 98-99 percent control. Derris (4 percent rotenone) gave 95.5 percent clean corn. Of the dust materials, DDT (3 percent) gave practically complete protection, Fixed Nicotine Dust (4 percent nicotine) 97 percent, and Ryanex 94 percent.

Potato Spraying Experiments. (A. I. Bourne.) The plots were planted May 9 and the plants made normal and satisfactory progress throughout the early season. The plots were partially submerged by the heavy rains in late July when 4 to 5 inches of rain fell within about two days' time. Rains thereafter kept most of the field rather wet and checked growth somewhat. Most of the plants remained alive and green until killed by frost October 13-14 (the first serious killing frost). The field was dug October 14. Damage from excessive water was such that records could be taken only from the higher portion of the field.

Flea beetles were slightly less than normal in abundance; the early attack was very light. A rapid and heavy build-up of leafhoppers occurred between July 17 and 25. One application of DDT (1 pound actual) in 10-5-100 Bordeaux on the 25th not only practically eliminated leafhoppers but wiped out the late brood of flea beetles; neither insect was present in any amount for the remainder of the season. Potato aphids began to appear in all plots about mid-July during the hot dry weather which prevailed at that time. The infestation was subdued with nicotine sulfate in the application of July 17. The records indicate that the application of DDT practically eliminated insect pests with the exception of potato aphids, and even in the case of potato aphids prevented a serious build-up. By mid-August practically all insects had been eliminated and the insignificant damage to foliage was shown by records of flea beetle perforations on the foliage: 6.4 punctures per growing tip on August 17 and 2.5 punctures per growing tip on August 20.

Sprays were applied at approximately 7-day intervals from June 12 when the plants were about 4 to 6 inches high until September 18 when most of the plants were still green but were beginning to ripen. The sprays from August 28 were for protection of green tips only. There was practically no evidence of insect presence after early August.

Evidence from these tests, as well as results of experiments elsewhere, indicate that DDT is very effective against the major insect pests of potato. In laboratory and field tests, DDT either as a dust or as a spray controlled Colorado potato beetle, leafhoppers, flea beetles, and plant bugs, if thoroughly applied to reach both upper and under leaf surfaces. There is indication that potato aphids can be held to low numbers by a regular schedule of DDT, although there is still some doubt whether heavy outbreaks will be checked quickly enough to prevent damage when DDT dusts or wettable powders are used.

Control of Onion Thrips. (A. I. Bourne.) The test plots were planted to onion sets April 18. Cool dry weather slowed early development somewhat, but with plentiful rainfall in May and early June, growth was more normal and the plants made rapid advance. The growth was checked somewhat by the 5-week period of dry weather which followed. The plants had become well established by mid-June so that the check was not serious, and the plots matured a good crop which was ready to harvest by early August.

Thrips were delayed somewhat in early spring by the cold weather but found the hot dry weather of late June and July very favorable, and built up rapidly. Throughout the Connecticut Valley, thrips were not of serious abundance; set onions escaped any appreciable injury, and the small plantings of seed onions were not seriously attacked.

Black Leaf 40 and derris sprays again gave consistently high control in all cases. Ryanex, DDT, and DDD sprays also proved effective (above 90 percent effective control). DDT and DDD were superior to the other sprays in residual effects, allowing no increase in thrips population during a 7-day period following application.

Of the dusts, Multicide and Multicide + pyrethrum gave a consistently high degree of immediate protection and good residual effects. Following a very heavy application, sabadilla gave very good control but appeared to have very little residual value. Ryanex dust appeared to kill rather slowly but to furnish good lasting effects. DDT dusted plants showed even fewer thrips after a 7-day interval than 24 hours after the application.

None of the sprays or dusts used caused any plant injury.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) Experimental plantings in 1946 verified previous observations that varieties of *Cucurbita moschata* are immune to squash vine borer. Three varieties of *C. maxima* averaged 2.88 borers per vine, and three varieties of *C. pepo* averaged 1.70 borers per vine.

Insecticide applications in July with 3 percent DDT–talc dust, 20 percent sabadilla–lime dust, and ½ percent DDT plus 0.06 pyrethrins dust gave satisfactory protection; while applications of 10 percent sabadilla–lime dust and ½ percent DDT–talc dust were unsatisfactory as used.

A 5 percent benzine hexachloride-talc dust applied while the plants were small caused so much injury that it was necessary to replant. The 3 percent DDT-talc dust caused slight temporary stunting to seedlings, which was most evident on cucumbers and least evident on Blue Hubbard squash.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) Field treatments for the control of the cabbage maggot in early Golden Acre cabbage were compared with a natural 100 percent infestation on untreated plants, in which 84 percent of the plants were commercially damaged. DDT–talc dust, both 3 and 5 percent DDT, applied either with a hand duster in two applications at a weekly interval, or placed in a mound around the stem of the plant soon after the first eggs were laid, permitted 20 to 25 percent infestation and from 20 to 40 percent of the heads were unmarketable. Corrosive sublimate solution 1–1,280 in two applications, and 4 percent calomel–talc dust in a mound around the stem gave perfect protection from commercial injury. However, the outstanding treatment was two applications with a hand duster of benzene hexachloride–talc dust containing about 5 percent of the gamma isomer. This dust completely controlled the maggot on both cabbage and cauliflower as well as preventing blind heads due to cutworm injury. No evidence of contamination by the odor of the insecticide was evident at any time after the heads began to form. This treatment promises to have great commercial application.

Biology and Control of Red Spider Mite on Greenhouse Crops. (W. D. Whitcomb, Wm. Garland, and C. S. Hood, Waltham.) Spraying of greenhouse roses with hexa ethyl tetra phosphate solution resulted in excellent control of greenhouse red spider, but caused some injury to foliage and stunted the growth of the petals on the outside of rosebuds. Two commercial brands of this material diluted as recommended were equally effective and caused similar plant injury.

The effect of sodium selenate in red spider control was studied on potted carnations at low temperatures (55° F.) during the winter. Dosages of ½ gram, ¾ gram, and 1 gram per square foot caused a reduction in the spider population 50 days after treatment, and remained effective for 50 days longer (100 days after application). A dosage of ¼ gram per square foot became noticeably effective 60 days after application and remained effective only 30 days. Spider populations were not reduced as much by the dosages used as they were by similar treatments in spring and summer.

Apple Maggot Emergence. (W. D. Whitcomb, Waltham.) Apple maggot fly emergence in cages at Waltham occurred at about the normal period in 1946 although the number of maggots which survived the winter and transformed was low. Emergence peaks occurred at two periods, July 7 and 25, which verified the estimated dates for control by spraying. The emergence in two orchard cages was:

First fly emerged	June 29, 1946
25 percent of flies emerged	July 7-11
50 percent of flies emerged	July 14-22
75 percent of flies emerged	July 24-27
Last fly emerged	August 20
Percent of expected emergence	68.8
Percent of possible emergence	34.1

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) Although laboratory poison studies with plum curculio beetles confined with sprayed apples indicated reasonable control with DDT water suspensions containing more than 1 pound DDT per 100 gallons, orchard experiments with 1½ pounds DDT per 100 gallons were unsatisfactory. Two commercial brands of DDT wettable powder were compared, with almost identical results; namely, 48.47 and 48.54 percent of the apples stung by curculio.

A 50 percent hexachlorocyclohexane wettable powder containing 5+ percent gamma isomer combined with wettable sulfur failed to control the plum curculio (61.06 percent total fruit and 49.91 percent harvest fruit stung), when used in the regular schedule of applications. It was evident from observations, however, that more frequent applications would have been significantly more effective. Each of the following combination treatments was significantly more effective than lead arsenate alone in the same schedule, as shown by the percentage of harvest fruit free from stings.

Lead arsenate	4 pounds	75.71
Lead arsenate	4 pounds + DDT 50 wettable 2 pounds	97.31
Lead arsenate	2 pounds + DDT 50 wettable 2 pounds	87.62
Lead arsenate	4 pounds + BHC 50 wettable 2 pounds	86.90
DDT 50 wettable 2 pounds + BHC 50 wettable 2 pounds		86.51

This is the second season when sprays containing combinations of insecticides have been outstandingly effective for control of the plum curculio, and significant evidence of their practical value is rapidly accumulating.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) Several materials were used experimentally for the first time in an effort to find a fumigant which was effective against both greenhouse red spider and aphis.

The most promising fumigant was prepared by adding small amounts of the pure gamma isomer of $C_6H_6Cl_6$ to commercial Fulex paste. Addition of 1.24 percent, 2.48 percent, and 4.96 percent gamma isomer were equally effective and gave complete kill of aphids while retaining the usual high kill of red spider from Fulex.

Pressure fumigation cans containing 17.5 percent azobenzene were very effective against red spider and practical in spite of slight bleaching of pink flowers. The addition of 10 and 16 percent azobenzene to Fulex paste was slightly less injurious than the azobenzene, and effective.

Other materials were discarded for reasons indicated:

Amino azobenzene—effective, but left disastrous yellow residue.
Isopropoxyl diphenyl amino—ineffective.
Vultrol (U. S. Rubber Co.)—ineffective.
Dichloraniline—effective but caused severe plant injury.
$C_{10}H_6Cl_8$ (Velsicol) ½ ounce–1,000 —ineffective as used.

Biology and Control of the Celery Plant Bug. (W. D. Whitcomb and Wm Garland, Waltham.) The results of the insecticide experiments on the celery plant bug in 1946 show that nearly all of the materials used killed the bugs well and eliminated them from the plants immediately after treatment. From the standpoint of lasting protection, however, the sprays of DDT wettable powder were outstanding and no bugs were found on the count plants in these plots for the remainder of the season.

From a practical standpoint, 1 pound of 50 percent DDT wettable powder in 100 gallons of spray (½ pound actual DDT) was as effective as the 2 pound–100 gallon dosage. DDT–talc dusts containing 3 and 1 percent were effective for a month and gave good protection from black heart; but ½ percent DDT dust apparently requires applications at 10–15 day intervals to give adequate protection. Dry Pyrocide 7½ dust is also effective but requires more frequent applications. Special Multicide (½ percent DDT and pyrethrum) was the most effective dust used, with 97.94 percent of the plants free from black heart injury, and was very promising under the conditions of the experiment. Applications of this dust at 30-day intervals should be satisfactory. Sabadilla–lime dust 10 percent gave protection for only a few days.

Based on these experiments, practical control of the celery plant bug, *Lygus campestris*, and the resulting black heart injury should be obtained by spraying about August 10 with ½ pound of DDT (1 pound 50 percent DDT wettable powder) in 100 gallons of water or fungicide, and if necessary following with Dry Pyrocide 7½ dust about September 20 when the second generation of the plant bugs is most abundant.

The use of DDT on celery involves a residue tolerance which has been set, at present, by the U. S. Food and Drug Administration at 7 parts per million. Analyses to determine the relation of the effective treatments to the residue tolerance will be made as soon as possible.

Biology and Control of the Grape Cane Girdler. (W. D. Whitcomb and Wm. Garland, Waltham.) On unsprayed grape canes, grape cane girdler beetles lived an average of 114.2 days and made 18.8 scars per beetle. Sprays of DDT wettable powder killed the beetles in 2.57 days and reduced the scars to 0.23 per beetle. There was no significant difference in effectiveness of ½, 1, 2, 3, or 4 pounds actual DDT per 100 gallons, and DDT was equally effective when combined with basic copper sulfate or Fermate. Benzene hexachloride 50 percent wettable powder containing 6 percent gamma isomer was also effective, at the above dosages, when repeated after 5 days. Lead arsenate was slightly less effective at dosages of 3 or 4 pounds per 100 gallons. The most effective treatments were combinations of DDT, 1 pound actual, with 2 pounds of benzene hexachloride as above, or with 2 pounds of lead arsenate per 100 gallons of water.

In the vineyards, prevention of girdled canes and other injury was more dependent on spraying whenever the canes increased their growth about 6 inches than on the insecticide formula used.

Sprays to Prevent Scolytid Infestation of Elm Logs. (W. B. Becker.) At Springfield, a number of sprays including different concentrations of DDT (dichloro-diphenyl-trichloroethane) and DDD (dichloro-diphenyl-dichloroethane) were applied once (May 14 to 16) to the entire bark surface of elm logs before scolytids could attack them in the spring. Each test involved 20 to 31 square feet of bark with a maximum thickness between 3/8 and 7/8 of an inch. The percentages of prevention were based on the number of exit holes found per square foot of bark in the late fall, compared with those in unsprayed logs. In each instance the quantity of spray applied was what the operator estimated to be necessary to thoroughly wet the surface of the bark (58 to 166 ml. per square foot). *Scolytus multistriatus* Marsham was much more abundant than *Hylurgopinus rufipes* (Eich.) in both sprayed and unsprayed logs.

No. 2 fuel oil alone gave 100 percent prevention, as did also orthodichlorobenzene and No. 2 fuel oil, mixed 1 to 8 by volume. DDT solutions in No. 2 fuel oil, at concentrations between 0.0625 and 5.0 percent actual DDT, gave 99.7 to 100 percent prevention. A 50 percent DDT wettable powder in water gave 74.6 percent prevention at 0.0625 percent DDT, 95.4 percent at 0.125 percent DDT, 97.4 percent at 0.25 percent DDT, and 100 percent prevention in concentrations containing from 0.5 to 5.0 percent DDT. A 25 percent DDT emulsion in water gave 98.5 to 100 percent prevention in all concentrations used, from 0.0625 to 5.0 percent actual DDT. A 25 percent DDD emulsion in water gave 70.6 percent prevention at 0.0625 percent DDD, 95.1 percent at 0.125 percent DDD, 94.8 percent at 0.25 percent DDD, 98.3 percent at 0.5 percent DDD, 99.5 percent at 1.0 percent DDD, and 100 percent at 3.0 and 5.0 percent DDD.

Sprays to Kill Scolytids Breeding in Elm Logs. (W. B. Becker.) At Springfield, DDT and DDD sprays at the same concentrations used for the preventive applications were applied once to elm logs in an attempt to control established scolytid infestations. Relatively light applications (between 27 and 53 ml. of spray per square foot of bark) were made on June 11 to recently cut elm logs soon after the scolytids attacked them. Beetle emergence commonly starts about the first of August from such logs. Because of the timing of the applications, the spray residues weathered for the longest period of time which would ordinarily be required in any one growing season. Each test involved 22 to 31 square feet of bark of a maximum thickness of 5/8 to 1 inch. In these, as in all other spray applications, the sprayed logs were covered with a single layer of other logs to avoid larval mortality from high subcortical temperatures caused by the rays of the sun.

There was no apparent relationship between the strength of the sprays used and the number of brood galleries constructed in the various sets of logs. Based on the number of empty exit holes per brood gallery in the autumn, the DDT sprays gave no control at the lower concentrations and mostly poor control at the higher concentrations. At 5 percent DDT, the oil solution gave 81.5 percent control, while the wettable powder and emulsion sprays gave approximately 54 percent control. The DDD sprays gave no control.

Best results were obtained with the higher concentrations of DDT in oil solution, possibly because of the presence of the oil, which causes mortality by itself when applied in sufficient quantities; and possibly because the DDT was carried down into the bark by the oil solution and so killed beetles before they could reach the surface. Probably the DDT in water emulsion and especially the

DDT in water suspension remained at the surface of the bark to a greater extent, and so permitted more adults to tunnel out to the surface.

It was interesting to note, however, that as the concentration of DDT and DDD in the sprays was increased, usually a higher percentage of adults was found dead in exit holes in the autumn, a phenomenon which has not been observed to result from the types of sprays tried previously. This suggests that some emerging adults were killed by the DDT and DDD spray material they encountered very close to or at the surface of the bark. No one type of DDT spray proved to be consistently superior, in this respect, to the others at the several concentrations used in these tests.

To what extent DDT caused mortality among the adults which completely emerged from the bark was not determined. It would no doubt be influenced by the amount of DDT residue remaining effective on the surface of the bark when they emerged and by the extent to which the adults crawled around on the bark immediately after emerging. The extent of this crawling may be influenced by the environmental conditions on the surface of a log.

Preliminary Spraying Experiments to Prevent Twig Feeding by the Smaller European Elm Bark Beetle. (W. B. Becker.) Feeding on live elm twigs by the smaller European elm bark beetle (*Scolytus multistriatus* Marsham) after it emerges from dead elm bark is at present believed to be one of the more important methods by which the fungus which causes Dutch elm disease, *Ceratostomella ulmi* (Schwarz) Buisman, is introduced into living elm trees. Since twig feeding may occur from spring to autumn, it is desirable that any preventive spray should give protection for as long as possible, to keep the number of spray applications at a minimum. Some of the newer types of spray materials which leave a deposit having a relatively long residual effect were used in attempts to reduce the amount of such twig feeding. Commercially prepared DDT and DDD sprays were used in concentrations between 0.0625 percent (which is slightly less than the strength used to combat defoliating insects on living plants) and 5.0 percent (which is the strength commonly used for some household pests where spray injury to plants is not a problem.

Sprays were applied directly to low branches of living American elms, *Ulmus americana* L., until or almost until the spray began to run off. Three series of applications were made, each on different elms *in full foliage*, two series in June and one in August. A three-gallon compressed air sprayer was used with a Mohawk adjustable nozzle which gave a cone-shaped spray pattern. Feeding tests were run in the laboratory with freshly cut twigs from sprayed elms placed in gallon size glass jars with newly emerged beetles. Control estimates are based on a comparison between the number of punctures which reached the cambium of sprayed and unsprayed twigs kept in separate jars.

At spray concentrations near those now used for defoliating insects, prevention of *S. multistriatus* twig feeding did not last as long as would seem desirable. As the concentrations were increased, much more lasting protection was obtained, but unfortunately the foliage injury to elms caused by the DDT emulsions increased to an undesirable point, and injury to hard maples and some other plants on which the spray drifted was even greater. While the DDT wettable powders caused no injury worth mentioning, the spray deposit left by the higher dosages was quite noticeable and the nozzle frequently clogged. Mites also caused some very noticeable browning of the sprayed leaves, as other workers with DDT have reported. Such high spray concentrations would cost correspondingly more than the lower strengths commonly used for defoliating insects.

At comparable strengths, the DDT emulsions lasted longer than the DDT wettable powder sprays; and as far as the test went, the DDD emulsions seemed to give results somewhat below those obtained with the DDT wettable powders.

In the early spring of 1947, several commercial DDT emulsion concentrates were applied while the trees were still dormant, at strengths up to 2.0 percent DDT, and no noticeable injury to the elms was observed. The long-term residual effects of these spray deposits are being studied, as is also the possibility of beetles feeding on the new unsprayed twig growth which appears after the dormant spray application.

Future studies may reveal whether laboratory feeding tests such as these approximate what might actually happen in the field where the beetles can move about freely, and to what extent the occurrence of Dutch elm disease will be affected by the reduction of this twig feeding.

Use of a Mist Blower to Apply Concentrated Sprays to Elms to Prevent Twig Feeding by the Smaller European Elm Bark Beetle. (W. B. Becker.*) A new Buffalo turbine blower was used to apply DDT to large elm trees in the forms of concentrated (up to 15 percent) oil solutions and water emulsions. The spray nozzle was altered so two cone-shaped jets of spray were ejected into the high velocity air current in the mouth of the blower. An output of as little as nine gallons of spray per hour could be applied.

Preliminary experiments with this mist blower resulted in relatively long lasting prevention of *S. multistriatus* twig feeding in the lower portions of an elm (20 to 25 feet from the ground) when sufficient spray was directed at the tree. However, in the upper portions of medium-sized elms (60 to 65 feet high) protection was often relatively short, even when one and two gallons of a 12 percent spray were applied to one such elm. When dosages were near those used to combat defoliating insects (approximately one quart of a 12 percent DDT spray), long-term protection against *S. multistriatus* twig feeding was often not satisfactory even on the low branches 20 feet from the ground. Freshly cut twigs from different heights in the elms were tested in gallon size jars as described under the preceding title.

Preliminary experiments with this mist blower point out that for reaching the tops of shade trees best results are obtained when there is no wind movement. Naturally, when using such strong insecticides, even in mist form, one must avoid getting too close to the plants, and also avoid putting on an excess of the spray mist; otherwise plant injury may result.

Experiments are being continued with different types, strengths, and volumes of spray.

*The author is indebted to entomologists at the Field Headquarters, Gypsy and Browntail Moth Control, of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, at Greenfield, Mass., for much helpful information about mist blowers and their operation.

FEED AND FERTILIZER CONTROL SERVICES

John W. Kuzmeski in Charge

The feed, fertilizer and milk testing laws are administered as one service and the operations of each, with the exception of the milk testing law, are reported in annual bulletins.

Under the milk testing law 11,089 pieces of Babcock glassware were calibrated and 191 certificates of proficiency in testing were issued. All milk depots and milk inspection laboratories in the Commonwealth were visited at least once to check apparatus and general conduct of the work.

In addition to the regulatory work the Feed and Fertilizer Control laboratories have examined feeds, fertilizers and other agricultural materials for citizens of the Commonwealth without charge whenever the results were considered of interest to the general public or to the Control Services.

Considerable work has been done on research projects in cooperation with other departments of the University and Experiment Station. The results of such work are reported by the departments originating the projects.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Variety Improvement and Disease Resistance. (Harold E. White, Waltham.) The variety Helen Tobin and a pink-flowered inbred line P-41 intercrossed yielded progeny that was 90 to 100 percent resistant to rust under field conditions. Hybrid progeny from these crosses was more vigorous than the parent lines and more uniform as to flower colors. The P-41 strain is resistant to rust and transmits this character readily to rust-susceptible varieties when crossed with them.

A number of samples of seed from the Field Station hybrids have been distributed to local growers. Several growers have reported that the hybrids are an improvement over many of the commercial varieties and that cut blooms from them have brought better monetary returns.

Six of the Field Station hybrid lines were tested in California where they did not prove to be resistant to Form 2 of the snapdragon rust, even though they were resistant to Form 1 which is prevalent in Waltham.

Strains of snapdragon from Waller Franklin Seed Company, Guadalupe, California, were tested at Waltham and found to be highly resistant to the form of rust present here. However, they are not as free flowering as the Field Station strains.

Subirrigation Methods of Watering Carnations. (Harold E. White, Waltham.) Three different systems of applying water to subirrigated benches were studied: constant water level with regulation by a float valve, manual injection, and automatic injection.

The automatic injection method was of two types, whereby (1) a solenoid valve was operated through a relay and time clock, and (2) a solenoid valve was controlled through a pneumatic and a pressuretrol control regulated by means of a stoker timer. This pneumatic system was connected to an air pressure thermostatic control unit used to operate the greenhouse heating system. Soils were watered by manual and automatic injection systems when between 2 and 3 pounds vacuum pull in the soil showed on the tensiometer vacuum gauge.

Investigation of the pneumatic system of automatic water injection is being conducted through cooperation with the Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota.

Varieties of carnations used in the tests were: Weld, Northland, Tom Knipe, Hercules, Salmon Virginia, and Dark Pink Virginia. The soil, which had been used for carnations the previous year, was sterilized with steam.

Carnation plants made equally good growth under all three methods of watering. Flower production on the differently watered benches did not vary significantly. Splitting of the blooms was not noticeably affected by the different methods of watering. The plants grew and produced equally well in ground concrete beds and in raised concrete benches.

Roots of carnation plants grown under subirrigation methods do not penetrate the gravel layer beneath the soil to any great degree. Examination of plants carefully removed from such benches showed that the roots mat in a layer at the junction of soil and gravel level, closely comparable to the condition that occurs with roots of plants grown in clay pots.

Observations of top-watered benches in commercial ranges where carnations are grown show that, in comparison with subirrigation methods of watering, carnation plants are in greater danger of being inadequately supplied with water rather than of being over-watered, as most growers fear. This is particularly true during summer months, early fall, and spring.

Losses of plants from stem, root, or branch rots were not observed to be any more prevalent under constant water level methods than in manual or automatic injection systems of watering.

Sodium Selenate as a Red Spider Control. (Harold E. White, Waltham.) The use of sodium selenate for red spider control by commercial flower growers in the State continues to increase. This past year between 40,000 and 50,000 pounds of P-40 were used by carnation and chrysanthemum growers in Massachusetts. The P-40 is granular superphosphate impregnated with 2 percent of sodium selenate and is the popular form used since it can be applied to bench soils as readily as fertilizer. Growers of bench crops have shown greater interest in sodium selenate than growers of pot plants.

A few growers of hardy chrysanthemums have tried sodium selenate for control of foliar nematode, a disease that has become more common in hardy chrysanthemum plantings outdoors.

Experiments so far at Waltham have been confined to the use of sodium selenate as a method of insect pest control from the viewpoint of commercial application. From these tests certain information has been derived, and problems have arisen that indicate a need for more detailed investigations.

Rooting of Carnation Cuttings in Subirrigated Sand and Vermiculite. (Harold E. White, Waltham.) Cuttings of ten varieties of carnations were used for rooting tests in Vermiculite (mica), subirrigated and top-watered, and in sand, subirrigated and top-watered. The ¼-inch and ½-inch grades of Vermiculite were compared as rooting media, as were mixtures of sand and Vermiculite; but appreciable differences were not distinguished in the use of the two sizes of Vermiculite.

When root formation on cuttings rooted under the different treatments is evaluated in terms of excellent to good, the ratings in percentage of rooting are as follows: sand subirrigated 71; sand top-watered 75; Vermiculite subirrigated 72; and Vermiculite top-watered 83.

When all the rooted cuttings of a treatment are grouped together without classification, the results are: sand subirrigated 77 percent; sand top-watered 90 percent; Vermiculite subirrigated 81 percent; and Vermiculite top-watered 90 percent rooted.

The results of these tests show that a mixture of sand and Vermiculite when top-watered produced a higher percentage of rooted cuttings than similar media subirrigated. However, even though sand top-watered was comparable to Vermiculite in percentage of cuttings rooted, the roots formed in the Vermiculite were 50 percent greater in length and more numerous on individual cuttings. Initiation of roots on cuttings in the Vermiculite does not appear to occur sooner than in sand, but roots grow much more rapidly once they are formed. This striking difference in rate of growth between roots produced in the two media probably is due to a more uniform supply of available moisture to the roots in Vermiculite. Also, there is better aeration due to less tendency of the Vermiculite to pack.

Since cuttings transplanted from a rooting medium such as Vermiculite have roots with thinner cellular tissue, the soil into which the roots are placed must be kept more moist until they have become established in it.

Dusting China Asters with Insecticides for Control of Yellows. (Harold E. White, Waltham.) During the summers of 1945 and 1946 various kinds of insecticidal dusts were applied to China Asters under field conditions to determine the effectiveness of such treatments in control of leafhoppers which carry the yellows disease.

In 1945, test plots were dusted at 7 to 10 day intervals with a 2½ percent DDT–sulfur dust and a 5 percent DDT–sulfur dust. Two formulations of each of these dusts were used, one being a fused DDT-sulfur and the other a mechanical mixture of DDT–sulfur.

The treatments in 1946 were along similar lines with 1 percent DDT, 3 percent DDT, sabadilla 10 percent, pyrethrum dusts, and a formulation known as X 155 which contained 12 percent nicotine and 7 percent DDT.

Tests made with these different insecticidal materials on living leafhoppers confined in a cage showed them to be toxic to the insects. However, the field tests made by dusting China Aster plants in the open yielded no significant data insofar as reduction of the yellows disease was concerned. Apparently these dusts, as used under field conditions, were not sufficiently repellent to prevent leafhoppers from feeding on plants and transmitting the yellows virus.

From these tests, it would seem that insecticides applied to asters in order to control yellows must be of a highly repellent nature to keep the leafhoppers from the plants.

DEPARTMENT OF FOOD TECHNOLOGY

C. R. Fellers in Charge

Incidence of Home Canning Spoilage Bacteria in the Soil. (W. B. Esselen, Jr., G. K. Lycarzyk, and C. R. Fellers.) During the summer of 1945, 325 samples of soil and raw vegetables were obtained from 15 gardens of Amherst and vicinity; and in 1946, 671 samples were collected from 12 gardens of the same locality. The samples were examined bacteriologically in order to study the incidence and factors influencing the incidence of thermophiles, putrefactive anaerobes, and flat sour organisms, these being representative of important groups of spoilage bacteria encountered in home canning.

These three groups of bacteria showed considerable variation in numbers during the season. Rainy weather seemed to favor their development. In general, the number of thermophiles present in the soil samples greatly exceeded the numbers of putrefactive anaerobes and flat sour organisms. Gardens treated with fertilizers of various kinds tended to show higher counts of the organisms studied than did untreated gardens.

Stability of Riboflavin in Processed Foods. (W. B. Esselen, Jr., J. E. W. McConnell, and J. P. Crimmins.) Studies of factors which influence the stability of riboflavin in canned foods, packed in glass or metal containers, have been continued. Experimental packs of green beans and of synthetic solutions of riboflavin in cans and glass jars were prepared so that the effects of acidity, added iron, tin, ascorbic acid, sodium bisulfite, and sodium dichromate could be observed. Changes in the riboflavin content of these different packs during storage were determined. The results to date are all in general agreement and indicate that the stability of riboflavin in processed foods may be influenced to some extent by the relationship of oxidizing and reducing conditions present in the product and container. The presence of a relatively small proportion of ascorbic acid or tin (stannous chloride) tended to cause a greater loss of riboflavin during storage than occurred in control samples; but when the proportion of ascorbic acid or tin was increased, it tended to reduce the loss of riboflavin, particularly in an acid medium. The addition of iron (10 and 100 p.p.m. of ferrous chloride) to glass-packed green beans and synthetic riboflavin solutions had little or no effect on the stability of riboflavin.

The Use of Calcium Chloride to Maintain Firmness in Canned and Frozen Apples. (W. B. Esselen, Jr., and W. J. Hart, Jr.) The effectiveness of treatment with calcium chloride in retaining the firmness of canned and frozen sliced McIntosh and other varieties of apples has been reaffirmed. September through December were found to be the best months for freezing McIntosh apples. When held in cold storage for longer periods, this variety reached a point where the use of calcium chloride was no longer effective in maintaining firmness.

After the apples are peeled, cored, and sliced, the slices may be readily treated by dipping them in a dilute solution of calcium chloride (U.S.P. grade). The strength of the solution required will depend upon the variety and condition of the apples, the time of dipping, and the ultimate degree of firmness desired. Under most conditions a five-minute dip in a 0.1 percent calcium chloride solution was found to yield a very satisfactory product. In many cases the calcium treatment can be combined with the treatment used to prevent darkening.

Calcium chloride was found to be effective as a firming agent for fifty varieties of apples when they were canned or frozen. With apples that were quite firm initially, there was no advantage in using the calcium treatment, and in some cases the treated slices may be objectionably firm and rubbery.

Laboratory and commercial tests have indicated that sliced McIntosh and Wealthy apples may take up calcium in amounts ranging from .019 to .054 percent calculated as anhydrous calcium chloride, with average values of .030 to .045 percent. While there has been no official ruling on the use of calcium salts for firming apple slices, it may be noted that under the Federal Food and Drug Administration Regulations it is permissible to add up to 0.07 percent of calcium chloride to canned tomatoes to aid in maintaining their firmness.

Home Freezing. (W. B. Esselen, Jr., J. E. W. McConnell, N. Glazier, and C. R. Fellers.) A bulletin on home freezing has been prepared and printed. It is based on work carried on here and by other agencies and contains information on such phases of home freezing as economics, comparison with home canning, freezer operation, varieties of fruits and vegetables for freezing, technics, and a discussion of the importance of home freezing in Massachusetts.

Work was continued on the quality of different varieties of fruits grown in this area when frozen by home-freezing methods. Samples of fruits were provided through the cooperation of the Department of Pomology. The products frozen during the 1946 season included 11 varieties of strawberries, 4 of raspberries, 15 of plums, 7 of currants, 9 of cultivated berries, and 26 of peaches. This variety investigation is being continued during 1947 in order to obtain additional information over a period of several seasons.

The addition of small amounts of ascorbic acid to home-frozen peaches was effective in improving the color and flavor of the finished product.

In the course of other investigations, during the past five years, approximately 10,000 jars of fruits, fruit juices, vegetables, meats, fish, and poultry have been frozen under typical home-freezing conditions. Glass containers are satisfactory for home freezing as they provide a moisture-proof container which can be re-used many times. No trouble from breakage has been encountered. The chief objection to glass jars is that inherent in all round containers; they waste space in the freezer, as compared with square-sided containers. This disadvantage would probably be offset by the advantages in many cases.

Nutritive Value of Cultivated Mushrooms. (C. R. Fellers, J. E. W. McConnell, and W. B. Esselen, Jr.) A five-year investigation of the nutritive value of cultivated mushrooms (*Agaricus campestris*) has been completed and the results summarized in Experiment Station Bulletin 434 which was published last summer. Data were obtained on the proximate composition; protein, carbohydrate, and vitamin content; and the effect of cooking, canning, dehydrating, and freezing on their "B-vitamin" content. Mushrooms were found to be excellent sources of certain of the B vitamins, such as riboflavin and nicotinic acid. They also contain approximately 2.6 percent of protein and all of the essential amino acids, at least in small amounts.

Jar Rings for Home Canning. (W. B. Esselen, Jr.) An investigation of factors which influence the quality of jar rings for use in home canning, initiated in 1943 in cooperation with the jar ring industry, the Department of Agriculture, and other Government agencies, is being continued. Tests completed in August 1946 indicated that the use of natural rubber in place of synthetic rubber (both in combination with reclaimed rubber) did not necessarily produce jar rings which were free from off-flavors. It has been shown that reclaimed rubber and certain chemical accelerators and antioxidants used in jar rings may be important causes of off-flavors. Tests are in progress now on jar rings made entirely of natural rubber and of a combination of natural and synthetic rubber.

Processing Methods for Home Canned Fruits. (Cooperative Project with the Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.) (W. B. Esselen, Jr., A. C. Avery, and J. E. W. McConnell.) Additional heat penetration data have been obtained on home-canned rhubarb, strawberries, sliced apples, blueberries, peaches, tomatoes, and plums. Tests were made on both pint and quart jars filled at temperatures of 80°, 140°, and 175° F. The jars were processed until internal "cold point" temperatures of 155°, 175°, 185°, and 200° had been reached. The process times thus determined averaged a little less than those recommended in most home-canning instructions. From observations and data obtained on recommended home-canning procedures for fruit, it was evident that such variable factors as intensity of heat source, variety and maturity of the fruit, and temperature and circulation of cooling air may have a decided effect on the required process times. Allowances should be made in prescribed process times to cover these variations.

Glass-Packed Citrus Juices. (W. B. Esselen, Jr., J. E. W. McConnell, and C. R. Fellers.) Further storage tests at 35°, 50°-60°, and 70°-85° F. (room temperature), on commercially packed grapefruit juice, orange juice, and a blend of grapefruit and orange juice, in cans and in glass containers, substantiated previous observations that the ascorbic acid content is well retained after storage for one year. Juices stored at 35° and at 50°-60° for one year showed no significant change in color and flavor, while samples stored at room temperature (70°-80°) retained their original quality for six months but after that showed a marked deterioration in flavor. At room temperature the color of the glass-packed orange juice stood up quite well, but the grapefruit juice and the grapefruit-orange juice blend packed in glass containers darkened considerably after six months. From the experimental results it appears that it should be possible to place good-quality glass-packed citrus juices on the market if warehouse temperatures are maintained at 50°-60° F. or lower. Cold storage at temperatures of 35°-40° F. is not necessary.

Prevention of Darkening and Deterioration in Flavor of Citrus Juices. (J. E. W. McConnell, W. B. Esselen, Jr., C. MacCormack, A. Kaplan, and C. R. Fellers.) The addition of ascorbic acid or the storage in an inverted position of bottles sealed with plain tin coated caps favored color retention in citrus juices. The combination of both factors produced more favorable results than either alone.

Added tin in the form of stannous ions had a stabilizing effect on the color of bottled orange juice. The optimum concentration of stannous ions, as determined by accelerated storage tests, was between 100 and 200 p.p.m. Small amounts of iron (above 8 p.p.m.) accelerated darkening of the juice.

The value of various substances as antioxidants for orange juice was investigated by adding them to the juice at 0.1 percent concentration and submitting the bottled, pasteurized juice to an accelerated storage test at 125° F. Among the substances tested were *p* hydroxydiphenyl, *p* aminoacetophenone, *b*-hydroxy quinoline, orcinol, catechol, caffeic acid, glycine, ethyl and propyl gallate, and a series of quinones having oxidation-reduction potentials between +0.131 and +0.656 volts. The gallates and sodium 2.7 anthraquinonedisulfonate (oxidation-reduction potential +0.242) were the only substances tested which protected the orange juice against flavor deterioration; however, they had little or no effect on the color.

Color Measurement of Citrus Juices by Means of a Photoelectric Reflection Meter. (W. B. Esselen, Jr., M. Paparella, J. E. W. McConnell, and C. R. Fellers.) Determination of the amount of light reflected by citrus juices by means of a photoelectric reflection meter was found to provide a rapid and accurate index of the color of the juices and a good method for following color changes in the juices during storage. Correlation with visual grading was as good as or better than the correlation between visual grading and light transmission values determined on the filtered juices. This method of color determination should be especially useful in following surface discoloration.

A white reference standard may be used, but maximum sensitivity may be obtained by using a colored reference standard similar to the color of the product being examined. In following color changes of foods during storage, the band of light giving the best correlation with visual color changes and the maximum sensitivity must be determined for each product.

Process Times for Glass-Packed Foods. (J. E. W. McConnell and W. B. Esselen, Jr.) A cooperative project with the Glass Container Manufacturers Institute, the National Canners Association (Washington, D. C., and San Francisco, Calif., laboratories), and the California State Department of Health was undertaken to compare the heating rates and sterilizing values obtained with comparable sizes of glass containers and cans under different retort and processing conditions.

Bentonite suspensions (1 and 5 percent) were used to simulate convection and conduction heating products, respectively, as this offered a stable medium which could be duplicated and used several times in succession. The third type of food product, that exhibiting a "broken curve," could not be satisfactorily represented by a bentonite suspension because the heating characteristics varied with successive runs. Investigation of bentonite suspensions which produce a "broken curve" revealed that the rate of heating has a marked effect on the type of curve obtained. Rapid heating, with its accompanying greater convection currents until close to retort temperature, when the rate of heating and convection currents markedly slow down and permit the suspension to change from a sol to a gel state, is essential in obtaining a good broken curve.

It was concluded that the longer come-up time used in glass processing and home canning can markedly affect the type of heating curve between cans and glass containers to influence this type of broken curve obtained.

The Stability of Carotene and Vitamin A in Mixed Rations and the Comparative Efficiency of These Components for Egg Production and Growth. (Cooperative project with Department of Poultry Husbandry. L. R. Parkinson and C. R. Fellers.) Controlled levels of carotene (derived from alfalfa) and vitamin A (from fish liver oils) were added to broiler rations at the start of the experiments. Periodic determinations indicated that carotene was destroyed more rapidly than vitamin A during the first two weeks of storage; but after two weeks the vitamin A decreased at a more rapid rate. At the end of 8 weeks 61.5 percent of the vitamin A remained, whereas at the 12-week interval only 37 percent of the original amount was left. The broiler ration containing the largest amount of carotene lost 36 percent of its carotene in the first 2 weeks, but at the end of 12 weeks 49 percent of the original amount still remained. The ration containing the smaller amount of carotene showed a loss of 36 percent during the first 2 weeks, but thereafter the rate of destruction was less, and at the end of 12 weeks 62.5 percent of the original amount still remained.

Superior feathering of broilers was obtained in this experiment by feeding vitamin A in the form of a carotene extract from alfalfa.

No deficiencies in fleshing were noted regardless of whether carotene from alfalfa or natural vitamin A was fed at equivalent levels.

Normal egg production was obtained at a level of 3000 International Units of vitamin A per pound of feed, whether this was natural A or carotene extract from alfalfa. There was little difference in egg production at the feeding level of 1000 International Units of natural vitamin A per pound of feed. There seems to be no advantage in feeding three times this amount for egg production alone; but to obtain good strong, healthy chicks, a higher level of vitamin A is indicated by the hatchability and viability data.

Red Squill Toxicity Studies. (L. R. Parkinson and C. R. Fellers.) In previous work in this department, it was found that the toxic properties of raw red squill were extremely variable. Many of the squills being shipped to this country were of such inferior toxicity that their use in rat control operations was impractical. The possibilities of extracting the toxic principle from these low-quality squills were investigated with the idea of making them suitable for successful rat control. A direct result of this work was the appearance of several methods of fortifying these relatively poor quality squills.

During the past year several samples of raw red squill, originating from the Mediterranean area, were tested for their toxic effect on rats. The majority of these proved to be of poor toxic value. These findings prevented the distribution to the general public of a considerable amount of poor red squill. The processors of this material will subject it to a fortification process, thereby making a highly acceptable poison for rats.

Preservation of Pheasant Meat by Canning, Freezing, and Smoking. (C. R Fellers, E. E. Anderson, and H. U. Goodell.) In cooperation with R. E. Trippensee of the Wildlife Department, experimental packs of pheasant, which were canned in glass, frozen, or smoked, proved to be highly satisfactory in palatability and appearance. In general, only slight revisions of the procedures normally employed for the handling of chicken were required.

The Composition and Nature of Apple Protein. (S. G. Davis and C. R. Fellers.) Despite the widespread use of apples in food and food products, and the numerous chemical and nutritional studies to which the fruit has been subjected, little attention has been given to the amount and composition of apple protein. The scarcity of such data may well be explained by the fact that the protein content of the apple, in common with that of most fruits, has not been considered nutritionally significant. Estimated on the basis of the alcohol-insoluble nitrogen fraction, the protein of the apple flesh (exclusive of skin and seeds) per 16 grams of nitrogen is around 0.15 percent, alcohol-insoluble nitrogen representing approximately 50 percent of the total nitrogen of samples tested.

Significant amounts of an apple protein fraction can be removed from samples of frozen tissue, thawed, and finally macerated in an alkaline buffer solution, by means of a flotation method whereby the protein is dispersed and collected in a foam. The material as collected and dried has a nitrogen content of approximately 10 percent without purification.

Amino-acid determinations, performed on both dried apple flesh and protein extracts by microbiological methods, indicate the presence of the indispensable amino acids, with the exception of tryptophane, in proportions similar to those of most common proteins.

Work is continuing on the non-indispensable amino acids and the characterization of the protein system.

The Viability of Dried Bakers Yeast. (R. E. Morse and C. R. Fellers.) A study is under way to determine the factors which influence the viability of dried yeast. There are two major phases of the work: the factors which exert their influence during the production of the yeast, and those which are exerted during storage of the finished product.

To study the important phases of yeast production, a laboratory-scale replica of a yeast-producing plant has been set up. Here the steps used in commercial production of yeast are duplicated. The steps that are being observed for their influence on the viability of the final product are the seed yeast, the nutritive factors during yeast production, and the method of drying, including temperature and time.

The storage factors were studied after a suitable fermentmeter had been constructed which permitted the recording of gas pressure produced by a mixture of yeast, flour, and water. Dried yeast was then packed in various gas atmospheres such as carbon dioxide, nitrogen, oxygen, and air; and stored at various temperatures, including −5°, 40°, 70°, and 100°F. Various containers were also used, in order to determine the effect of light during storage. Temperature appears to be the most important factor of all. In 18 days, dried yeast stored at 100°F. was no longer suitable for baking bread, regardless of the container or the gas atmosphere used.

Vitamin D Bioassay Research. (C. R. Fellers and L. R. Parkinson.) As yet, no physical or chemical methods have been devised that are accurate for the determination of vitamin D in food. A literature survey has been made of likely procedures, and research will be carried out to check new laboratory methods against the standard rat bioassay. An enormous saving of time and cost will result if chemical or physical procedures can be perfected.

Of the 72 samples of vitamin D milk assayed during the year, two were seriously deficient and three slightly deficient in vitamin D.

Fish Investigations. (C. R. Fellers and A. Lopez-Matas.) Studies on fresh, frozen, canned, and smoked swordfish have been completed, and three scientific papers prepared for publication. The study covers both technological and nutritional aspects.

Rapid Estimation of Added Aluminum in Foods. (C. R. Fellers and R. Barton.) A nephelometric method has been perfected which is accurate for inorganic aluminum to ±10 parts per million. The brine or pickle is cleared with phosphotungstic acid, the pH adjusted, and the aluminum hydroxide precipitated with ammonia. The density of the suspended aluminum hydroxide is read in a specially constructed nephelometer. A description of the procedure is being prepared for publication.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Julia O. Holmes in Charge

Losses of Iron in the Menses of Women. (A. W. Wertz, B. V. McKey, and J. O. Holmes.) Because of the loss of blood in the menses it is customary to recommend a higher level of iron for women than for men. As a part of the study on the metabolism of iron in women, conducted last year, a collection was made of the menses throughout the 115-day experimental period. Because of its significance in determining the requirement of iron by women the results of the analyses of the material are presented here. The losses of iron by these four women varied markedly, although the loss of an individual woman was fairly constant from period to period. The subjects ranged in age from 24 to 37 years; none had had any children. The range in iron excreted per menstrual period was as follows: Subject A, age 28 years, 1.98–2.49 mg.; Subject B, age 29 years, 2.6–8.13 mg.; Subject C, age 24 years, 15.13–33.9 mg.; Subject D, age 37 years, 8.04–10.98 mg. There appears to be no correlation between the age of the subject and the amount of iron excreted per period. From the limited data presented here, it appears evident that there is a wide range in the amount of dietary iron needed by different women to offset the loss of iron in the menses. For example, Subject C, losing an average of 25 mg. of iron per menstrual period and being able to utilize about one-third of her dietary iron (1946 Exp. Sta. Ann. Rept.), would probably need about 3 mg. of iron in the daily diet to offset this loss. On the other hand, Subject A, losing an average of about 2 mg. of iron per period and being able to utilize about one-third of her dietary iron (1946 Exp. Sta. Ann. Rept.), would need only 0.5 mg. iron in her daily diet to offset this loss.

Iron Content of Milk. (A. W. Wertz, B. V. McKey, and J. O. Holmes.) Although it has long been appreciated that milk is a poor source of iron, the values in the literature range from 0.114 to 1.4 mg. per liter. Over a period of 115 days, milk was obtained from the Dairy Industry Department of the University and analyzed for iron. Six quarts were obtained daily and well mixed; aliquots from the mixture were taken and pooled for five consecutive days. Iron determinations were made on 23 pooled samples. The organic matter in the milk was destroyed by wet ashing with nitric and sulfuric acids. O-phenanthroline was the color reagent used for formation of the colored complex, the intensity of which was measured in a Beckmann spectrophotometer. The amount of iron present was calculated from a calibration curve. Because of the large amount of calcium present in the milk, a heavy white precipitate was formed after digestion which necessitated filtering. In order to determine whether any iron was lost throughout the procedure because of the formation of insoluble iron salts, etc., the following procedure was used for several determinations as a check on the method. Six 100 ml. aliquots of milk were measured into 500 ml. erlenmeyer flasks. To three of the flasks containing milk a known quantity of iron was added. The contents of these six flasks, 3 control flasks containing only the standard iron solution and 3 control flasks containing only the reagents used, were carried through the entire procedures of evaporation, digestion, filtration, development of color, and measurement in the spectrophotometer. The data obtained on 8 different series show that recovery of the added iron was 100.05 percent. These results indicate that the wet digestion method of ashing and the use of O-phenanthroline as the color reagent is suitable for the determination of iron in milk. The average value for 23 samples of milk covering a period from January through May was 0.30 mg. iron per liter with a range from 0.25 to 0.38 mg. per liter. The lowest values—0.25–0.29 mg. per liter, were consistently obtained during March and April.

The Excretion of Iron by the Kidney. (B. V. McKey, D. C. Staples, J. O. Holmes, and A. W. Wertz.) It has long been known that the quantity of iron in the kidney secretion is small. At the time when the study on iron utilization by women was being planned, the question arose as to whether or not the urinary iron had to be determined. This question was of great importance not only for its significance in the experiment, but also from the standpoint of the work involved in the determination. Therefore, a survey of the studies reported in the literature since 1880 was made. The range in the urinary iron values reported by various laboratories was found to be great; e.g., some workers reported urinary excretions as high as 1 mg. iron per day and one laboratory reported iron excretion by one individual which ranged from 0.01 to 1.93 mg. per day and averaged 0.24 mg. These high values, as well as the great variability in values, indicated that a careful study of urinary iron would be expedient, particularly since a diet very low in iron was to be fed. During the first 50 days of the experiment when the subjects ate 3.75 mg. iron daily, the daily iron content of the urine or subjects B, D, E, and G was 0.041 ±0.011, 0.045 ±0.012, 0.059 ±0.019 and 0.062 ±0.019 mg. respectively. In terms of percentage of the quantity of iron eaten these values for urinary iron represent only 1.1, 1.2, 1.6 and 1.6 percent. During a subsequent 35-day period in which the iron intake was increased to 5.8 mg. daily, the urinary excretion of iron did not rise; on a percentage basis, the values were, therefore, lower; namely, 0.6, 0.6, 0.4 and 0.9 percent. No correlation was found between the daily volume of urine excreted and the daily urinary iron. From the data obtained, it is evident that even on extremely low dietary levels of iron, it is not necessary to determine the iron content of the urine.

Tooth Decay Studies: Sucrose, Glucose and Lactose as Cariogenic Agents. (Julia O. Holmes, L. R. Parkinson, Lois Brow, and Anne W. Wertz.) As a result of last year's findings that dental caries could be induced in the *Norwegian* albino rat by feeding sugar as the sole source of carbohydrate in an adequate diet, this year other types of sugars have been fed. The sugars selected were those that form the major portion of man's sugar consumption; namely, sucrose as found in cane and beet sugar, dextrose which occurs in fruits and corn syrup, and lactose, the sugar of milk. These sugars were fed to numerous groups of rats over a period of two years as the only source of carbohydrate in "synthetic" diets which contained all *known* nutrients. Although the rats grew well and were in good health, they developed tooth decay, irrespective of the type of sugar fed. These results showing the cariogenic properties of sucrose and glucose are in accord with the findings of the Wisconsin investigators who have reported that the *cotton* rat will develop tooth decay if fed excessive amounts of fermentable carbohydrates. The National Health Institute reported in 1945 that they had induced caries in about 30 percent of one group of *Norwegian* rats fed sucrose; but that in subsequent groups fed glucose or sucrose, either commercial or confectioners grade, caries did not occur. In respect to lactose, no other report has been found in the literature indicating that it, too, is a cariogenic agent. Since lactose does not undergo fermentation as do the other mono- and di-saccharides, it is obvious that the tooth decay-inducing properties of a sugar are not dependent upon the fermentability of that sugar. It is also obvious that if milk contains some substance which protects against tooth decay, as has been reported by the Wisconsin investigators, that substance is not the milk sugar, lactose.

Tooth Decay Studies: Excessive Use of Sugars Not Sole Cause of Tooth Decay. (Julia O. Holmes, L. R. Parkinson, and Lois Brow.) Although the feeding of sugars to rats as their sole source of carbohydrate has resulted in the early development of tooth decay, tooth decay has been experimentally produced this year in rats that had never been fed sugar. The finding that other types of carbohydrates as well as glucose and sucrose would permit the development of tooth decay, is in direct contradiction to the results of other investigators who have asserted that caries does not develop in diets in which sugar is replaced by starch or dextrin. The first indication that a sugar-free diet is conducive to tooth decay came as a result of an attempt to construct a "synthetic" diet which would have some of the essential features of the "corn-meal" diet used by many laboratories for the development of caries in animals. Since the corn-meal diet is notable for its high content of raw starch and its relatively low content of protein, a diet containing starch as its sole carbohydrate and 15 percent of the milk protein, casein, was constructed. It contained all the *known* ingredients necessary for good growth. The observation that some of the rats fed this ration had cavities on the grinding surfaces of their teeth came as a distinct surprise. As a result of these findings many rats have been reared on diets containing raw or cooked corn starch as their sole source of carbohydrate. Caries has been found in all groups fed such rations. Experiments are now in progress to determine the conditions under which tooth decay will result in the presence of starch. It is felt that research on diets containing raw or cooked starches provides a promising line of investigation since few human beings consume diets in which the major portion of their carbohydrate is sugar.

Tooth Decay Studies: Raw Corn Contains a Caries-Inducing Factor. (Julia O. Holmes, L. R. Parkinson, Anne Wertz, and Lois Brow.) A "corn-meal" diet is used in most laboratories today to produce tooth decay in experimental animals. This diet is composed of 66 parts of coarsely ground whole corn, 30 of whole-milk powder, 3 of dried alfalfa meal, and 1 of pure table salt. Since this diet is notorious for the rampant caries it produces, it was decided to feed various fractions of corn to determine whether or not a fraction could be found which had cariogenic properties. The corn fractions were obtained from the Corn Products Refining Company, Argo, Illinois. They included a crude corn oil obtained from the corn germ: corn steepwater, which contained the major part of the water-soluble minerals and vitamins of the kernel; zein, one of the corn proteins; and a gluten fraction which contained, in addition to the corn gluten, zein and some of the corn xanthophyls, and which assayed about 50 percent protein. To the basal ration into which these fractions were incorporated, corn starch and 15 percent casein were added as the sole carbohydrate and protein. The rations were ground to the fineness of flour. The rats receiving corn steepwater developed no more tooth decay than did their brothers and sisters receiving the basal diet only. In contrast those receiving gluten, zein, and crude corn oil had twice as many sites of decay as did their controls on the basal diet. This is the first demonstration of the presence, in a food, of an agent which accelerates the decay of teeth. The findings suggest that, if sugar is a cariogenic agent, it may be only one of many. One of the plans for the immediate future is to determine the nature of the cariogenic factor in corn.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Control of Weeds in the Nursery by Chemical Sprays. (C. H. Gilgut, Waltham.) Of the chemical weed killers in common use at present, the industrial solvent Savasol No. 5 shows most promise for control of weeds in the nursery. It was extensively tested in 1946 in the Field Station nursery and in nearby commercial nurseries. As a result, a number of the more progressive nurseries are using this weedicide in their weed control program. The oil is used undiluted.

So far, the best method of applying the oil is with a hand operated tank sprayer equipped with a nozzle that gives a flat fan-shaped spray. This gives good control of the spray and permits wetting weeds close to a plant without wetting the plant enough to injure it.

Spraying small weeds is more effective and cheaper than spraying large weeds. The small weeds are killed more quickly; there is less risk of injury to the plants since the spray is kept close to the ground; less material is used; and it takes less time to spray a given area.

Late fall spraying of grass weeds which winter over reduces the number of such weeds in the spring.

To the list of narrow-leaved evergreens which are highly tolerant can be added mugho pine. Less tolerant is the Greek juniper, *Juniperus excelsa stricta.*

Study of Herbaceous Perennial Material. (C. J. Gilgut, Waltham.) Fifty varieties of plants in the perennial test gardens did not survive the winter. Of these, sixteen were so-called "hardy chrysanthemums," and it is increasingly evident that most chrysanthemums are not reliably hardy here when not protected by mulch or wintered in a cold frame.

Few replacements have been made and no new plants acquired because the gardens are to be moved to another location to make way for the new laboratory and administration building. The preparation of the new location—clearing, grading, laying out of beds, and seeding of walks—is slowly being finished and it is hoped that by fall many of the plants will have been moved in from the old garden.

The collection of American and English hybrid delphinium—among them Gold Medal Hybrids, the color series of Giant Pacific hybrids, Wrexham hybrids, and Blackmore and Langdon hybrids—made good growth and an excellent display in the spring. The Giant Pacific hybrids were awarded the L. H. Leonian Memorial Cup for excellence by the American Delphinium Society, and a cultural certificate and silver medal by the Massachusetts Horticultural Society.

The phlox collection of varieties in commerce is not yet complete, but it is apparent that some are not true to name and several are being sold under different names.

Factors influencing the Rapidity of Growth of Nursery Stock. (C. J. Gilgut, Waltham.)

Rhododendron Leaf Bud Cuttings. Leaf bud cuttings of 30 named varieties of hybrid rhododendrons taken in November, and again in February, treated with the more common root-inducing substances in liquid and powder form, and placed in various propagating media in the greenhouse failed to root. A few were still alive in June.

Effect of pH and Nitrogen, Phosphorus, and Potash on Growth of Yews. It is a common belief among some nurserymen that yews grow better at a pH above 5.8. When the pH of unfertilized field soil was adjusted at pH 4.5, 5.0, and 7.0, there was no appreciable difference in the growth of rooted cuttings of *Taxus media hicksi* and *Taxus cuspidata nana* during the first season.

These varieties grew equally well in unfertilized field soil and in field soil treated so that (1) the nitrogen, the phosphorus, or the potash was high; (2) the nitrogen and phosphorus, the nitrogen and potash, or the phosphorus and potash were high or (3) the nitrogen, phosphorus, and potash were high.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Asparagus Investigations. (Robert E. Young, Waltham.) The second generation asparagus planting has been cut now for seven full years and has about reached the half-way point of economic production. The third cutting season produced the greatest yield. The yield for 1945 was only 51 percent of this 1942 yield, and the 1946 crop although greatly improved was still only 71 percent of the highest yield.

An examination of the yield data indicates a decided tendency toward biennial bearing not unlike that found in apples. While only seven years records are available for study, there always have been alternate high and low yields; never two successive increases or decreases. Attempts to correlate this rise and fall of yields with rainfall have been unsuccessful, and there is only a slight relationship to spring temperatures. As might be expected the highest producing strains show the greatest variation in yield from season to season.

This second generation of plants has spread out so far in the rows that it is no longer possible to obtain accurate individual plant records as previously. Of the plants whose accumulative yield places them in the top 50 (12 percent), only four have been in this category all seven years. This also demonstrates the extreme variation in production of asparagus plants. The male asparagus plant is considered the better producer and 72 percent of the plants in the top 50 are males.

In 1942 plants which had started to produce high yields were chosen as parents for the third generation. It is interesting to note that of ten so chosen nine remain in the top 50. A study of the yield records shows that very few plants which produced well at the start have dropped, while there are some which started poorly that are now yielding well.

The highest yielding plant in the experiment is No. 4-79 which produced an average of 2.6 pounds of asparagus per year as compared to the annual average of 0.88 pounds per year for all the plants.

To determine whether the high yielding plants can transmit this characteristic to the next generation, a third planting was made using various combinations of male and female plants previously described. This planting has been set for two years, and the count of the summer stalks in 1946 followed the same pattern as in 1945, with the most vigorous plants producing twice as many stalks as the commercial varieties.

Forty-six plants died during the second year which, with the 19 that died the first year, makes a total of 63 out of 1900. Of those that died in 1946, half had shown no weakness the previous year, which brings up the question of winter-killing. There are five strains that still have a perfect stand and none of the strains have lost over 5 percent; while the two commercial varieties have lost 11 and 13 percent. These plants did not die because the crowns planted were too small, since there was no significant difference between the weight of the crowns of the plants that lived and those that died. The data appear to indicate that it is possible to breed a hardy strain of asparagus. Loss of plants after an asparagus planting has been established is one of the reasons for low yields and the low economic returns from this crop.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding work has been conducted with broccoli, greenhouse cucumber, celery, rutabaga, New York type lettuce, tomato, carrot, and Butternut squash. While progress has been made in the development of strains of celery, rutabaga, and greenhouse cucumber better adapted for local use, it is insufficient to justify detailed discussion.

Broccoli. The 1946 fall broccoli plots came into production during unseasonably warm weather with the result that many varieties and strains failed to make a marketable head. Under these conditions, a fall type, tentatively called Strain 29, was outstanding. This strain is a slow-growing type which requires so much time to produce the head that short periods of unseasonable weather have little effect on it. It was tried in the spring and found worthless. Seed has been produced for expanded fall trials and further purification.

The spring trials in 1947 showed the two strains recently developed for this season, namely Waltham No. 7 and No. 11, to be outstanding producers as an early crop. They also gave total yields considerably higher than that of the best commercial variety. The commercial variety which was best in early yield was only average when the total yields were considered; and the variety that ranked next to Nos. 7 and 11 for total yield was only 75 percent as productive in the early season.

Thus, it would seem that we have been able to retain characteristics for good early yield with the necessary vigor that makes for large total yields. Tests with growers indicate that strains No. 7 and 11 have real value, but they require a little more selection for uniformity.

Carrot Seed Production. The maintenance of a supply of stock seed of the Field Station strain of Hutchinson carrot has always been a part of the Carrot Breeding Project. To produce this seed, which is supplied to the carrot seed growers, a fall crop was grown and selected roots placed in a storage pit. In the spring these were re-selected for shape and external color, and internal color was observed by cutting off the bottom third of the root. Then the roots were planted in the field in early spring. By that method there was a small amount of crossing with wild carrot, and the resulting hybrids were sometimes overlooked in the seed fields in the west. This accounted for the presence of a small percentage of white, yellow, and poor-shaped roots found in the local carrot fields.

A method has now been developed whereby this seed is grown in the greenhouse with bees used as pollinators, and it is mature before the wild carrot blooms. By this procedure the off-color carrots were reduced from 2 percent in field-grown stock to none in the greenhouse crop. It is planned to supply seed producers an ounce or so of this elite stock seed, and they in turn can multiply the seed in California where wild carrots are not a problem.

The breeding of a better carrot continues, but last season work was considerably handicapped by the presence of an unusually high percentage of aster yellows which destroyed some of the best breeding lines.

New York Type Lettuce. The testing of Waltham Imperial Lettuce on a sufficient scale to really determine its place has been delayed by lack of seed. The seed crops, both local and that grown in California, have been disappointing.

In the 1947 crop in which early plants were set in the field, Waltham Imperial showed much more uniformity of plants and in maturity than did Great Lakes. At the time of the first cutting Great Lakes produced 55 percent marketable heads while Waltham Imperial produced 70 percent.

While Great Lakes, Waltham Imperial, and several other new strains of similar type, have about taken care of the requirements for a late set lettuce, there remains a definite need for a first early type. Several lines are now being purified with this in mind. Even with Great Lakes, growers located away from the cooling effect of the seashore have had trouble with the lettuce crop seeded in the field due to scald, breakdown, and slime in the heads, brought on by hot weather at heading time. The experimental plantings were so affected this year, and almost 100 percent of the Great Lakes type plants which have an unprotected head were unmarketable because of breakdown. The only plants not affected were those of the so-called crinkle type which have leaves that are savoyed, and also have more protection from leaves on top of the head. A seed crop of this type of plant is being produced for more extensive trials next year.

Trellis Tomatoes. The work and publications of plant breeders, and the offerings of commercial seedsmen of hybrid tomato seed, have created an interest among local market gardeners. Because of market customs and preference, the type of tomatoes produced elsewhere cannot be used locally by commercial growers. To determine whether there is sufficient advantage to warrant the higher cost, five different tomato hybrids were planted Several combinations of strains and varieties were used in a search for the best hybrid.

The early yield of the five different hybrids, all of which had as one parent either Trellis No. 22 or Waltham Forcing, was 25 percent greater than that of either of these two, which are the standard by which the hybrids must be measured. The advantage at the three-quarter harvest period had shrunk to 16 percent, and it was only 10 percent for the complete harvest.

Since the greatest returns are for early tomatoes, a difference of approximately 1 pound more per plant from the hybrids at this stage would seem to more than justify the expenditure of 1 cent per plant, which is one current quotation for hybrid tomato seed.

The fruit from some hybrids was too soft; from others too small. Considerable more testing will be required to find the best combination.

A hybrid between determinate varieties, such as Red Cloud and Victor which are very early, and Trellis No. 22, when grown by the flat culture method, produced a sufficient increase in yield to offer promise for the future for those growers who do not trellis tomatoes.

Progress is also being made in testing Selections No. 1 and 3 by growers. Selection No. 3, which has been named Waltham Scarlet, shows promise for the home garden, and will be so featured by a Boston seed firm.

Butternut Squash. Progress has been made towards the breeding of a strain of high-yielding Butternut squash with a minimum of crooked, cracked, and too long fruits. Inbred lines were grown during the year that produced no fruit which was too long. That same strain also had no crooked fruit. An analysis of the percentages of the various grades produced by the inbred lines shows that, if too much reduction in the length of fruit is made, an increase occurs in the percentage of culls, i.e., fruit less than 7 inches or weighing less than a pound.

The occurrence of cracks in the fruit seems to be associated with moisture supply. Cracking takes place during and after rains that break long dry periods. The tendency to crack seems to be at least partially genetic as some lines had only 5.8 percent cracked fruit while others had as much as 27 percent. There does not seem to be any association between cracking and any other grade defect, such as large or crooked fruit.

In storage experiments of an exploratory nature to determine the conditions under which to test the inbred lines for keeping qualities, loss in weight of Butternut squash was 29 percent at the end of 14 weeks. The greatest loss occurred in the first two weeks. Dipping the squash in a wax emulsion at harvest or two weeks later reduced the loss to 17.5 percent. Squash placed in a refrigerator at 35° F. showed very little loss in weight and kept for three to four weeks, but rot was general and complete at the end of six weeks. Other low-temperature conditions will be tested in an effort to find a means of cutting the loss on Butternut squash intended for short storage.

Weed Control in Vegetable Crops. (William H. Lachman.) The use of Stoddard Solvent as a weed killer in fields of carrots and parsnips has increased greatly during the past year. A survey made during 1946 revealed that about 1000 acres were kept free of weeds by this method in Massachusetts alone.

Briefly, the method consists of spraying undiluted Stoddard Solvent on weedy carrot fields at the rate of 100 gallons per acre when the carrot plants have developed one to four true leaves and while the weeds are small; that is, not more than two inches tall. Best results are obtained when the oil is applied with a nozzle that delivers a flat-fan spray at 75 to 100 pounds pressure. Hand weeding has been eliminated except where ragweed is prevalent. For some unexplained reason, ragweed is not killed along with the other weeds.

Susceptible plants are killed very rapidly. They begin to wilt a few minutes after spraying and are dead within two or three days. The spraying usually results in a slight over-all bleaching effect on the green color in the carrot plants. This does not appear to be associated with any damage to the plants, and the darker color that is characteristic of unsprayed plants usually returns within ten days.

Sometimes one or more of the older leaves in the outermost whorl of young carrot plants were rather seriously scorched or burned as a result of spraying with Stoddard Solvent. It has been rather definitely established that this damage was most apt to occur after the plants had been sprayed while wet from a rain or heavy dew. Repeated tests indicated that the yields of sprayed carrots were not affected adversely, and there was no apparent differential susceptibility among sixteen varieties and strains that had been sprayed three times with oil.

Consumers often complain that California-grown carrots taste of oil, but we have had no rejections of sales nor adverse comment from 1500 acres grown and sprayed with oil in Massachusetts during the past two years.

Of the various Umbelliferous crops tested, carrots displayed the greatest resistance to damage from Stoddard Solvent, but even carrots are damaged when sprayed after the roots attain a diameter of ¼ to ½ inches. When sprayed after this stage the oil often destroys the heart of the plant and may envelop the core of the root. Parsnips were sprayed with relatively little injury up to the 4-leaf stage, but they were badly injured when sprayed in later stages of development.

Small celery seedlings grown out-of-doors were resistant to Stoddard Solvent but were damaged beyond recovery when sprayed after the 2-leaf seedling stage. Parsley, fennel, caraway, coriander, dill, celeriac, and parsnip-rooted parsley were also resistant to the oil in their early growth stages.

Injury to the growing point of various Umbels from Stoddard Solvent seems to be associated with the development of the characteristic hollow or groove on the top side of the petiole which directs the flow of oil down to the growing point of the plants where the rate of evaporation is low, and here the oil damage is at the maximum.

Stoddard Solvent killed such crops as beets, spinach, beans, corn, cabbage, lettuce, and onions, except where it was applied to the ground before the plumules of these crops emerged. A number of chemicals showed promise as pre-emergence sprays on these crops.

The new hormone weed killer, 2, 4-D, was most damaging to all vegetable crops except corn. When applied just after the corn was planted, 2, 4-D controlled grassy and broad-leaved weeds without appreciable damage to the corn. When applied after the weeds had started growing, 2, 4-D killed only broad-leaved weeds.

Breeding Sweet Corn, Peppers, and Field Tomatoes for Massachusetts. (William H. Lachman.)

Sweet Corn. Considerable attention has been paid to the selection of especially early types of sweet corn as well as those that exhibit good flavor and tenderness of pericarp. Several thousand plants were self-pollinated during the year to stabilize the various factors sought within the strains. Several hundred hybrids that were produced from inbreds of this station as well as from several other experiment stations have been tested and compared with existent commercial types.

One of the most outstanding of these hybrids resulted from a cross between Connecticut 27, an inbred out of Whipples Yellow, and Massachusetts 32, an early type of Purdue 39. This hybrid is midseason in maturity and the plants produce an excellent yield of large attractive ears.

Another hybrid which is especially noteworthy resulted from crossing Connecticut 3 with Massachusetts 2410-191. For two years this hybrid has matured earlier than any other variety in our trials. The seed is being increased for test on a large scale.

Considerable attention has been paid to an unusual type of corn called supersugary. Several strains of this type are approaching uniformity and should provide very sweet types of corn.

An interchange of breeding material among members of the Northeastern Corn Breeding conference has made a great deal of valuable material available for further breeding work. Several of the strains obtained in this manner combine very well with some of our inbreds, but further testing is necessary before this material can be made available for distribution.

Peppers. Further selection work has isolated a number of promising strains of peppers but they are not yet sufficiently uniform to send out for trial. One of these is of the Worldbeater type and has very attractive fruit with thick flesh. This appears to be resistant to certain strains of tobacco mosaic. Another strain resembles the variety Merrimac Wonder very much and it is also resistant to some strains of tobacco mosaic. Definite progress is being made in developing strains that are mosaic resistant.

Tomatoes. A large number of advanced generation selections from crosses among such varieties as Bounty, Earliana, Pennheart, Valiant, Bestal, and Firesteel have been carried along for several years. Very little work has been accomplished during the year because of a most severe infestation of late blight. It was clear that none of the selections exhibited any resistance to this disease. A few early fruits escaped the disease to allow for one more generation of selection. Several F_1 hybrids were included in the variety trials and a few of these were rather outstanding in yielding ability. Of the hybrids under test, Fordhook Hybrid, performed especially well during the early part of the season.

The Culture and Nutrition of Vegetables. (W. H. Lachman.)

1. Tomato plants grown in plots mulched with manure did not succumb to foliage diseases (particularly late blight) as badly as those mulched with straw or those grown without mulch. Sugar cane fibre used as a mulch continued to have a marked depressing effect on the growth and yield of tomato plants.

2. Red Cloud and Pennheart produced more early fruit than any other tomato varieties in this year's trials. Cracking of fruit has been the most important factor in lowering the grade of out-door tomatoes. A rather late variety named Crack-Proof was practically free from cracking this year.

3. The variety Fordhook 242 lima bean outyielded all other varieties in our trials. This variety has consistently performed well in our plots.

4. The use of a plant hormone applied as a spray significantly increased the set of greenhouse tomatoes. About 50 percent of the fruits were seedless and many had objectionable air pockets where one would ordinarily expect to find pulp.

5. Carotene analyses of carrots continue to indicate wide differences among the varieties. Morse's Bunching and Imperator are among the highest in carotene content. Roots of all varieties increased in carotene as the growing season advanced, and roots stored for five months contained appreciably higher amounts of carotene on a fresh weight basis than when they were placed in storage.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and W. D. Weeks.) For the fourth successive year there was frost damage in the large stock-scion orchard. It requires many years to determine the value of these stocks for the many varieties in cultivation. At present we believe that Malling I and II are the most desirable for commercial orchards where the grower desires trees not so tall as ordinary seedling-rooted trees. They stand winds nearly as well as seedling-rooted trees, require a little less space, begin to bear younger, and give larger acre yields. Malling VII is promising but we have not had as much experience with it. It is believed that Malling XVI is superior, at least for McIntosh, but it dwarfs the trees little or not at all. Trees on Malling IX are excellent for home gardens but many require support. They are not recommended for commercial orchards.

The question of varietal adaptation is complicated and requires further study. In general, the best varieties for dwarf and semi-dwarf trees are those that make moderately vigorous growth. The very vigorous ones, such as Gravenstein and Baldwin, tend to overgrow the stock; and the weaker ones, like Duchess and Wagener, do not begin to bear much earlier than they do on seedling roots. Northern Spy and Yellow Delicious are among the best varieties to grow on dwarfing roots.

Two papers were published in Volume 48 of the *Proceedings of the American Society for Horticultural Science.*

Lethal Incompatibilities Between Clonal Stocks and Varieties of Apples. (J. K. Shaw and W. D. Weeks.) It was reported last year that buds from shoots of the normal strain G which had grown in the top of a tree of the lethal strain

R were still alive. Later in the summer all the trees of this hitherto normal strain died in typical fashion. This seems to prove that the lethal factor in strain R had passed into strain G and indicates that the lethal factor is of a virus nature. If this is true, no vector is present in our nursery, or the virus can be transmitted only by actually transferring virus tissue to a healthy tree. This is the first indication we have observed that a healthy tree can acquire the lethal factor.

The observation that Blaxtayman budded on Spy 227 grows vigorously the first year and then dies has been confirmed. Trees of several lethal strains were budded on Spy 227 interstock, on Spy 227-2 and on Spy 227-12. Those with Spy 227-12 roots grew much better than those on Spy 227-2 roots.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and W. D. Weeks.) The examination of fruit-tree nurseries for trueness-to-name, which began in 1921, still continues. This inspection was extended to Tennessee and Alabama last year and in 1947 will extend to Iowa and Kansas, and include about 30 different nurseries. Although many of these nurseries have been examined annually for many years and the misnamed trees eliminated, still new mixtures appear. But these are detected at once, which practically prevents propagation and distribution to growers. New varieties appear and must be studied; thus this project is one that has no end.

Effect of Orchard Mulches on the Plant Nutrients in the Soil. (J. K. Shaw and W. D. Weeks, in cooperation with the Chemistry Department.) This project has been interfered with by the war. Soil samples were taken this year and the hay mulch applied. The trees with hay mulch look the best and the unmulched trees the poorest. Further comments on this project may be found in the Report of the Chemistry Department.

The Nature of Winter Hardiness in the Raspberry. (J. S. Bailey, A. P. French, and R. A. Van Meter.) It seemed possible that there might be a relationship between the rest period of raspberries and the amount of cold the plants will stand in winter; therefore, a study of the rest period was started three years ago. Each fall during November and December raspberry canes of six varieties were brought into the greenhouse at regular intervals and the time necessary to force the buds into growth was determined. From this work the following conclusions can be drawn: (1) The deepest rest, when the buds are hardest to start, is reached about November 1. (2) The time at which the deepest rest is reached is dependent on both the variety and the season, but the season is the more important factor. (3) The buds come out of the rest gradually, the rate depending mostly on the variety and to a lesser degree on the season. (4) The time the buds are through the rest period depends largely on the time they went into the rest and hence on the season. It depends to a lesser extent on the variety. (5) Those varieties which are most resistant to winter cold are usually the slowest to come out of the rest period. This suggests a relationship between rest period and cold resistance. Varieties which are least irritable, that is, are least apt to be started into growth during warm periods in the winter, are most cold resistant.

Blueberry Culture. (J. S. Bailey.) The attempt to control mummy berry by spraying with Fermate was continued in 1946. Some bushes received six, some seven, some eight, and some nine sprays. Primary infection of shoots and blossom clusters was much lighter than in 1945. There were also fewer mummied berries on the unsprayed bushes than in 1945. Although the differences among the various numbers of sprays were too small to be significant, the spraying definitely reduced the number of mummies. This work is being continued.

In the experimental plantings there are a number of bushes infected with blueberry stunt, a virus disease. These are being kept to watch the progress of the disease. As yet, there has been no evidence of any spread from diseased to adjacent healthy bushes. However, the progress of the disease in an infected bush is much more rapid than had been anticipated. So far diseased bushes have been found in only two varieties, Cabot and Concord. Since the symptoms differ in each variety, buds from diseased bushes were set in healthy bushes of several other varieties so that the symptoms might be studied as they developed.

An infestation of a Lecanium scale had been slowly building up, particularly on the variety Concord. Previous attempts to control it had been only partially successful. In the spring of 1947 delayed dormant sprays of DDT emulsion, D-542, and "Peninsula Oil" were applied in cooperation with the Entomology Department. The DDT emulsion had little effect, "Peninsula Oil" killed most of the scale, and D-542 eliminated them almost completely.

Nutrition of the High-Bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) For many years it was believed that manure would kill cultivated blueberry bushes. A comparison of horse, poultry, and cow manure over a period of five years has shown that (1) the bushes will thrive where as much as 20 tons of horse manure per acre are applied, and (2) there is no significant difference among manures when they are used in such quantities as to give about the same amount of nitrogen per acre. This phase of the work has been concluded.

In the summer of 1946, leaf symptoms of what appeared to be magnesium deficiency were observed on a few blueberry plants. Chemical analyses of the leaves of several bushes revealed that they contained only 0.14 percent magnesium or less. With the apple, 0.20 percent is considered the danger line. When the analysis gets that low, an effort should be made to get more magnesium into the tree. This situation in blueberries is being studied further.

Magnesium Deficiency in Massachusetts Apple Orchards. (J. K. Shaw and W. D. Weeks.) The leaf scorch typical of this deficiency has been little in evidence during the past three years. This is not saying that magnesium deficiency is no longer present. Probably it may interfere with best growth and fruitfulness and still no serious leaf scorch be present. Moderate to heavy applications of Epsom salts were applied to a large number of trees and leaf samples from 110 trees collected for analysis. The analytical work is not yet completed, but so far there is little indication of success in getting magnesium into these mature apple trees. The recommended measures to alleviate magnesium deficiency are still 20 pounds of Epsom salts in 100 gallons of the regular spray solution applied in three or four of the earlier foliage sprays for immediate results, and dolomitic limestone, 1 to 2 tons per acre, for more lasting results.

Thinning Apples with Sprays. (W. D. Weeks.) Because of a light bloom in most of the Station orchards and injury to blossoms from spring frosts, extensive trials to thin apples with sprays were not attempted in 1947. However, some results were obtained with a commercial preparation of naphthalene acetic acid, 20 p.p.m. Early McIntosh, Golden Delicious, Red Astrachan, Wealthy, and Lobo were thinned quite effectively; while Kendall, Melba, Blackmack and Richared were thinned excessively. Considerable dwarfing and distortion of the leaves was caused by the naphthalene acetic acid on Wealthy, Early McIntosh, and Melba; while Golden Delicious, Richared, Blackmack, Red Astrachan, Kendall, and Lobo varied from no apparent injury to moderate injury.

Limited trials were also made with a new thinning mixture which the Delaware Station reported as showing much promise. The mixture consisted of polyethylene polysulfide (Goodrite p.e.p.s.) and a complex product of zinc dimethyl dithiocarbamate "Zimate" with cyclchexylamine. It was used at the rate of 2 pounds of Goodrite and 1/8, 1/4, and 1/2 pound of the "Zimate" complex per 100 gallons. Applications were made on single branches of several varieties at one and two weeks past full bloom. Under the conditions of the test none of the sprayed branches showed a significant reduction in set over the checks.

Chemical Control of Poison Ivy and Other Weeds. (J. S. Bailey.) Poison ivy is often a serious pest in orchards where it grows under fruit trees, often in rank profusion. Workers are sometimes seriously poisoned when picking up dropped fruit at harvest time or when working in the orchard at other times. During 1946, several materials were used as sprays in an attempt to kill this pest. Four formulations of the new weed killer, 2, 4-D, were tried. Two of these were esters, one a butyl and the other a methyl ester. Both of these were tried at the usual strength of 1,000 p.p.m. and at 2,000 p.p.m. None of the four formulations was effective. Mixtures of several different concentrations of ammonium thiocyanate with tar acid oil and kerosene were tried. These killed only the tops and new tops developed from the old roots. A proprietary mixture of sodium chlorate and a deflagration agent was also tried, used at 1 pound per gallon of water. This was more effective than the 2, 4-D sprays but eradication was not complete. As in 1945, ammonium sulfamate proved to be the most effective eradicant for poison ivy. At ¾ pound per gallon it was 90 percent effective, and at 1 pound per gallon it was almost 100 percent effective.

American bamboo (*Polygonum Seiboldii* De Vriese) is one of the most persistent and fast growing weeds imaginable. It is not a common weed, but where it has become established, it can take over large areas in a short time. Two ester formulations of 2,4-D at single and double strength were tried, without effect other than a little twisting of the tender tips. Two applications of ammonium sulfamate at 1 pound per gallon, the first June 26 and the second August 8, failed to kill this pest.

Ammonium sulfamate is very toxic to peaches and cultivated blueberries but harmless to apple trees four years old or older when sprayed on weeds under them. Its effect on four-year-old pear, plum, and cherry trees was tested by applying the spray on the weeds around them at 1 pound per gallon, 1 gallon per 100 square feet. One spray was applied June 25 and a second September 6. No visible effects have been observed on the trees; so that material appears to be safe for use around cherries, plums, and pears, at least after they are four years old.

A proprietary mixture of sodium chlorate and a deflagration agent was also found to be safe around four-year-old cherries, plums, and pears when used at 1 pound per gallon, 1 gallon per 100 square feet. This mixture is toxic to cultivated blueberries.

Witch grass, sometimes called quack grass or twitch grass, is often a problem around young trees in an orchard. Previous experience indicated that fall applications of ammonium sulfamate were more effective than summer applications. A series of plots was laid out in the summer of 1946 to test the effectiveness of ammonium sulfamate and a proprietary mixture of sodium chlorate at different times, at different concentrations, and at different rates of application. It was found that ammonium sulfamate at ¾ pound per gallon or the chlorate mixture at 1¼ pounds per gallon, used at the rate of 1 gallon per 100 square feet, did a 95 to 100 percent job of killing the witch grass. In the summer of 1947 it was observed that the witch grass came back into the plots from around the edges faster in the ammonium sulfamate plots than in the chlorate mixture plots.

A butyl and a methyl ester formulation of 2,4-D were tried on chokecherry at 1,000 p.p.m. and at 2,000 p.p.m. in August, 1946. The materials were equally effective, and single was as good as double strength. Growth of the treated bushes was very weak and very abnormal in 1947. Leaves were very narrow, curled, very sharply serrated, and mottled. Fruiting stems made an abnormally vigorous growth but died without producing fruit.

DEPARTMENT OF POULTRY HUSBANDRY

F. P. Jeffrey in Charge

Broodiness in Poultry. (F. A. Hays and Ruby Sanborn.) Selective breeding has not been successful in entirely eliminating the broody instinct in Rhode Island Reds. A limited life span particularly in males, no manifestation of the character in males, and incomplete progeny testing because of deferred broodiness offer many difficulties. The fact has been clearly demonstrated that broodiness depends upon two dominant complementary genes and that quantitative factors affecting the degree of broodiness are in operation. There is a definite linkage between broody genes and intensity of laying, and clucking without cessation of laying has been shown to indicate broody inheritance. Females should be tested for at least three laying years to discover their phenotype for the broody instinct. The last generation to complete its first laying year exhibited no broodiness in the daughters of one 36-month-old sire; but the other sire, 24 months old, gave one broody daughter from a hen of the same age. These daughters are being retained for a further performance record.

The Effectiveness of Selective Breeding to Reduce Mortality in Rhode Island Reds. (Regional Poultry Research Laboratory and Departments of Veterinary Science and Poultry Husbandry, Massachusetts Agricultural Experiment Station, cooperating.) Results of breeding high and low mortality lines through three generations were completed in November 1946. The two lines differed significantly in mortality rates to eight weeks, from eight weeks to six months, and from six to eighteen months in both sexes. The low mortality line exhibited a higher mortality rate than the control line during the same period. Complete data are ready for publication.

Genetic Laws Governing the Inheritance of High Fecundity in the Domestic Fowl. (F. A. Hays and Ruby Sanborn.) A number of phases of the problem of breeding for high fecundity have been studied. The value of egg records as a criterion for selecting breeding females was reported in *Poultry Science* for November 1946. The accuracy of limited trapnesting has been investigated and results reported in Station Bulletin 438. Further consideration has been given the problem of intensity, particularly from the inheritance standpoint, and the report is being published as a Station bulletin. The data point to the importance of heredity in developing high intensity. There is no evidence of sex-linked genes being concerned. A special study is being made of the value of progeny testing in breeding for high fecundity, and of the possible effect of air temperature on egg size in Rhode Island Reds.

Early sexual maturity, very low broodiness, and high persistency are well fixed in the flock, but intensity and incidence of winter pause remain variable. Efforts are being made to reduce variability in egg production by a search for inherited factors operating.

A Study of Fertility Cycle in Males. (F. A. Hays.) Synthetic thyroxin was used in the spring of 1947 to activate males of various ages to higher fertility. Artificial light was also tested. Results showed that the hormone was not quite so effective as artificial light. Cockerels have not been affected by any agents used.

The complete report of this and previous years' tests is now in press.

Genetic Analysis of Rhode Island Red Color Inheritance. (F. A. Hays.) This project was completed in the fall of 1946. Colorimetric analysis of intensity of soluble feather pigment suggests that less intense pigmentation depends on several dominant genes. A complete report is ready for publication.

Secondary and Adult Sex Ratio in Relation to Hatchability. (F. A. Hays.) High and low hatchability lines have been developed through the third generation, but have not yet been carried long enough to be definitely established. A search for lethals responsible for low hatchability and abnormal sex ratios has not been very fruitful as yet. Preliminary evidence indicates, however, that sex differences in embryonic mortality rates play considerable part when secondary sex ratios are abnormal.

Breeding for High and Low Incidence of Internal Defects in Hen's Eggs. (F. P. Jeffrey and C. E. Walker.) Strains of Rhode Island Reds have been bred which differ significantly in incidence of meat spots in their eggs. Continued selection will be practiced to further differentiate these strains. There is a small but significant association between incidence of meat spots and degree of shell color, the eggs with darkest shell color tending to carry more meat spots than those with the lightest shell color. Egg shell color varies widely in these strains.

Breeding White Plymouth Rocks for Eggs and Meat. (F. P. Jeffrey.) A strain of White Plymouth Rocks has been developed which is pure for the Columbian pattern; that is, males of this strain when mated with Rhode Island Red or New Hampshire females give red pullets and "Columbian" males.

Hatchability Factors in Products of Vegetable Origin-Distillers' Dried Solubles as Supplements to Soybean Meal Rations. (Marie S. Gutowska.) Two types of basal rations were used in making up the eight experimental rations. Type I consisted largely of corn and soybean meal supplemented with methionine and choline and small amounts of alfalfa meal. Type II contained less soybean and corn meal but included also wheat bran and oats. Mineral and vitamin supplements were added to both types on an equal basis. Soludri regular and Soludri 3N (Distillers' Dried Solubles), both fermentation products of vegetable origin, were the materials tested for their value as supplements.

The results demonstrated clearly that, whereas the basal Type I ration maintained hatchability at a low level of 49 percent of fertile eggs, the hatchability was improved considerably (36 percent) when a supplement of 3N Soludri was added. However, hatchability increased only 26 percent when Soludri regular was added, either with or without fish meal. It seems, therefore, that the necessary hatchability factor(s) could be provided by the addition of distillers' fermentation products to a ration of Type I, and that in some cases fish meal does not contribute additional hatchability factors.

The value of the supplements was less pronounced in raising hatchability on rations of Type II. The basal ration maintained hatchability at 63.5 percent level. The addition of Soludri increased the hatchability 16.5 percent; but, in order to obtain a good hatchability (87 percent), it was necessary to add 2.5 percent of fish meal in addition to 5 percent Soludri. In this case, the unknown hatchability factor(s) could not be produced without adding a protein of animal origin.

This study suggests the need for further attempts to work out a basal formula for high hatchability laying rations deriving their protein from vegetable sources only. Apparently soybean meal rations of Type I can be used successfully when supplemented with Soludri, especially Soludri 3N, possibly because this supplement may create favorable conditions for microorganisms and synthesis.

SEED CONTROL

Frederick A. McLaughlin in Charge

The Massachusetts Agricultural, Vegetable and Flower Seed Law was amended in 1946 and became effective on August 24 of that year. More comprehensive requirements of the amended act, together with a growing appreciation by the public of the merits of tested seed, resulted in a greatly increased number of samples received by the laboratory over any previous year. From July 1, 1946, to June 30, 1947, 5,853 samples were received and worked in the seed laboratory; an increase of 679 samples over the previous year. The laboratory also received and cleaned 100 lots of tobacco seed.

Enforcement of the Seed Law, together with an increased interest in good seed on the part of seedsmen and the public, has resulted in more correctly labeled and better quality seed being offered for sale. In 1947 only 1.94 percent of the vegetable seeds sampled by a State inspector and tested at the seed laboratory were found to be below standard. There has been a marked increase in the number of samples above standard each year since 1936 when 28.36 percent were found below.

Operation of the Seed Law is reported in an annual bulletin issued for that purpose.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, G. H. Snoeyenbos, O. S. Flint, F. G. Sperling, M. K. Clarke, O. M. Olesiuk, and E. M. Allen.

1. *Pullorum Disease Eradication.* During the year 1946-47, a total of 1,271,378 blood samples was tested—1,238,983 from chickens, 19,796 from turkeys and 12,599 from other fowl. A total of 651 chicken and turkey flocks was tested The percentages of positive tests were 0.13 for chickens, 0.51 for turkeys, and 0 for other fowl tested. There was a slight increase over the previous season in the number of flocks and samples tested.

It is encouraging to note that the pullorum disease status of Massachusetts poultry flocks has steadily improved during the past six years, even though both the poultrymen and the laboratory have been faced with many difficulties. Massachusetts can feel proud of the fact that 95 percent of the chickens tested are in 100 percent non-reacting flocks.

2. *Diagnostic Service.* During the calendar year of 1946, 4763 specimens were received in 858 consignments, of which 448 were delivered in person. The specimens were classified as follows: 4028 chickens, 642 turkeys, 18 pheasants, 17 rabbits, 11 each of bovine semen and canine feces, 10 each of ducks and pigeons, 7 quail, 3 trout, 2 bovine organs, and 1 each of bovine blood, bovine fetus, canary, and swine.

Coccidiosis (105), tumors (64), pullorum disease (58), fowl paralysis (37), and Newcastle disease (47) were the disturbances identified most frequently. A definite diagnosis was not reached in 46 outbreaks of respiratory disease. Avian tuberculosis was not identified during the year. Fowl cholera was identified in 19 instances, including 10 new premises. Fowl typhoid was recognized 19 times, and 17 were on premises where the disease was not known to have existed previously. There were fewer cases of cholera and more of typhoid than in the previous year.

Cockleburs caused severe injury in one group of chicks three weeks of age. Peanut shell litter containing cockleburs had been added to the litter already on the floor, and the chicks began eating the burs almost immediately. As many as five were found in some of the chicks examined. The cockleburs caused severe mechanical injury and inflammation at the site of lodgment, usually the lower esophagus.

The 642 turkeys were received in 140 consignments. More than half of the examinations were on birds less than four weeks old. Coccidiosis, paratyphoid infection, pullorum disease, and swine erysipelas were the conditions encountered most frequently.

The number of cases of *E. rhusiopathiae* infection (swine erysipelas) in turkeys called to the attention of the laboratory equalled that of the previous ten years combined. In previous years the outbreaks had occurred principally on porches in September and October or on range in November and December. In 1946 one outbreak occurred in February in housed breeders, and several were on range during the summer and early fall. The latter outbreak continued for some time and one owner reported losses of approximately 12 percent.

3. *Flock Mortality Studies.* Necropsies were made on 225 birds from the Experiment Station flock, including 141 females, 76 males, and 8 unidentified of the group hatched in the spring of 1945. No new observations of significance were made on examinations of these birds.

4. *Infectious Bronchitis Control.* During 1946, 217 flocks were enrolled in the infectious bronchitis control program. The results continue to be satisfactory, and the flock owners regard this control program as a valuable service to the industry. During the year birds from 101 flocks were tested for their immunity to infectious bronchitis, 64 of which were found to be immune, 35 susceptible, and 2 questionable.

Furthermore, 114 flocks were tested for Newcastle disease with the serum-virus neutralization and hemagglutination-inhibition tests; and 47 were found positive, 64 negative, and 3 questionable. When indicated, attempts were made to isolate the virus from tissues of infected birds. The disease was identified in Berkshire Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Plymouth, Suffolk, and Worcester counties. Whenever possible, complete case histories on natural outbreaks are being collected, and that information should be helpful in investigating and controlling this disease.

In 8 flocks, eggs collected during active outbreaks of Newcastle disease were examined for the presence of virus. Among 256 eggs examined, the virus was recovered from 34 eggs received from 4 flocks.

Preliminary studies reveal that birds recovering from exposure to the Newcastle virus will give a positive test with the hemagglutination-inhibition test (H I) in a shorter time than with the serum-virus neutralization test. Hemagglutination inhibiting bodies have been found in sera of birds as early as five days after artificial infection. The H I test should prove of great value in the early diagnosis and control of the disease.

A few flocks (approximately 10,000 birds) were vaccinated with a commercially produced, killed vaccine. The vaccine failed to induce a definite immunity.

A limited number of experiments was conducted to determine whether eggs selected during the active and terminal stages of an outbreak of Newcastle disease would produce infected chicks on hatching or during the first two weeks of the brooding stage. The trials conducted thus far have yielded negative results. This phase of the disease is being investigated further since the virus has been detected in fresh eggs, and field observations have led to the recovery of the virus from two-day-old chicks.

5. *Mastitis Testing Laboratory.* At the end of the calendar year 1946, facilities for operation of the laboratory were incomplete. Plans were made to set up and test equipment early in 1947.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon, In Charge

The members of the research staff of the Waltham Field Station are assigned to this branch by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to reports of these Departments for results of investigations conducted at this Station.

PUBLICATIONS

Bulletins

436 Annual Report for the Fiscal Year Ending June 30, 1947. 70 pp. September 1946.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

437 Home Freezing in Massachusetts. By William B. Esselen, Jr., Katherine M. Lawler, and Carl R. Fellers. 27 pp. illus. October 1946.
Home freezing of foods is arousing much interest. In Massachusetts freezing seems best suited as a supplement to other methods of home food preservation. Questions frequently asked by prospective home freezer owners are answered.

438 The Value of Limited Trapnesting to Poultry Breeding. By F. A. Hays. 24 pp. September 1946.
Limited trapnesting reduces labor costs and affords a method by which breeders may secure records on larger numbers of birds. Data reported in this study indicate that safe estimates of complete performance may be made from certain short-time records.

439 Clearing and Improvement of Farm Land in Massachusetts. By Charles R. Creek, Joseph F. Hauck, and Virgil L. Hurlburt. 31 pp. illus. July 1947.
The primary purposes of this study have been to appraise the methods used in farm land improvements, to examine the results in terms of cost-benefit comparisons, and to study the significance of land reclamation for the future of agriculture in Massachusetts.

Control Bulletins

128 Twenty-sixth Annual Report of Pullorum Disease Eradication in Massachusetts. By the Poultry Disease Control Laboratory. 15 pp. June 1946.

129 Inspection of Commercial Feedstuffs. By Feed Control Service Staff. 28 pp. July 1946.

130 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 27 pp. July 1946.

131 Seed Inspection. By F. A. McLaughlin. 33 pp. December 1946.

Meteorological Bulletins

691-702, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness, M. J. Markuson, and F. J. Sievers. 4 pp. each.

Reports of Investigations in Journals

NUMBERED CONTRIBUTIONS

525 Effect of institutional cooking methods on vitamin content of foods. II. Ascorbic acid content of potatoes. By Anne W. Wertz and C. Edith Weir. Food Res. 11 (4):319-326. 1946.

567 Composition of squashes after winter storage. By Arthur D. Holmes and Albert F. Spelman. Food Res. 11 (4):345-350. 1946.

571 Influence of purified lignin on nitrification in soil. By James E. Fuller. Science 104 (2701):313-315. 1946.

577 The vitamin content of canned and cooked fresh mushrooms. By Angela M. Filios and William B. Esselen, Jr. Jour. Amer. Dietet. Assoc. 22 (9): 772-777. 1946.

578 Nutritional status of women students. By Marie S. Gutowska and Evelyn B. Ellms. Jour. Amer. Dietet. Assoc. 22 (9):763-765. 1946.

579 Enhancing the riboflavin content of mare's milk. By Arthur D. Holmes. New England Jour. Med. 235:360-362. 1946.

580 Carbohydrates in cultivated mushrooms (Agaricus campestris). By John E. W. McConnell and W. B. Esselen, Jr. Food Res. 12 (2):118-121. 1947.

583 The use of oil sprays as selective herbicides for carrots and parsnips. II. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 47:423-433. 1946.

585 Sodium selenate for red spider control in Massachusetts. By Harold E. White and Warren D. Whitcomb. Amer. Soc. Hort. Sci. Proc. 47:503-506. 1946.

586 Fermate and its effect on rooting of geranium cuttings. By Harold E. White. Amer. Soc. Hort. Sci. Proc. 47:522-524. 1946.

588 Evaluation of tests for rancidity in edible packaged oils. By John E. W. McConnell and W. B. Esselen, Jr. Oil and Soap 23 (12):369-374. 1946.

589 Effect of storage conditions and antioxidants on the keeping quality of packaged oils. By John E. W. McConnell and William B. Esselen, Jr. Jour. Amer. Oil Chem. Soc. 24 (1):6-13. 1947.

590 Stability of vitamins in stored ice cream. By Arthur D. Holmes, John W. Kuzmeski, and Frank T. Canavan. Jour. Amer. Dietet. Assoc. 22 (8): 670-672. 1946.

592 Fermate for the control of mummy berry of the cultivated blueberry. By J. S. Bailey and Thomas Sproston. Amer. Soc. Hort. Sci. Proc. 47:209-212. 1946.

593 The decomposition of certain plant tissues with and without added lignin. By Emmett Bennett. Amer. Soc. Hort. Sci. Proc. 47:252-254. 1946.

595 The influence of Malling clonal rootstocks on the growth of certain apple varieties. By J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 48:171-179. 1946.

596 The anchorage of clonal stock apple trees. By J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 48:166-170. 1946.

597 Bactericidal properties of some surface-active agents. By W. S. Mueller, Emmett Bennett and James E. Fuller. Jour. Dairy Sci. 29 (11):751-760. 1946.

598 Effect of storage temperature on processed and dehydrated foods. By John E. W. McConnell, C. R. Fellers, and W. B. Esselen, Jr. The Glass Packer, 25:714, 716-717, 800, 824-826, 828. 1946.

599 Egg records as a criterion for selecting breeding hens. By F. A. Hays. Poultry Sci. 25 (6):622-627. 1946.

601 Some observations on "quality" in hays. By J. G. Archibald, E. Bennett, and J. W. Kuzmeski. Jour. Dairy Sci. 29 (11):795-800. 1946.

604 Vitamin C content of hens' vital organs after long continued ascorbic acid injections. By G. Howard Satterfield, Thomas A. Bell, F. W. Cook, and Arthur D. Holmes. Poultry Sci. 26 (2):163-166. 1947.

605 The fortification of fruit juices with ascorbic acid. By William B. Esselen, Jr., John J. Powers, and Carl R. Fellers. Fruit Prod. Jour. and Amer. Food Mfr. 26 (1):11-14, 29. 1946.

606 The protection of lilies against damping off. By William L. Doran. Natl. Hort. Mag. 25:4 :385-386. October 1946.

607 Firmness in frozen sliced apples. By William B. Esselen, Jr., W. J. Hart, Jr., and C. R. Fellers. Quick Frozen Foods 9 (5):66 (II), 1946.

608 Preparation of holocellulose from nonwoody plant material. By Emmett Bennett. Analytical Chem. 19:215. 1947.

609 Relationship of seed plant development to the need of magnesium. By Walter S. Eisenmenger and Karol J. Kucinski. Soil Sci. 63(1):13-17. 1947.

610 Food value of hormone-treated tomatoes. By Arthur D. Holmes, Albert F. Spelman, John W. Kuzmeski, and William H. Lachman. Jour. Amer. Dietet. Assoc. 23 (3):218-222. 1947.

616 Cobalt in cows' milk. By J. G. Archibald. Jour. Dairy Sci. 30 (5):293-297. 1947.

619 Composition of mares' milk as compared with that of other species. By Arthur D. Holmes, Albert F. Spelman, C. Tyson Smith, and John W. Kuzmeski. Jour. Dairy Sci. 30 (6):385-395. 1947.

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The feed dealer—An agricultural missionary. By J. G. Archibald. Amer. Feed and Grain Dealer 30 (10):14-15 et seq. September 1946.

Some lessons to be learned from the feed shortage. By J. G. Archibald. New Eng. Farm Finance News 1 (10):4. October 1946.

Now we're learning what it takes to feed a cow. By J. G. Archibald. Eastern States Cooperator 22 (11):11-14. November 1946.

Roughage as a factor in winter feeding. By J. G. Archibald. Canad. Jersey Breeder 2 (1):14 et seq. December 1946.

This feed shortage. By J. G. Archibald and F. H. Branch. Mass. State Coll. Ext. Serv. Spec. Cir. 141. July 1946.

Control of damping-off by a delay in first watering after seeding. By William L. Doran. Phytopath. 36:8:679. August 1946.

Fungicides applied in fertilizer for the control of cabbage clubroot and damping-off. By William L. Doran. Ann. Meeting Northeast. Div. Amer. Phytopath. Soc., November 26, 1946. (Abstract will appear in Phytopathology.)

Present status of the Dutch elm disease in New England. By Malcolm A. McKenzie. Report for 22d Conference convened by New England Council. November 22, 1946.

Troublesome tree diseases in New England and their control. By Malcolm A. McKenzie. 22d Natl. Shade Tree Conf. Conv. Proc., Boston, August 27-30, 1946 (pp. 134-7).

Dutch elm disease in Massachusetts. Forest and Park News. February 1947.

Dutch elm disease. By Malcolm A. McKenzie. (Five progress reports—mimeographed.)

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 442 JULY 1947

Mortality Studies in Rhode Island Reds II

By F. A. Hays

Mortality from all causes is one of the most important problems of poultrymen. This report gives the final results of an attempt to breed lines of Rhode Island Reds resistant or susceptible to mortality from all causes.

UNIVERSITY OF MASSACHUSETTS

AMHERST, MASS.

MORTALITY STUDIES IN RHODE ISLAND REDS II[1]

By F. A. Hays

Research Professor of Poultry Husbandry

Many attempts have been made to study the part played by heredity in controlling the mortality rate in chickens. Most studies have suggested that selective breeding offers possibilities for reducing mortality rate from all causes at different ages. A review of previous work was included in the first report of this series and need not be repeated.[2]

From an economic standpoint, mortality rate is very important. With constantly improved methods of feeding and management, heavy losses still persist in many flocks and the gross losses from all causes are enormous. Genetic principles are being applied more and more in poultry breeding, and the accomplishment as far as fecundity is concerned is very gratifying. Any information that the science of genetics may furnish with regard to the mortality problem will be highly valuable.

MATERIALS AND METHODS

The plan of matings was changed in 1943 so that three generations from 1943 to 1945 were produced largely by half-brother–sister matings and a few full-brother–sister matings. The low-mortality line was reproduced by yearling sires and dams and the high-mortality line from cockerels and pullets only. All birds were Rhode Island Reds, and the sole basis of selecting breeders was the family mortality rate. All offspring was carried until eighteen months of age and mortality rates from all causes were recorded for three periods: the first eight weeks, from eight weeks to six months, and a full year in the laying houses. The control line was bred especially for high fecundity without inbreeding and with some attention given to mortality rate. Stock of all lines was reared and housed together.

Consideration is given first to mortality rates in the three lines for the different periods. This is followed by a study of the causes of mortality as determined through the cooperation of the Department of Veterinary Science.

MORTALITY RATES

The First Eight Weeks

Since the sexes were not separated until the birds were eight weeks old, the mortality rates for this period include both sexes. In the first generation the mortality rate for the low-mortality line was extremely small, being less than 1 percent. At the same time mortality rate in the high line was 36.5 percent, and in the controls 7.4 percent.

In the second generation there was very high mortality in the high line, and the low line showed a death rate almost double that of the controls.

The third generation exhibited a mortality rate of 50 percent for the high line. The low line increased to 16.7 percent mortality, which was nearly double the rate for the controls.

[1]This is a cooperative project financed in part by the Regional Poultry Laboratory.

[2]Hays, F. A., 1944. Mortality studies in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 420

In general, the data show a significant difference in mortality rates between the high and the low line. There was also a significant increase in mortality in both the high and the low lines through three generations. In the second and third generations mortality was significantly higher in the low line than in the controls. This fact suggests a lack of progressive reduction in mortality in the low line. The line selectively bred for low mortality was not equal to the controls after the first generation.

From Eight Weeks to Six Months of Age

During this period the sexes were carried separately on good grass range. Complete families of males and females were retained in the high and low lines. In the control line, complete families of females were retained but only partial families of males.

In the high line, mortality among the males amounted to 44.1 percent in the first generation, increased to 62.9 percent in the second generation, and fell to 20.0 percent in the third. There was a highly significant difference in mortality rates between the high and low lines. Males in the low line compared favorably with the controls in the three generations. A lack of progressive decrease in mortality was noted in the low line.

Females of all three lines had a very low mortality rate in the first generation. In the second generation female mortality rose to 52.5 percent in the high line but remained low in both other lines. In the third generation mortality remained high in the high line, and showed an increase in the control and low lines. There appeared to be a significant difference in mortality of females in the high and the low lines.

From Six to Eighteen Months of Age

During the period of one year in the laying houses, males of the high and low lines exhibited a significant difference in mortality rates. Mortality in the low line was higher than in the controls. For the three generations there was no increase in mortality in the control line.

For the first year in the laying houses, pullets of the high and low lines were not consistently different in mortality rate. This variability may have been due in part to small numbers. Neither of the selected lines was as good as the controls. Small numbers of both males and females in the two selected lines were caused by low hatchability and high mortality up to the age of six months.

The means of three generations, given at the bottom of the table, appear to suggest two possibilities: first, that selective breeding for high and low mortality does result in a very significant difference in mortality in the two lines; and second, that selective breeding for low mortality did not produce a line superior to the controls, which were bred for high fecundity characters.

The annual egg records are given in the last column of Table 1. The small number of normal egg records for the high-mortality line is very evident. There was a pronounced decline in annual egg production during the three generations. The low-mortality line, however, did not decline in egg production after the first generation, but the limited data indicate that they failed to maintain a satisfactory production level. The control line maintained a high level of production throughout the experimental period.

TABLE 1.—MORTALITY RATES IN LINES OF RHODE ISLAND REDS BRED FOR HIGH MORTALITY, FOR LOW MORTALITY, AND FOR HIGH FECUNDITY (CONTROLS).

(Matings in the high and low lines were half-brother x half-sister or closer. Control line was not inbred.)

Group and Year Hatched	To Eight Weeks		Eight Weeks to Six Months				Six Months to Eighteen Months				Annual Production	
	Sex Unknown		Males		Females		Males		Females			
	Number of Birds	Percent Mortality	Number of Birds	Percent Mortality	Number of Birds	Percent Mortality	Number of Birds	Percent Mortality	Number of Birds	Percent Mortality	Number of Normal Records	Production
1943												
Controls	1501	7.4	158	4.4	690	4.9	60	48.3	266	28.2	161	231.6
High Mortality	219	36.5	59	44.1	80	6.3	33	93.9	62	40.3	31	184.2
Low Mortality	241	.9	95	8.4	116	3.5	71	59.2	74	35.1	45	183.5
1944												
Controls	1910	5.6	320	8.1	866	7.7	60	36.7	387	15.0	286	229.7
High Mortality	106	28.3	35	62.9	40	52.5	12	83.3	19	63.2	5	126.2
Low Mortality	154	9.7	69	1.4	70	2.9	67	53.7	68	2.9	62	230.2
1945												
Controls	2151	9.4	378	9.0	927	7.2	71	43.7	515	15.9	365	223.8
High Mortality	38	50 0	10	20.0	9	22.2	8	75.0	7	28.6	1	85.0
Low Mortality	126	16.7	49	14.3	56	8.9	42	61.9	50	22.0	36	193.3
Means for Three Generations												
Controls		7.5		7.2		6.6		42.9		19.7		228.4
High Mortality		38.3		42.3		27.0		84.1		44.0		131.8
Low Mortality		9.1		8.0		5.1		58.3		20.0		202.3

CAUSES OF DEATH

Facilities were such that the percentage of birds sent to the laboratory for necropsy was far too low, and no necropsies were made on chicks that died before the age of eight weeks. The findings of the diagnostic laboratory are presented, however, in the hope that they approximate a reasonable sample of disorders in the flock. The same grouping of diseases and disorders employed in the first report is made use of in Table 2. Since a bird may show more than one of these disorders, the sum of percentages from left to right is often greater than 100.

From Eight Weeks to Six Months of Age

The control stock showed a high incidence of the leukosis complex during this period. Kidney disorders appeared second in importance. Miscellaneous tumors, reproductive disorders, miscellaneous disorders, and cannibalism each appeared in about one bird out of seven examined.

The high-mortality line exhibited a large amount of cannibalism and injuries during the first two generations. No cases of the leukosis complex were discovered in these birds. Miscellaneous tumors and kidney disorders were also less frequent than in the controls.

The low-mortality line was affected mainly by causes that were not specific; also with parasites and cannibalism. No avian leukosis was discovered.

From Six to Eighteen Months of Age

The leukosis complex was somewhat more prevalent in the control line than in either of the other lines. Control males had more cannibalism and a greater number of miscellaneous disorders than any other abnormalties. The incidence of the leukosis complex was much higher in females than in males. Cannibalism was also very high in control females.

In the high-mortality line there was little evidence that the leukosis complex was very high. Cannibalism was prevalent in both males and females. There was also evidence of considerable digestive trouble, and females had a significant amount of reproductive disorders.

The low-mortality line was freer from the leukosis complex than either of the other lines. Cannibalism and miscellaneous disorders seemed to be rather prevalent.

In general, cannibalism in females and injury from fighting in males were widespread. The two inbred lines appeared to be more affected by a considerable array of disorders than was observed in the controls.

TABLE 2.—DISTRIBUTION OF PATHOLOGICAL CONDITIONS AND DISORDERS IN BIRDS SUBJECTED TO NECROPSY.

Group and Year Hatched	Percentage of Birds with Various Diseases and Disorders											Number of Birds Examined	Percentage of Dead Birds Examined
	Avian Leukosis Complex	Miscellaneous Tumors	Digestive Disorders	Kidney Disorders	Reproductive Disorders	Staphylococcic Disorders	Parasites	Injury	Miscellaneous	Cannibalism	No Diagnosis		
Between the Age of Eight Weeks and Six Months													
1943													
Control	21.4	14.3	7.1	21.4	14.3			7.1	14.3	14.3	7.1	14	34.2
High Mortality		11.1		11.1				11.1		66.7	11.1	9	30.0
Low Mortality							20.0		20.0		60.0	5	41.7
1944													
Control	47.3		10.5				26.3	21.1	10.5	5.3		19	20.4
High Mortality				20.0				60.0		20.0		5	11.6
Low mortality												0	—
1945													
Control	45.2		6.5	3.2	3.2	3.2	9.7	3.2	16.1	3.2	12.9	31	30.7
High Mortality												0	—
Low Mortality		20.0	20.0				40.0			40.0		5	41.7
Between the Age of Six and Eighteen Months													
1943													
Control													
Male	5.3			10.5		36.8			31.6	26.3	10.5	19	65.5
Female	10.2	10.2	6.8	6.8	22.0	3.4		5.1	33.9	33.9	6.8	59	78.7

High Mortality													
Male	3.3	6.7	3.3	6.7		6.7			3.3	80.0		30	96.8
Female	4.8	9.5		4.8	23.8			4.8	23.8	52.4	4.8	21	84.0
Low Mortality													
Male				2.6		7.9			15.8	73.7	7.9	38	90.5
Female	4.2	4.2		4.2	4.2	8.3			50.0	25.0	12.5	24.	92.3
1944													
Control													
Male			13.3	6.7		6.7		6.7	20.0	40.0	20.0	15	68.2
Female	16.3	10.2	22.5	4.1	20.4	2.0	2.0	6.1	28.6	4.1	4.1	49	84.5
High Mortality													
Male	40.0		30.0						20.0	50.0		10	100.0
Female	40.0		20.0	10.0				10.0		10.0	20.0	10	83.3
Low Mortality													
Male		3.0	27.3	3.0	3.0	21.2	3.0			72.7	9.1	33	91.7
Female			50.0	100.0				50.0				2	100.0
1945													
Control													
Male	7.7	3.9	15.4	3.9	3.9	3.9	7.7	3.9	23.1	19.2	15.4	28	83.9
Female	36.0	13.1	9.8	1.6	16.4			9.8	14.8	24.6	6.6	61	74.4
High Mortality													
Male										100.0		6	100.0
Female		100.0			100.0				100.0			1	50.0
Low Mortality													
Male			10.5		5.3		5.3		10.5	89.5	5.3	19	73.1
Female	12.5	12.5		12.5	25.0				12.5	25.0	25.0	8	72.7

SUMMARY

Records on mortality were secured on three generations of Rhode Island Reds including two inbred lines: one selectively bred for high mortality rate, and the other for low mortality rate. Stock bred for high fecundity, without inbreeding, was used as controls. Samples of morbid and dead birds were examined by pathologists. From these data the following deductions were made:

1. Selective breeding using half-brother and sister matings produced two lines that differed significantly in mortality rate.
2. Selective breeding failed to give a line that had a lower mortality rate than was observed in the controls.
3. Although the avian leukosis complex appeared in all lines, it was not a major disorder in the two inbred lines. This disease was the major cause of death in the controls from eight weeks to six months but not between the ages of six and eighteen months.
4. The incidence of the avian leukosis complex was higher in females than in males.
5. Cannibalism was more prevalent in the two inbred lines than in the controls.
6. Injury from fighting was an important cause of death of males in all lines.
7. High-mortality line females were very inferior egg producers; low-mortality line females were mediocre egg producers; and the control line females were superior layers.
8. In general, the data indicate that heredity does play an important part in mortality rate.

AGRICULTURAL EXPERIMENT STATION
MASSACHUSETTS

BULLETIN NO. 443 JULY 1947

The Inheritance of Intensity of Laying in Rhode Island Reds

By F. A. Hays

Intensity of laying is one of the most important characters associated with high fecundity. Particular attention is given in this report to different methods of measuring intensity and to evidence regarding its inheritance.

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THE INHERITANCE OF INTENSITY OF LAYING IN RHODE ISLAND REDS

By F. A. Hays,

Research Professor of Poultry Husbandry

Internal factors affecting egg production have been studied by various investigators since their value was first stressed by Goodale in 1918. Attention has been directed toward the possible modes of inheritance of several of these characters and especially to their interrelationships and importance from the standpoint of fecundity. More recently attempts have been made to account for the wide variability in egg production so characteristic of high-producing flocks (See Lerner and Taylor, 1943 and Hays, 1944a).

As the level of egg production goes higher, breeding operations become more difficult. It is well known that operating with large numbers is a very great advantage from the standpoint of selection, yet much is still unknown regarding the genetic nature of particular characters. There is a great need for information regarding the possibilities and limitations of selective breeding under carefully controlled environmental conditions. Any information concerning the inheritance phase of the problem should be of value to the breeder.

REVIEW OF LITERATURE

Dryden (1921) used the best two months' record as a measure of intensity and concluded that intensity is an inherited trait.

In a study of the mode of inheritance of winter rate of laying, Hays (1924) suggested that two complementary genes R and R′ were concerned. Gross winter rate was calculated by dividing the number of eggs laid from first egg up to March 1 by the number of days concerned. A rate of 50 percent or more in this period was considered high.

Intensity in Rhode Island Reds was given further consideration by Hays and Sanborn in 1927. Four measures of winter intensity were employed: first 60 days' production, mean winter clutch size, net winter rate, and annual rate. Mean winter clutch size was found to be a satisfactory measure of winter intensity and its mode of inheritance was studied. Again two complementary genes I and I′ were suggested as governing the inheritance of large clutch size.

The problem of intensity was further examined by Hays and Sanborn in 1932. Mean clutch size in winter, in spring (March, April, and May), and in summer (June to end of year) was studied and interdependence determined. Important associations were reported between intensity of laying at different seasons of the year. No important association was observed between winter pause duration and clutch size. Winter, spring, and summer clutch size were all rather intimately correlated with annual egg production.

Jull (1924) used gross winter rate as a measure of intensity. In his calculation of rate he divided the number of eggs laid from first pullet egg up to March 1 by the total days concerned. Jull did not consider winter pause a separate entity as has already been suggested. He found the correlation in winter rate between mothers and daughters to be .154 in Rhode Island Reds and .108 in White Leghorns, but considered them of little biological significance.

Lerner and Taylor (1936) used two measures of rate in White Leghorns: net winter rate and net spring rate. The net winter rate was calculated from November 1 or from first egg after November 1 to March 1, a period of 120 days. The number of eggs laid was divided by 120 less the number of pause days in pauses of seven or more days. Winter pause was considered a separate entity due to inherited and environmental factors. Net spring rate was calculated for the period from March 1 to June 28 after deducting spring pauses. A significant correlation was observed between winter and spring rate, but the evidence was not conclusive that winter and spring rates are governed by the same set of genes. The correlation between winter rate and winter production was more significant than that between spring rate and winter production.

Tomhave (1941) measured winter intensity by percentage production during the period from first egg to February 1, from which period all pauses of five days or more were deducted. He was able by sib-testing breeding cockerels for winter intensity to produce lines that were significantly different in rate of laying.

Lerner and Taylor (1943) showed that the degree of heritability between families for net winter rate of laying was 21.8 percent.

Hays (1944) reported a correlation in winter clutch size between mothers and daughters with the value +.1365 which was barely significant. He emphasized that the dams used for breeding failed to breed true for intensity.

MATERIALS AND METHODS

The stock used in this study were Rhode Island Reds bred for characters associated with high fecundity. Seven generations of pedigreed pullets were included covering the hatching years of 1937 to 1943. All calculations were based on first-year trapnest records of mothers and daughters. The types of matings to produce each generation of daughters consisted of both young and old parents with emphasis on progeny testing and on low mortality rates. The study included 237 mothers producing a total of 2407 daughters.

Winter clutch size was calculated in the usual manner by counting the number of clutches of eggs from the first pullet egg through to March 1. The number of eggs was then divided by the number of clutches to get the mean clutch size. Spring clutch size was calculated in a similar way for March, April, and May; summer clutch size for June, July, and August; and fall clutch size for September and October. Mean clutch size is considered a good measure of intensity because it is not known to be affected by pauses of various kinds.

The coefficient of correlation may be used as a measure of inheritance. In a homozygous population of mothers there should be an intimate correlation between mothers and daughters for a particular character even though the fathers were more or less heterozygous. In this study consideration is given first to the correlation between all mothers and daughters with no regard to the phenotype of mothers with respect to clutch size. As a partial assurance of homogeneity of mothers, the data are next broken down into daughters from three possible phenotypes of mothers.

SECTION 1. MEAN CLUTCH SIZE AS A MEASURE OF INTENSITY

Correlation in Winter Clutch Size between Mothers and Daughters

The entire population of mothers and daughters was tabulated with respect to winter clutch size. Although the mean clutch size of all dams was high, the actual range in the dams used was from 1.5 to 14.5. This would include some mothers that lacked genes for high intensity. Dams with no genes for high intensity might produce mediocre daughters unless all sires transmitted high intensity. These conditions operate to reduce the correlation between mothers and daughters in the total population.

The correlation between mothers and daughters in winter clutch size was $+.1385 \pm .0135$, with linear regression. With 753 degrees of freedom r is statistically significant. It is probable, therefore, that the correlation coefficient is significant; but winter clutch size does not furnish an accurate criterion for selecting breeding females to raise the level of intensity, as Jull (1934) pointed out.

Dams were classified as phenotypically low in winter intensity if their winter clutch size fell below 3. There were 74 dams in this group with 724 daughters. Very low variability in winter clutch size was anticipated and observed in the dams. Their daughters, however, covered a wide range in clutch size. No significant correlation between mothers and daughters was observed, although regression was linear.

Medium intensity mothers had a winter clutch size of 3 to 4.5, and 109 individuals fell into this group. The fact should be noted that the mean clutch size of daughters from medium intensity dams was slightly larger than that of daughters from low intensity dams. Again there was no significant correlation between mothers and daughters in winter clutch size, but regression was linear.

Highly intense mothers had a winter clutch size of 4.6 or more, and there were 54 dams in this group with a range in clutch size from 4.6 to 15.5. Daughters from the most highly intense dams exhibited a higher mean clutch size than the daughters of low or medium dams, but the differences were not great. There is no evidence of a significant correlation between mothers and daughters on the basis of 170 degrees of freedom, though regression was linear.

These data on Rhode Island Reds indicate some correlation between mothers and daughters in winter intensity for the total population. When the variability in dams was reduced by selecting three possible phenotypes with respect to winter clutch size, this correlation was reduced to insignificance. These facts suggest that winter clutch size depends upon a series of inherited and environmental factors so that a dam's record for intensity is a poor criterion of her transmitting ability. Even dams that were classed as low in intensity failed to breed true, and those grouped as extremely high in intensity failed to transmit this superiority to their daughters with any degree of constancy.

Correlation in Spring Clutch Size between Mothers and Daughters

Egg production is generally at a high level in the spring months of March, April, and May. In an earlier report (Hays and Sanborn, 1932), the facts was pointed out that spring clutch size was rather intimately correlated with annual egg production in Rhode Island Reds bred for high fecundity. The value of spring clutch size as a criterion in selecting breeding females requires further study.

The tabulation of daughters against their mothers gave a coefficient of correlation of $+.1226 \pm .0139$, but regression was not strictly linear. An examination of the regression line shows that digression from linearity occurred in the 113 daughters of the 9 dams whose clutch size ranged from 11 to 16. In other words, this small group of extremely intense dams failed to transmit their very high intensity to their daughters. With 733 degrees of freedom, the coefficient of correlation is significant. The above data point to spring clutch size of dams as a poor criterion for selection in breeding for high intensity.

Mothers have been classed as low in spring intensity if their mean clutch size was below 4.2. The 104 mothers in this class gave daughters whose average clutch size was greater than their own, but the daughters were highly variable. On the basis of 312 degrees of freedom, there was no significant correlation between mothers and daughters.

Those mothers whose spring clutch size ranged from 4.2 to 5.7 were considered of medium intensity and there were 71 individuals in this class. Daughters from these mothers were extremely variable in spring clutch size, and there was no correlation between mothers and daughters although regression was linear.

Dams whose spring clutch size ranged from 5.8 upward were considered to be highly intense. A total of 60 dams fell into this group. Regression of the daughters on mothers in this group was non-linear and examination showed that regression was linear for mothers with a clutch size up to 10. There were 158 daughters from dams with a spring clutch size above 10, and here regression was definitely non-linear. With 191 degrees of freedom, neither the correlation coefficient nor the correlation ratio is significant.

Judged on the basis of the correlation between mothers and daughters, there is no evidence in these data to indicate that selection of dams on the basis of spring clutch size is effective in increasing spring clutch size in daughters.

TABLE 1.—CORRELATION BETWEEN MOTHERS AND DAUGHTERS IN CLUTCH SIZE FOR IDENTICAL PERIODS.

Periods	Number of Dams	Number of Daughters	Coefficient of Correlation	Correlation Ratio
Winter				
Total population	237	2407	+.1385	
From low dams	74	724	−.0131*	
From medium dams	109	1135	+.0423*	
From high dams	54	548	+.1344*	
Spring				
Total population	235	2301	+.1226	.1751
From low dams	104	948	+.0801*	
From medium dams	71	731	−.0106*	
From high dams	60	622	+.1106*	.2076
Summer				
Total population	230	2006	+.0686*	.1289
From low dams	83	651	+.1233	.2682
From medium dams	90	828	−.0421*	.1458
From high dams	57	527	+.0679*	
Fall				
Total population	218	1621	+.0956*	
From low dams	36	224	−.0832*	
From medium dams	127	1008	+.0048*	
From low dams	55	389	+.1643*	

*Not statistically significant.

Correlation in Summer Clutch Size between Mothers and Daughters

High intensity may be difficult to maintain during the summer because of unfavorable temperatures and the greater prevalence of diseases and disorders. It is desirable, however, to know whether there is an intimate correlation between mothers and daughters in summer intensity. Records were available on 230 dams with 2006 daughters.

The data show that summer clutch size was highly variable in both mothers and daughters, the actual range being from 1 to 15 for dams and from 1 to 22 for daughters. The mean summer clutch size of both mothers and daughters was essentially the same as the mean winter clutch size. Regression was non-linear and the correlation was insignificant. A study of the regression line showed that the digression from linearity occurred only in daughters from dams with a summer clutch size of 10 or more. In any case, there appears to be no important association between the summer clutch size of mothers and their daughters.

Since mean summer clutch size in the whole population studied was essentially the same as winter clutch size, the same classification of dams into low, medium, and high types was used. There were 83 dams that had a summer clutch size under 3. These dams produced daughters whose mean clutch size was greater than their own. This could be attributed to the males to which they were mated. Regression of daughters on mothers was not linear, so that the correlation ratio of .2682 expresses the association, which is probably significant.

There were 90 dams with a mean summer clutch size ranging from 3 to 4.5. These have been considered medium for intensity. No correlation was observed between these mothers and their daughters, and regression was found to be non-linear.

There were 57 dams in the highly intense group, with a range in summer clutch size from 4.6 to 15.5. The daughters fell far below their mothers in summer clutch size. Actually, this group of daughters had a slightly lower mean clutch size than the daughters of the medium group of dams. The coefficient of correlation was so low that no association was indicated, but regression was linear.

In general, a study of the correlation between mothers and daughters in summer clutch size has indicated very little advantage in selecting for breeding purposes hens that have exhibited very large summer clutch size. The data would only warrant the selection of breeders with a summer clutch size ranging from 3 to 4.5. There is the possibility that hens exhibit a summer clutch size greater than about 4.5 only under most favorable internal and external invironmental conditions.

Correlation in Fall Clutch Size between Mothers and Daughters

Pullets completing their first laying year usually have a slow rate of laying in September and October, but the rate of laying at this time is extremely important from the standpoint of annual egg production, as Knox, Jull, and Quinn (1935) have pointed out. These workers reported the partial correlation between August and September production and annual production as .733 for White Leghorns and .727 for Rhode Island Reds. The fact becomes very evident, therefore, that criteria for selecting female breeders that will transmit high fall intensity to their daughters are very important. The simple correlation between mothers and daughters in fall clutch size should furnish some information.

The variability in fall clutch size was considerably lower in mothers than in their daughters, and the mean fall clutch size of the daughters was low compared with clutch size earlier in the laying year. No significant correlation was observed between mothers and daughters in the total population, although regression was linear. This absence of correlation seems to indicate that fall clutch size is affected by many environmental factors.

Dams with a mean clutch size in the months of September and October below 1.7 have been considered low in intensity. There were 36 such individuals that produced 224 daughters. These low intensity dams produced daughters that were far superior to themselves as far as fall intensity is concerned. As might be anticipated, there was no significant correlation between mothers and daughters, although regression was linear.

The medium group of mothers ranged in clutch size from 1.7 to 3.2. There were 127 mothers in this group. As a whole, the daughters were similar to the mothers in mean fall clutch size, but there was no correlation between mothers and daughters. Regression was found to be linear by Blakeman's test.

The small group of dams with a fall clutch size of 3.3 or greater was considered highly intense. In the population studied there were 55 dams in this class. The mean clutch size of their daughters was slightly greater than was observed for the daughters of medium dams. Although regression was linear, with 144 degrees of freedom, the coefficient of correlation was insignificant.

In general, selection of breeding females on the basis of fall clutch size does not appear to be a satisfactory method, judged by the character of daughters produced. It seems probable, therefore, that careful progeny testing is necessary to solve the intensity problem.

SECTION 2. VALUE OF FOUR TYPES OF INTENSITY RECORDS IN DAMS FOR PREDICTING INTENSITY OF DAUGHTERS

Section 1 of this report was concerned with the correlation between mothers and daughters in clutch size for each of the four seasons of the year. Section 2 gives consideration to the value of clutch size of mothers during each of the four periods in relation to the clutch size of daughters during other seasons of the year. For example, is there a significant association between dams' winter clutch size and daughters' spring, summer, and fall clutch size? All such combinations are shown in Table 2 and discussed in this section.

TABLE 2.—CORRELATION BETWEEN MOTHERS AND DAUGHTERS IN CLUTCH SIZE FOR DIFFERENT PERIODS.

Periods	Number of Dams	Number of Daughters	Coefficient of Correlation	Correlation Ratio
Dams' winter clutch size and				
Daughters' spring clutch	237	2315	+.0931*	
Daughters' summer clutch	237	2032	+.0517*	
Daughters' fall clutch	237	1710	+.0712*	
Dams' spring clutch size and				
Daughters' winter clutch	236	2392	+.1226	.1702
Daugnters' summer clutch	236	2021	+.0922*	.1402
Daughters' fall clutch	236	1700	+.0926*	
Dams' summer clutch size and				
Daughters' winter clutch	234	2376	+.0944*	.1392
Daughters' spring clutch	234	2285	+.0982*	
Daughters' fall clutch	234	1687	+.0745*	
Dams' fall clutch size and				
Daughters' winter clutch	224	2275	+.0726*	.1121
Daughters' spring clutch	224	2193	+.0959*	
Daughters' summer clutch	224	1929	+.0928*	.1314

*Not statistically significant.

Winter Clutch Size of Dams

The same population was examined as in Section 1, but the number of individuals varies somewhat, largely because of mortality during the year. From 237 dams with a winter record, 2315 daughters with spring records were obtained. The data show that mean spring clutch size in daughters was essentially the same as the mean winter clutch size in their mothers. The fact should be noted that the dams are much less variable in winter clutch size than the daughters are in spring clutch size. While regression was linear, there was no significant correlation between mothers and daughters on the basis of 739 degrees of freedom. Summer records were available for 2032 of these daughters, but no correlation was found between daughters' summer clutch size and mothers' winter clutch size, although regression was linear. The number of daughters having a fall record was again reduced over that of the two previous periods. There was no significant correlation between dams' winter clutch and daughters' fall clutch, but regression was linear.

The table indicates an insignificant correlation between mothers' winter clutch size and daughters' spring, summer, and fall clutch size. These data suggest that selection of breeding females on the basis of their winter clutch size is not a rapid method for improving intensity in other periods of the year.

Spring Clutch Size of Dams

Spring clutch records were available on 236 dams. The correlation between the dams' spring clutch and the winter clutch size of 2392 daughters approaches significance, but the regression is not linear. The correlation is so low that it would be of little value from the standpoint of selection. Summer clutch records were obtained for 2021 daughters. Regression of daughters' summer clutch on dams' spring clutch was non-linear, and the correlation was so low that it was insignificant. The data available for 1700 daughters showed no significant correlation between dams' spring clutch size and daughters' fall clutch, although regression was linear.

Selection of breeding females on the basis of their spring clutch size offers an unsatisfactory method of improving intensity, with the possible exception of winter intensity.

Summer Clutch Size of Dams

Summer clutch records are available for 234 mothers. The summer clutch size of these mothers was definitely superior to the winter clutch size exhibited by their 2376 daughters, but variability was greater in the dams. Regression was non-linear and there was little evidence of correlation between mothers and daughters. No significant correlation was observed between mothers' summer intensity and the spring intensity of 2285 daughters, though regression was linear. Regression of daughters' fall clutch size on mothers' summer clutch size was linear, but no significant correlation was found.

Fall Clutch Size of Dams

Intensive laying in the fall at the close of the first laying year has been recognized as very important from the standpoint of egg production. Its value in selective breeding, therefore, requires study.

Regression of daughters' winter clutch size on mothers' fall clutch size was not linear and no significant correlation appeared. There was no significant correlation between dams' fall clutch size and daughters' spring clutch size, although regression was linear. Regression of daughters' summer clutch size on mothers' fall clutch size was not linear, and there was no significant association.

In general, the data in Section 2 do not disclose significant correlations between dams' clutch size in the different seasons of the year and the clutch size of their daughters at other seasons of the year. In other words, the selection of dams for large clutch size at one season of the year gives no assurance that their daughters will exhibit large clutch size at other seasons.

SECTION 3. INTRACLASS CORRELATIONS

In order to secure further evidence on the inheritance phase of intensity as measured by clutch size, intraclass correlations were calculated and are shown in Table 3. The population of daughters was grouped by sires and by dams. Evidence regarding sex linkage will also be brought to light.

TABLE 3.—INTRACLASS CORRELATIONS.

Number of Sires	Sires' Intraclass Correlation	Number of Dams	Character of Dams	Dams' Intraclass Correlation	Simple Correlations Between Mothers and Daughters
			Winter Clutch		
45	.2512	74	Low intensity	.2243	−.0131
62	.1888	109	Medium intensity	.1724	+.0423
43	.0934	54	High intensity	.1315	+.1344
			Spring Clutch		
52	.1183	104	Low intensity	.1339	+.0801
49	.1262	71	Medium intensity	.1364	−.0106
43	.0624	60	High intensity	.0434	+.1106
			Summer Clutch		
53	.1665	83	Low intensity	.1573	+.1233
51	.0726	90	Medium intensity	.1398	−.0421
39	.1441	57	High intensity	.0945	+.0679
			Fall Clutch		
29	.0264*	36	Low intensity	.0298*	−.0832
60	.0827	127	Medium intensity	.0529	+.0048
40	.0848	55	High intensity	.0672*	+.1643

*Not significant according to the value of F.

The common formula $ri = \frac{Mx - M}{Mx + (K-1)M}$ given by Snedecor (1946, p. 245) was made use of. Dams were grouped into low, medium, and high phenotypes as was done in Table 1. Since all daughters were exposed to similar environmental conditions, the intraclass correlations should represent the inheritance phase.

The constants in Table 3 supply no evidence of sex-linked factors operating to regulate clutch size. These constants, with but three exceptions, indicate that heredity operates to regulate clutch size. Clutch size during September and October at the close of the laying year does not exhibit an important hereditary phase. In general, there was a higher intraclass correlation in daughters from low intensity dams.

Compared with the insignificant simple correlations between mothers and daughters, the intraclass correlations stress the importance of selecting breeding females on the basis of family means, which are logically a better measure of breeding ability than are individual records. These data support the ideas set forth by Lerner and Taylor (1943) that there are good opportunities for raising the level of intensity by selective breeding in improved flocks.

SECTION 4. RATE OF LAYING AS A MEASURE OF INTENSITY

Gross and net rates of laying were calculated on mothers and daughters, all calculations being made on the first laying year. Gross rates were calculated as follows: winter rate, number of eggs laid from first egg to March 1, divided by the number of days concerned; spring rate, number of eggs laid in March, April' and May, divided by 92; summer rate, number of eggs laid in June, July, and August, divided by 92; and fall rate, number of eggs laid in September and October, divided by 61. The net rates of laying in each of the seasons was calculated after deducting all pauses of eight or more days. Gross annual rate represents the production during the first 365 days after first egg, divided by 365. The net annual rate was calculated after the deduction of all pauses of eight or more days.

Table 4.—Correlation Between Mothers and Daughters in Rate of Laying and in Production by Periods.

Rate or Period	Number of Dams	Number of Daughters	Coefficient of Correlation	Correlation Ratio
Winter rate				
Gross	222	1705	+.1270	
Net	222	1705	+.1076	
Spring rate				
Gross	222	1705	+.1069	.1839
Net	222	1705	+.1203	
Summer rate				
Gross	222	1695	+.0756*	
Net	222	1695	+.1214	
Fall rate				
Gross	217	1473	+.0443*	.1280
Net	217	1473	+.0411*	.1288
Annual rate				
Gross	222	1705	+.1605	.2060
Net	222	1705	+.1413	
Gross production				
Winter	222	1705	+.1648	.2028
Spring	222	1705	+.1074	.1622
Summer	222	1705	+.0732*	.1303
Fall	222	1705	+.0698*	.1257

*Not significant.

Table 4 presents the simple correlation between mothers and daughters with respect to rate of laying. In cases where regression was non-linear by Blakeman's test, the correlation ratio is given. In all cases where regression was linear there was a small but significant correlation between mothers and daughters. When regression was non-linear, the magnitude of the correlation ratio suggests a significant association in mothers and daughters except for gross summer rate. In gross annual rate and net annual rate there was a higher correlation between mothers and daughters than was observed for any seasonal periods.

When gross egg production was studied by periods, it was found that in all cases the regression of daughters on mothers was non-linear. The association between mothers and daughters was closest during the winter and spring periods. The data do not suggest the possibility of accurate prediction of the character of daughters that may be produced by selected mothers. High production is most difficult to maintain in summer and fall, and there is lower correlation between the production of mothers and daughters in these two periods than was observed in winter or spring.

A comparison of data in Tables 4 and 1 shows that mean clutch size and net rate of laying afford similar measures of intensity. Data in both tables furnish some evidence of inheritance from mothers to daughters. Although the magnitude of the coefficients of correlation is small, the values are significant and further confirm the importance of selective breeding for high intensity.

Correlation Between Mothers and Daughters in Annual Egg Production

Hays (1946) studied this same population with respect to the correlation between mothers and daughters in annual egg production. The work of other investigators was reviewed and the review need not be repeated here. It seems desirable to conclude this study with a brief review of these findings. In the seven-year period mothers produced 1705 daughters with complete annual records. The constants calculated are presented below.

Number of dams	222
Number of daughters	1705
Dams' mean annual egg record	256.73
Standard deviation of dams' annual records	±27.67
Daughters' mean annual egg record	215.97
Standard deviation of daughters' annual records	±42.80
Coefficient of correlation	+.1590
Correlation ratio	.2161

The greater variability of daughters than of mothers is well illustrated by their respective standard deviations. Regression was non-linear by Blakeman's test. Using 753 degrees of freedom, r should equal at least .098 at the 1 percent level. It may be stated, therefore, that there is a significant correlation between mothers and daughters for annual egg production. The value of this constant is small, so that selection of breeding females on gross annual egg records is far from an exact method.

When the mean production of all daughters of each family was tabulated against the records of the respective dams, the correlation coefficient was .3064 and regression was linear. This confirms that the transmitting ability of a dam is measured by the means of her daughters.

In general terms, the gross annual egg record of a hen is a rather poor criterion of her breeding ability for egg production.

SUMMARY

A population of 2407 daughters hatched over a seven-year period from 237 dams has been studied to secure further information on intensity of laying. Attention was given to the value of clutch size in dams during the four seasons for predicting intensity of their daughters in the same and other seasons. Intraclass correlations for both sires and dams were calculated. Gross and net laying rate records were determined for the four seasons, and gross egg production was also used. The following deductions seem justified:

1. The simple correlation coefficient between mothers and daughters is not a satisfactory measure of heredity. This method does, however, disclose a significant association between mothers and daughters for the winter and the spring clutch size.

2. Dams' spring clutch size appears to be more important than her clutch size at other seasons of the year.

3. Intraclass correlations point strongly to the inheritance of clutch size from both sires and dams in all four seasons. This is particularly evident in winter, spring, and summer.

4. There is no evidence of sex-linked genes controlling clutch size.

5. Net rate of laying is closely related to mean clutch size in each of the four seasons.

6. In gross annual rate and gross annual production, mothers and daughters show the same magnitude of correlation.

7. Mothers and daughters show a significant correlation in both winter and spring production but not in summer and fall production.

8. The data on the whole substantiate that the mean performance records of families of daughters is the best measure of breeding ability of females.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 444 DECEMBER 1947

Fertilizer Experiments on an Abnormal Orchard Soil

By J. K. Shaw

This bulletin reports the response of fruit plants to a long continued fertilizer program of nitrogen, phosphorus, potash, and lime. The conditions were unusual; but the results are of value in suggesting right and wrong fertilizer programs in the orchard.

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FERTILIZER EXPERIMENTS ON AN ABNORMAL ORCHARD SOIL

By J. K. Shaw, Research Professor of Pomology

About 1890, shortly after the establishment of the federal system of experiment stations, several "soil test" fields were established in Massachusetts. One of these, called the North Soil Test, is still continued under a soil treatment similar to that begun more than fifty years ago. The purpose of these "soil tests" was to determine the fertilizer requirements of the various soils on which they were established. One soil might lack nitrogen, another phosphorus, another potash, and another lime. Consequently, these elements were supplied alone and in combination and the results measured in terms of various crops grown. The results from the North Soil Test were printed in many reports and bulletins of the Massachusetts Experiment Station and were summarized by Haskell[1] in 1922.

Field Tests

The plots each contain 1/20 acre and are approximately 10½ feet wide and 204 feet long, separated by a 3-foot space. The lower, west, half of each plot has been limed from time to time.

In 1922 each plot was set to apple, peach, grape, and raspberry plants. Each year a furrow was plowed along the edge of each plot and a subsoil plow run through the furrow. The purpose was to cut the tree roots and prevent trespass into the three-foot guard space and possibly into an adjoining plot. As the plots were narrow, the trees could not be maintained for many years.

In 1931 a new planting was made of apple trees only. Own-rooted McIntosh and Wealthy trees were used and great care was taken to make sure that the average size of the trees on each plot was exactly the same. These trees continued until 1938. Various measures of growth were made each year, some of the more significant being reported in this paper. The trees were not kept long enough to come into full fruit production, but some measures of early bearing are reported.

The field was managed on the cultivation–cover crop system using barley, rye, or buckwheat. On some of the plots the cover crop did not grow well and the organic matter in the soil must have been depleted. Unfortunately, no measures of soil organic matter are available.

The fertilizer treatments on the plots from 1922 to 1930 were similar to the previous applications. The amounts per acre were:

PLOT		POUNDS	PLOT		POUNDS
1, 4, 8, 12	no fertilizer		9	superphosphate	320
				muriate of potash	160
2	nitrate of soda	160			
			10	nitrate of soda	160
3	superphosphate	320		superphosphate	320
				muriate of potash	160
5	muriate of potash	160			
			11	gypsum	800
6	nitrate of soda	160			
	superphosphate	320	13	nitrate of soda	160
				superphosphate	320
7	nitrate of soda	160		muriate of potash	160
	muriate of potash	160		dried blood	160

[1]Haskell S. B. A Thirty Year Fertilizer Test. Mass. Exp. Sta. Bull. 212. 1922.

When the plots were replanted in 1930, the treatment of Plots 11 and 13 was changed to the following:

		POUNDS
Plot 11	nitrophoska	160
	superphosphate	160
	muriate of potash	110
Plot 13	tankage	240
	superphosphate	290
	muriate of potash	160

The amounts of nitrogen, phosphorus, and potash in the annual applications were kept very nearly constant over the entire period of fifty years. The only radical change was that from gypsum to a "complete" fertilizer in 1931.

Lime applications on the lower, west, half of the plots were made in 1899, 1904, 1907 and 1916, totaling 4½ tons per acre, and in 1931 at the rate of 2 tons per acre.

TABLE 1.—AVAILABLE SOIL NUTRIENTS, MAY 28, 1936.

Plot No.	Fertilizer Treatment	pH				Phosphorus Pounds per Acre*				Potassium Pounds per Acre*				Calcium Hundredweights per Acre*			
		NL		L		NL		L		NL		L		NL		L	
		S	SS	S	SS	S	SS	S	SS	S	SS	SS	SS	S	SS	S	SS
1	0	4.7	5.1	7.2	6.7	75	75	75	75	<25	<25	<25	<25	<4	<4	30	10
4	0	4.8	5.3	6.9	6.4	50	75	50	75	<25	<25	<25	<25	4	7.5	36	7.5
8	0	4.7	5.2	7.0	6.5	75	75	75	100	<25	25	<25	<25	<4	<4	20	7.5
12	0	5.0	5.3	6.7	6.3	75	100	75	75	<25	<25	25	<25	4	4	25	7.5
2	N	4.9	5.4	6.9	6.8	50	50	50	50	<25	<25	<25	<25	<4	<4	30	10
3	P	4.8	5.4	6.7	6.5	50	75	75	75	<25	<25	<25	<25	<4	<4	30	4
5	K	4.9	5.4	6.7	6.4	50	75	75	75	100	50	100	50	4	4	25	7.5
6	NP	4.9	5.3	7.2	6.7	75	75	75	75	<25	<25	<25	<25	<4	<4	30	7.5
7	NK	4.8	5.3	6.5	6.8	75	75	75	100	100	75	75	75	<4	<4	20	7.5
9	PK	4.8	5.3	7.3	6.1	50	75	75	75	75	50	100	<25	<4	<4	25	7.5
10	NPK	5.1	5.2	7.1	6.5	50	75	100	100	25	<25	50	<25	4	4	30	7.5
11	NPK-Gyp	4.6	5.1	6.9	6.4	50	75	75	75	50	25	50	<25	<4	<4	25	7.5
13	NPK	5.0	5.3	7.3	6.7	75	75	100	75	100	25	100	25	4	4	30	7.5

* These figures are based on Morgan's test and give only estimated relative amounts of available nutrients per acre.

Magnesium was uniformly low on unlimed plots and low to medium on limed plots.

NL = not limed   L = limed
S = surface soil   SS = subsoil

Lime was applied in 1899, 1904, 1907, 1916, 1931; total 6½ tons per acre

Two papers giving the results of this work have been published.[1]

The annual fertilizer applications over a period of 45 years have made small changes in the available nutrients in the soil and subsoil (Table 1). Phosphorus may be slightly higher where applied on the limed plots. Potash is extremely low where none has been added and very low even on the plots that have had annual applications.

Calcium is extremely low on the unlimed ends of the plots. The limed ends show much more calcium and a pH value near neutrality, while the pH of the unlimed area is generally less than 5 for the surface soil and over 5 for the subsoil. Probably the lime used was usually, if not always, a dolomitic limestone. This would account for the fact that the magnesium was uniformly low on the unlimed plots and uniformly low to medium on the limed plots.

Table 2.—Available Nutrients Beneath Good And Poor Trees, 1936.

Fertilizer Treatment	Trunk Diameter m.m.		pH		Phosphorus Pounds per Acre*		Potassium Pounds per Acre*		Magnesium Pounds per Acre*		Calcium Cwts. per Acre*	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
N + L	98	56	6.7	7.0	75	75	<25	<25	LM	LM	30	30
K	91	34	4.8	4.7	75	75	75	75	L	L	4	4
NP + L	96	60	6.8	5.3	75	75	<25	25	VL	VL	15	4
NK	84	30	4.7	4.7	75	75	75	100	L	LM	<4	<4
NPK	81	58	4.8	4.9	75	50	50	50	L	L	<4	<4
0 + L	94	68	6.2	6.6	75	75	50	<25	M	M	20	20

* These figures are based on Morgan's test and give only estimated relative amounts of available nutrients per acre.

The presence of extremely poor trees on some of the plots was frequently observed and there seemed to be no obvious cause of their poor growth. In 1936 six poor trees on as many plots were selected and each paired with a good tree on the same plot. Table 2 shows the trunk diameter of the good and poor trees, the pH, and the exchangeable phosphorus, potassium, magnesium and calcium in the soils which the roots of the trees exploited. It is evident that the soil factors measured show no relationship to the growth of the trees.

The response of the fruit plants to the abnormal fertilizer program on these plots was measured by the trunk diameter and by shoot growth. Because the plots were narrow, trees could not be grown for many years. Two lots were grown for eight years each. The average trunk diameter of the two plantings of apple trees and weights of the peach trees when they were removed are shown in Table 3. The growth of the McIntosh should be the most dependable because there were eight trees of exactly the same diameter planted on each plot. There were only two trees per plot of Wealthy.

There were four scattered check plots that had received no fertilizer whatever since 1889. The differences in growth on these plots are difficult to explain and give warning of the care necessary in ascribing differences of growth on the fertilized plots to the various fertilizers applied. The use of lime on these unfertilized plots seems to have been harmful rather than beneficial.

[1]Shaw, J. K. Some Unusual Results in Fertilizing Fruit Plants. Proc. Amer. Soc. for Hort. Sci. 21:281. 1924.

Shaw, J. K. Further Evidence of a Potash-Lime Deficiency in a Sandy Loam Soil. Proc. Amer Soc. for Hort. Sci. 27:12. 1930.

Growth of the trees was greater in some cases and in others less on the plots that had been variously fertilized than on the unfertilized plots. Among the unlimed plots only those receiving nitrogen and possibly phosphorus showed better growth. On the limed plots the evidence is quite emphatic that potash was the element most beneficial to growth.

The response of the plants as shown by shoot growth is also given in Table 3. The shoot growth of the apple and peach trees (Fig. 1) behaved much the same as trunk diameter. The grape canes were cut back to two buds each year and the resulting new growth measured. On none of the fertilized plots, with or without lime, did cane growth exceed the average of that on the check plots that had never been fertilized or limed. This lack of response to fertilizers may be related to the severe pruning the vines received each year.

The apple trees each year showed more or less severe leaf scorch. Estimates of its severity were made in several years. Plot averages in four different years are shown in Table 4. The highest numbers show the most severe scorch. No conclusion was ever reached as to what mineral deficiency the burn indicated. The

Table 3.—Growth, Shown by Trunk Diameter of Apple Trees, Weight of Peach Trees, and Shoot Growth of Apple, Peach, and Grape.

Plot No.	Fertilizer Treatment	Trunk Diameter, m.m.						Weight Pounds		3-Year Average Shoot Growth Feet							
		McIntosh		Wealthy		Red Astrachan		Peach		McIntosh		Red Astrachan		Peach		Grape	
		NL	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL	L
1	0	99	77	91	55	93	59	14	10	17	14	14	10	95	77	122	73
4	0	97	93	99	78	86	67	15	12	16	18	13	9	123	104	147	75
8	0	93	95	68	72	90	65	8	11	16	21	11	9	79	93	102	41
12	0	80	84	68	97	88	67	7	6	15	17	12	7	75	64	132	80
	Average	92	87	82	76	89	65	11	10	16	18	13	9	93	85	126	67
2	N	108	65	82	59	64	54	14	4	17	10	9	8	104	89	103	37
3	P	109	91	82	72	76	50	10	4	21	16	8	7	98	80	63	24
5	K	84	106	94	94	68	92	23	26	16	16	9	15	115	166	111	110
6	NP	120	95	101	79	76	66	11	7	21	17	11	9	121	96	116	54
7	NK	89	118	88	95	70	97	17	26	17	20	9	15	107	160	81	118
9	PK	69	102	61	90	72	130	10	30	11	17	9	24	100	175	66	108
10	NPK	100	117	85	95	84	115	11	21	17	22	12	19	99	149	82	96
13	NPK	85	119	82	91	110	133	13	36	14	20	18	26	123	141	120	103
11	NPK-Gyp	88	101	58	95	42	45	7	6	15	22	11	7	74	75	80	25

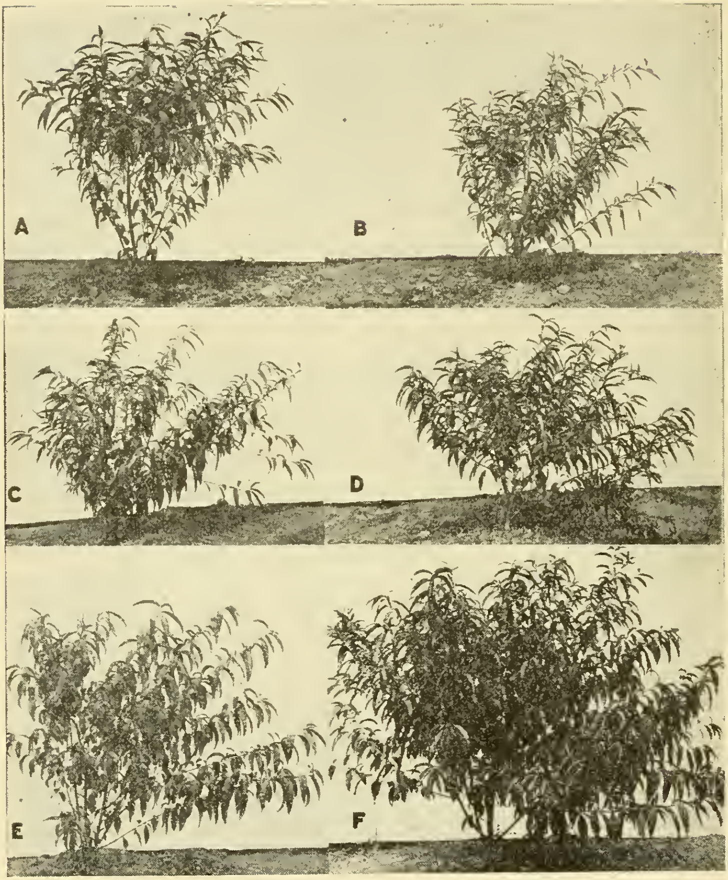

Figure 1. Growth of Peach Trees as Influenced by Soil Treatment. Trees set in 1922; photographed August 3, 1923.

A. Phosphorus only. **B. Phosphorus plus lime.**
C. Nitrogen and phosphorus. **D. Nitrogen and phosphorus plus lime.**
E. Nitrogen, phosphorus, and potash. **F. Nitrogen, phosphorus, and potash plus lime.**

puzzling feature was that the burn seemed to be of the same type on every plot. It was thought to look most like calcium deficiency burn. However, while worse on the unlimed plots, it was severe on some of the limed plots and on the gypsum plot which had large amounts of calcium sulfate for many years. Whereever potassium was applied scorch was more severe on the no-lime plots than on the lime plots. It was worse in some years but the relative rank of the different plots remained fairly consistent. There is a close but not perfect relation between the amount of leaf scorch and trunk diameter. The scorch appeared in July and on some trees destroyed 80 or 90 percent of the leaf surface.

In September, 1937, composite samples of leaves from each plot were collected and analyzed for ash, phosphoric acid, potash, calcium, and magnesium. The results are shown in Table 5. It seems rather remarkable that there were few, if any, cases of severe deficiencies on the unfertilized plots. Phosphorus was not

TABLE 4.—LEAF SCORCH, McINTOSH.

Plot	Fertilizer Treatment	Total percentages of leaf scorch found on the eight trees in each plot							
		July 27, 1933		Aug. 20, 1934		Sept. 16, 1936		July 7, 1937	
		NL	L	NL	L	NL	L	NL	L
1	0	0	12	1	56	7	76	7	45
4	0	8	0	42	3	6	1	10	10
8	0	78	10	146	8	43	11	19	18
12	0	36	31	60	42	42	7	18	13
2	N	6	35	2	121	20	305	10	110
3	P	0	6	3	26	0	60	6	18
5	K	80	2	170	10	186	5	23	10
6	NP	0	17	27	47	5	23	0	12
7	NK	120	0	260	13	231	7	25	4
9	PK	348	22	410	34	387	32	64	9
10	NPK	110	1	180	22	185	6	5	4
11	NPK-Gyp	72	0	175	6	93	2	6	5
13	NPK	77	0	185	9	57	0	6	3

TABLE 5.—ASH ANALYSIS OF APPLE LEAVES, SEPTEMBER 18, 1937.

Plot No.	Fertilizer Treatment	Percent of Dry Matter									
		Ash		Phosphoric Acid		Potassium		Calcium		Magnesium	
		NL	L	NL	L	NL	L	NL	L	NL	L
1	0	7.4	7.0	.66	.73	1.20	0.84	1.67	1.65	.34	.36
4	0	8.2	8.4	.42	.74	2.50	1.86	1.15	.53	.22	.22
8	0	8.0	9.0	.48	.87	2.26	2.01	1.19	1.67	.13	.21
12	0	8.1	8.6	.47	.57	2.22	1.62	1.02	1.63	.17	.22
	Average	7.9	8.25	.51	.73	2.03	1.58	1.26	1.62	.22	.25
2	N	6.6	6.5	.39	.63	0.78	0.58	1.65	1.70	.36	.29
3	P	7.6	8.1	.66	.95	1.81	1.43	1.22	1.71	.24	.26
5	K	8.4	9.0	.71	.53	2.34	2.26	1.16	1.53	.19	.21
6	NP	8.2	8.6	.43	.70	1.97	1.51	1.24	1.79	.23	.28
7	NK	8.2	8.9	.35	.56	2.23	2.21	1.12	1.51	.20	.17
9	PK	9.4	9.6	.68	.86	2.56	2.55	1.29	1.50	.17	.16
10	NPK	8.4	8.8	.43	.60	2.41	2.01	1.17	1.51	.19	.22
11	NPK-Gyp	8.2	9.2	.38	.76	2.40	2.12	1.09	1.70	.20	.17
13	NPK	8.8	8.7	.70	.49	2.60	2.16	1.13	1.41	.17	.22

dangerously low on any plot and potash on only one or two plots. Calcium was rather low on the unlimed plots and not very high on the limed plots. Magnesium was low on some plots and abundant on some. It is interesting to note that the extremes — 0.13 and 0.36 percent—appeared in the check plots.

Phosphorus was higher on the limed ends of all but two plots, the K plot and one of the NPK plots. Differences between the limed and unlimed ends were usually quite great. Potash was lower in trees on the limed ends of all plots; but only the nitrogen plot, both with and without lime, showed real deficiency.

Calcium and magnesium were about the same on the fertilized as on the check plots. It is difficult to say what is the critical percentage of calcium. For magnesium, 0.20 percent has come to be regarded as a possible marginal percentage, although trees with less may show no definite symptoms of magnesium deficiency and it sometimes shows on trees with a little higher amounts. Three limed plots and five unlimed plots were below the 0.20 percent limit.

Pot Tests

During the period from 1928 to 1932 studies of the effect of various treatments of the soils from these plots were made by means of pot tests.

The pots used were in part Wagner pots holding 17 kilos of soil and in part earthern jars holding 12 kilos of soil. All tests were made in replication of five jars with the same treatment; a total of usually 120 pots was used each year. Soil was brought from certain plots and weighed, sometimes for each pot and sometimes enough for a five pot lot. One lot of five did not receive any treatment and other lots of five were variously treated as shown in the tables.

Seedling peach trees were used as indicators. Sometimes they were self-pollinated Belle of Georgia seedlings and sometimes a miscellaneous lot of seedlings. They were started in flats filled with sand or sawdust. When the plants were 4–8 inches tall they were carefully graded as to size and origin and set, one plant in each pot, in late May or early June. They were watered carefully through a tube reaching to the bottom of the pot and the soil was not allowed to become excessively wet or dry. Care was necessary because the pots had no drainage. The pots were placed on cars holding 20 pots each, on tracks so that they could be rolled into a glass house when rain threatened and outside in clear weather.

The little trees were allowed to grow until leaf fall when they were removed from the pots, together with as many as possible of the roots, placed in a dry place to become thoroughly air dry, and then weighed.

TABLE 6.—POT CULTURES, 1928

Soil Treatment Field	Soil Treatment Pot*	pH	Soil Nitrates p.p.m.	Average Weight of Plants grams	Roots Percent
NL	0	5.9	126	21.4	56
NL	7K	6.3	19	26.9	55
PL	0	6.4	35	21.7	52
PL	7K	6.4	19	22.4	57
PKL	0	6.4	112	36.6	47
PKL	7N	6.3	318	30.8	41
0 L	0	6.3	79	30.1	50
0 L	7K 7P	6.2	72	26.3	43
P	0	5.0	82	19.4	54
P	7K 34L	5.8	49	23.6	48
K	0	4.6	54	5.7	47
K	34L	5.6	109	26.7	46
K	7P 34L	5.7	165	28.5	46
PK	0	4.9	147	20.8	50
PK	17L	5.3	134	20.8	49
PK	34L	5.8	150	32.6	50
PK	68L	6.3	332	29.8	59
Gyp	0	4.9	88	17.8	64
Gyp	34L	5.8	100	18.8	64
0	0	4.5	54	11.7	67
0	7K 17L	5.2	62	26.6	65
0	7K 34L	5.9	69	34.7	60
0	7K 68L	6.3	130	23.3	42

TABLE 7.—POT CULTURES, 1929.

Soil Treatment Field	Soil Treatment Pot*	Average Weight of Plants grams	Roots percent	pH
P	0	6.0	67	4.6
P	7K	3.3	61	
P	7K 34L	12.7	67	
P	4N	7.5	63	
PL	0	13.1	61	6.0
PL	7K	9.4	68	
PL	4N 7K	11.5	65	
PL	6 Tankage 7K	14.0	68	
K	0	4.0	63	4.5
K	4N	4.1	66	
K	4N 34L	8.1	68	
K	1N 4.4 Tankage	4.5	67	
0	0	5.9	71	4.4
0	7K 17Ca	8.9	72	
0	7K 34Ca	11.5	64	
0	7K 68Ca	19.5	71	
PK	0	7.5	67	4.4
PK	3N	6.3	65	
PK	6N	8.8	66	
PK	4N 34L	24.5	64	
Gyp L	0	10.5	73	5.9
Gyp L	7K	9 6	72	
Gyp L	4N	12.6	68	
Gyp L	4N 7K	9.3	67	

* Five pots received each treatment. The letters and figures in this column have the following meaning:

0 No treatment
N Nitrate of soda
P Precipitated bone
K Potassium chloride
L Magnesium limestone
Ca Calcium carbonate
The figures indicate grams per 17 kilos of soil.

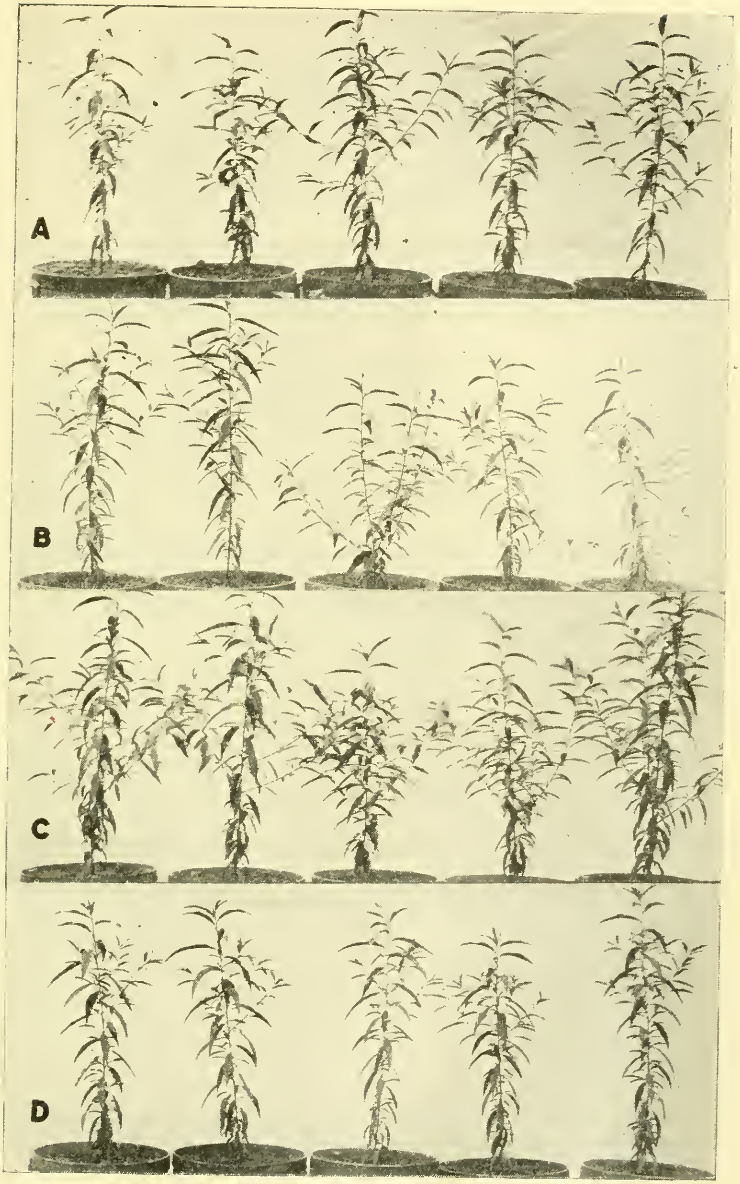

Figure 2. Peach Trees Grown in 1928 on Soil from the Unlimed Phosphorus-Potash Plot.
A. No treatment.
B. 17 grams Magnesium Limestone.
C. 34 grams Magnesium Limestone.
D. 68 grams Magnesium Limestone

In some years soil nitrates and pH values were determined one or more times during the seasons.

The results obtained in 1928 are shown in Table 6 and Figure 2. There is little evidence that any of the treatments of the limed soils increased tree growth except where K was added to the soil from the N + L plot. This plot was known to be very low in K and the increase here may have been caused by the added potassium. The addition of lime to the soil from the unlimed plots always increased growth and it is suggested that the optimum rate is about two tons per acre (34 grams per pot). In one case the weight of the check plants was only 5.7 grams, but if this is abnormally low it may still be inferred that lime increased the growth of the plants.

In 1929 the tests were planned to see whether additional nitrogen and potash with and without lime would favor increased growth of the plants. As in the previous year, lime seemed to favor growth, but the addition of nitrogen resulted in only slight or insignificant gains in growth while muriate of potash rather distinctly injured growth. In two cases tankage seems to have caused slightly better growth. (Table 7.)

The striking and consistent result of the 1929 pot trials is that lime is the only material that clearly promoted the growth of the peach seedlings growing in soils from the field plots chosen. The lime used in the soil from the unfertilized plot was a magnesium-free calcium carbonate. That used in the soil from the P, K, and PK plots was a dolomitic lime. In all the four cases where 34 grams of lime was added, growth was just about doubled. In other words, the pure $CaCO_3$ was as effective as the lime containing magnesium.

A deficiency of magnesium in the soil of a neighboring plot had been discovered before 1930. The pot tests in that year were planned to indicate whether a magnesium deficiency might exist in the orchard plots. Soil from plot 4 (unfertilized) was treated with pure calcium carbonate, 34 grams per pot, with and without N, P, and K. The weight of the trees from the untreated pots was low, but it seems clear that the calcium carbonate favored growth and that the N, P, K fertilization may have done so. (Table 8.)

Soil from plot 8, also an unfertilized plot, was treated with potash and calcium carbonate, with and without magnesium sulfate, also with potash and basic magnesium carbonate. The magnesium carbonate ruined the growth of the trees and the magnesium sulfate added to calcium carbonate seemed of doubtful value.

Soil from the unlimed PK plot treated with calcium carbonate gave the usual response to lime and here again the addition of magnesium sulfate gave no increase. (Figure 3.) The addition of potash did not materially increase growth. Soil from this same plot was not benefited by increasing amounts of nitrate of soda. (Figure 4.)

Soil from the unlimed NP plot was treated with 25 grams of powdered charcoal. The trees grew no better; when potash was added, growth seemed to have been injured, but calcium carbonate increased growth.

With soil from a limed no-fertilizer plot the addition of a complete fertilizer made a slight increase of growth but K and NK injured growth.

The pot tests of 1930 gave further indications that lime was the first need of this soil, either to correct acidity or to supply calcium, and that the addition of magnesium was of no benefit.

The tests in 1931 were directed mainly toward learning the effects of organic forms of nitrogen and of acidifying the soil with sulfur and with aluminum sulfate. Again the addition of magnesium limestone improved growth, but acidifying soil from the limed plots with sulfur was disastrous especially with the larger amounts.

Aluminum sulfate lowered the pH much less and the growth of the plants was not affected. In fact, when applied to soil from the limed complete fertilizer plots it appears to have increased growth. (Table 9.)

The addition of organic ammoniates increased soil nitrates and growth (Figure 5) and for some reason aluminum sulfate greatly increased soil nitrates.

The effect of sulfur was further studied in 1932 (Table 10 and Figure 6) with even more disastrous results, perhaps because soil from the unlimed plots was used. With the heavier applications of sulfur the plants were soon killed. Organic ammoniates applied to limed but unfertilized soils increased growth.

Soil from an orchard (Block A) where the apple trees were making a satisfactory growth, but on an equally acid soil, was used in one test. Acidifying the soil with sulfur was even more injurious to the plants.

No tests were made in 1933, but in 1934 further studies of the effect of other organic materials, including manure and peat, were made. All these organics contained approximately equivalent amounts of nitrogen per pot, except the manure which probably carried only about two thirds as much. Sulfur in lesser amounts than in previous years was also used. Again, the organic ammoniates increased growth even with 8 grams of sulfur, but inorganic ammoniates, except possibly nitrate of soda, were of doubtful effect. Peat seemed ineffective in all the combinations used. (Table 11.)

Table 8.—Pot Cultures, 1930.

Soil Treatment: Field		Soil Treatment: Pot*	Average Weight of Plants grams
0	(4)	0	4.1
0	(4)	12N 20P 5K	11.2
0	(4)	12N 20P 5K 34Ca	16.2
0	(4)	34Ca	13.7
0L	(4)	0	10.0
0L	(4)	12N 20P 5K	12.3
0L	(4)	7K	7.8
0L	(4)	10N 7K	8.4
NP		0	13.8
NP		25 Charcoal	13.0
NP		25 Charcoal 7K	8.0
NP		25 Charcoal 7K 34Ca	18.0
0	(8)	0	7.1
0	(8)	7K 34Ca	12.4
0	(8)	7K 34Ca 5Mg	13.7
0	(8)	7K 20Mg carbonate	1.7
PK		0	11.0
PK		34Ca	20.5
PK		34Ca 5Mg	20.5
PK		7K 34Ca 5Mg	21.1
PK		0	7.4
PK		5N	7.6
PK		10N	4.3
PK		15N	6.5

Table 9.—Pot Cultures, 1931.

Soil Treatment: Field	Soil Treatment: Pot*	pH	Nitrates p.p.m.	Average Weight of Plants grams
PK	0	4.4	57	14.1
PK	7 Blood	4.2	120	18.4
PK	2.5 Calurea	4.2	199	15.9
PK	2 Urea	4.1	115	13.8
PK	0	4.4	15	8.7
PK	4 Am	4.1	30	7.1
PK	10 Fish	4.3	23	22.0
PK	12 C.S. Meal	4.4	57	20.9
0	0	4.1	5	6.8
0	34L	5.7	78	11.5
0	5N 10P 7K 34L	5.9	110	14.7
PKL	0	5.6	11	20.5
PKL	10S	4.5	Trace	15.1
PKL	20S	3.8	Trace	1.4
PKL	40S	3.4	0	0.1
PKL	0	5.4	9	15.4
PKL	20Al	5.2	9.5	15.1
PKL	10Al 10S	4.2	Trace	3.5
PKL	10Al 20S	3.7	Trace	0.1
NPKL	0	5.6	20	12.3
NPKL	4Al	5.2	180	19.9
NPKL	8Al	4.8	159	21.0
NPKL	12Al	4.7	417	22.7

* Five pots received each treatment. The letters and figures in this column have the following meaning:

0	No treatment	Ca	Calcium carbonate
N	Nitrate of soda	S	Ground sulfur
P	Superphosphate	Am	Ammonium sulfate
K	Potassium chloride	Mg	Magnesium sulfate
L	Magnesium limestone	Al	Aluminum sulfate

The figures indicate grams per 17 kilos of soil.

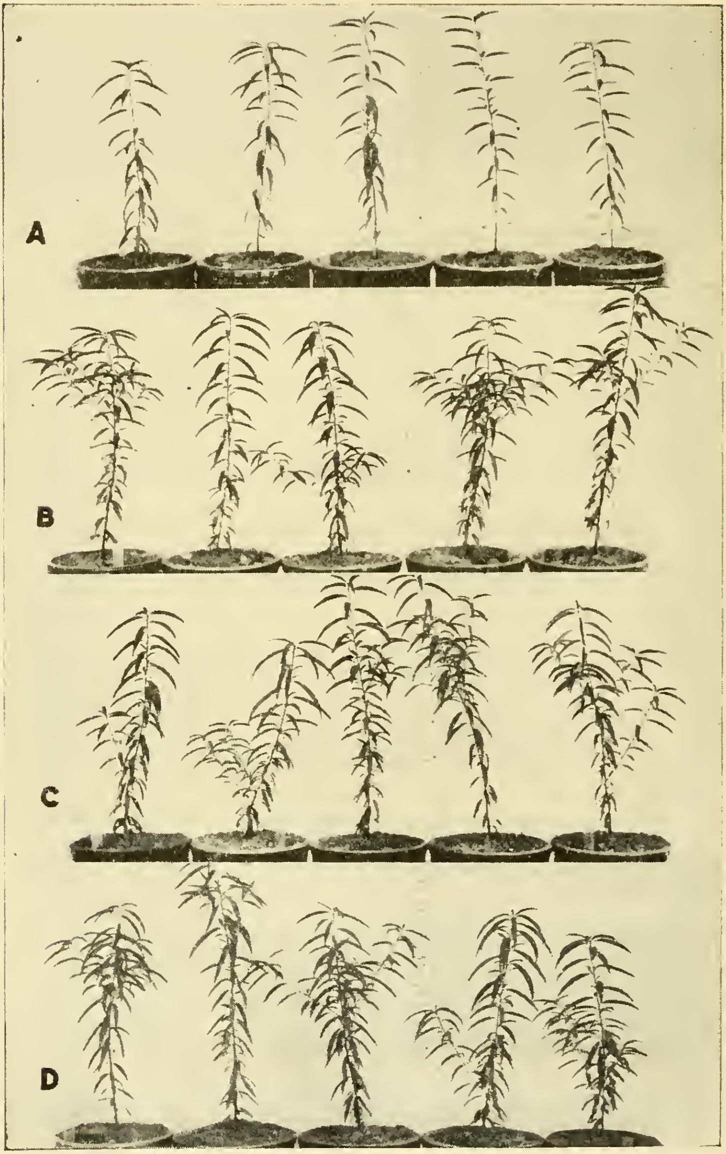

Figure 3. Peach Trees Grown in 1930 on Soil from the Unlimed Phosphorus-Potash Plot.
A. No treatment.
B. 34 grams Calcium Carbonate.
C. 34 grams Calcium Carbona'e, 5 grams Magnesium Sulfate
D. 34 grams Calcium Carbonate.
5 grams Magnesium Sulfate
7 grams Muriate of Potash

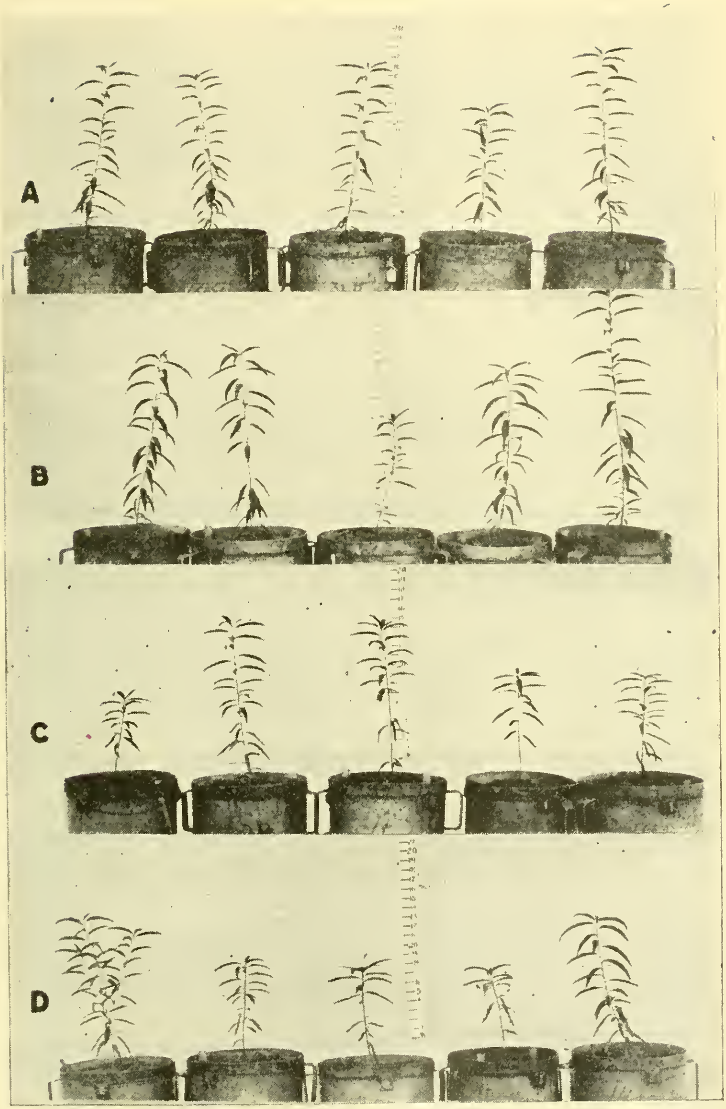

Figure 4. Peach Trees Grown in 1930 on Soil from the Unlimed Phosphorus-Potash Plot
A. No treatment
B. 5 grams Nitrate of Soda
C. 10 grams Nitrate of Soda
D. 15 grams Nitrate of Soda

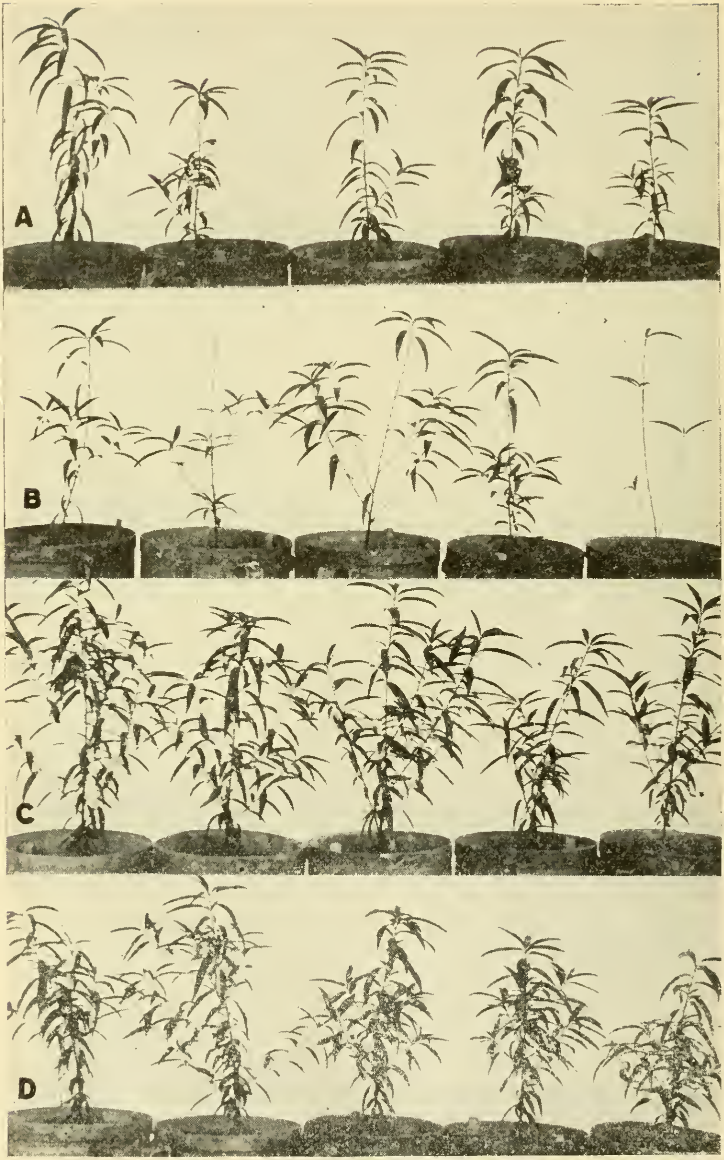

Figure 5. Peach Trees Grown in 1931 on Soil from the Unlimed Phosphorus-Potash Plot.
A. No treatment
B. 4 grams Ammonium Sulfate
C. 10 grams Ground Fish
D. 12 grams Cottonseed Meal

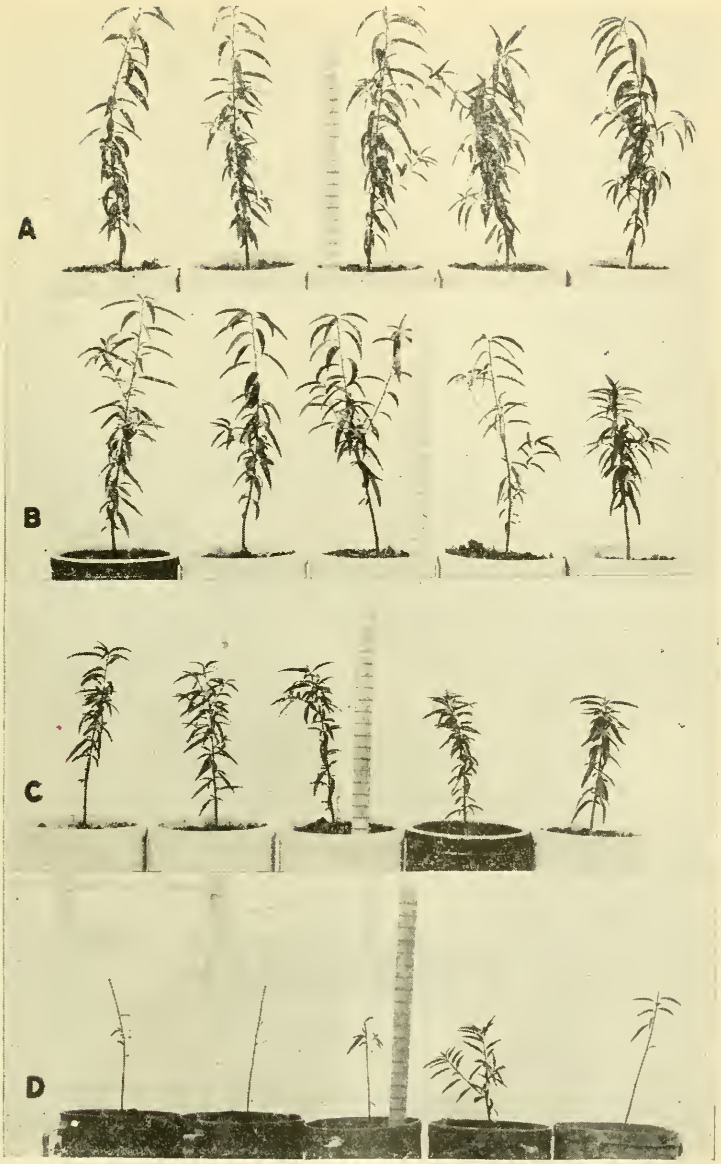

Figure 6. Peach Trees Grown in 1932 on Soil from the Unlimed Phosphorus-Potash Plot.
A. No treatment
B. 5 grams Sulfur
C. 11 grams Sulfur
D. 17 grams Sulfur

TABLE 10.—POT CULTURES, 1932.

Soil Treatment: Field	Soil Treatment: Pot*	pH	Average Weight of Plants grams
PK	0	5.8	20.5
PK	5S	5.0	17.1
PK	8S	4.7	13.0
PK	11S	4.3	9.4
PK	0	5.3	27.3
PK	14S	4.1	6.3
PK	17S	3.8	2.9
PK	20S	3.7	Dead
Block A	0	4.2	27.2
Block A	10S	3.8	1.3
Block A	20S	3.6	Dead
Block A	40S	3.2	Dead
0L	0	5.3	26.1
0L	10 Tankage	5.4	38.4
0L	10 Fish	5.4	37.8
0L	10 C.S. Meal	5.7	35.9
0L	0	5.7	25.8
0L	5N	5.6	33.3
0L	4Am	5.0	24.6
0L	4Am 34L	6.4	29.9
0L	0	5.9	19.7
0L	34L	6.9	22.3
0L	4Am	5.7	Lost
0L	4Am 34L	6.6	Lost

TABLE 11.—POT CULTURES, 1934.

Soil Treatment: Field	Soil Treatment: Pot*	pH	Average Weight of Plants grams
0L	0	5.9	23.2
0L	100 Manure	6.4	29.8
0L	100 Manure 8S	5.8	29.4
0L	100 Manure 20S	5.1	26.0
0L	0	6.5	25.2
0L	8S	6.2	23.2
0L	5N 8S	6.0	31.4
0L	7 Blood 8S	5.9	31.5
0L	0	5.6	24.5
0L	20S	5.0	18.7
0L	5N 20S	5.0	18.7
0L	7 Blood 20S	4.9	20.0
0L	0	6.9	24.6
0L	8S	5.9	24.6
0L	50 Peat 8S	5.7	21.3
0L	5N 50 Peat 8S	5.7	23.8
0L	0	6.1	30.9
0L	20S	4.9	27.6
0L	50 Peat 20S	4.9	26.1
0L	5N 50 Peat 20S	5.2	26.3
0L	0	6.6	26.1
0L	50 Peat 8S	6.6	24.5
0L	4.5Am 8S	5.5	26.0
0L	50 Peat 4.5 Am 8S	5.5	26.9

* Five pots received each treatment. The letters and figures in this column have the following meaning:
0 No treatment
N Nitrate of soda
L Magnesium limestone
S Ground sulfur
Am Ammonium sulfate
The figures indicate grams per 17 kilos of soil

Concluding Remarks

The abnormal conditions brought about in the soil by the long continued unusual fertilizer treatments have caused peculiar responses by the trees. There is no doubt that under normal conditions nitrogen is most likely to produce favorable results. In this experiment, nitrate of soda alone was injurious rather than beneficial to the trees. The growth of the trees on plots that were never fertilized was surprisingly good but not equal to that of a successful orchard. While cover crops of rye, buckwheat, or barley were grown each year, growth, especially on plots with no lime and phosphorus, was poor and added little organic matter to the soil.

Lime was almost always effective in improving growth of the trees and sulfur was very injurious. Whenever the pH was depressed below 4.0 the trees grew but little. This was closely correlated with soil nitrates. The addition of organic nitrogen to very acid soil increased soil nitrates and improved growth but inorganic sources of nitrogen were not very effective.

The behavior of grapes was not like that of apples and peaches. Lime was generally injurious and grapes grew about as well on the check plots as on the fertilized plots. Only in the presence of potassium was growth better on the limed plots.

Except for the suggestion that a long-continued program of nitrogen alone is not a good one, this experiment offers little in planning a practical fertilizer treatment. It must be remembered that the conditions of this experiment are most unusual.

MASSACHUSETTS AGRICULTURAL
EXPERIMENT STATION

Bulletin No. 445

Cranberry Insects In Massachusetts

By

HENRY J. FRANKLIN

January 1948

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 445 JANUARY 1948

Cranberry Insects in Massachusetts

By HENRY J. FRANKLIN

Insects take an annual toll of fully one-fifth of the cranberry crop in Massachusetts. Information essential for their control is herewith provided.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

CONTENTS

PUBLICATION OF THIS DOCUMENT APPROVED BY THE STATE PURCHASING AGENT
6m-6-48-24036

MATTERS OF GENERAL IMPORTANCE IN BOG MANAGEMENT

A PLENTIFUL WATER SUPPLY for flooding whenever necessary is a good and cheap insurance against insect injury on cranberry bogs, and should be provided if the cost is not prohibitive. Where a water supply is lacking or its use is for any reason impracticable, dusting, spraying, sanding, or other measures must be adopted.

Special attention should be given the various pests in those years when the crop prospect is poor. If they are properly reduced then, they often may be neglected safely when the crop promises to be heavy. Such treatments as flooding, sanding, ground-machine dusting, and spraying are likely to injure the vines more or less and so reduce the crop. The amount of this reduction usually is proportional to the crop promise. Limited water supplies for reflooding often should be saved for protection from frosts, and other methods of control used against pests.

Bog managers should learn to gauge insect infestations in their early stages so as to know when attacks may be neglected. The insect net is as important as any other bog equipment. The bogs should be examined with it every few days from May 10 till mid-July. For practical purposes the sweeping with the net may be done at any time of day, though it usually collects rather more cutworms and gypsy moth larvae as soon as the dew is off in the morning and just as it begins to form in the evening. If fifty sweeps of a net eleven inches in diameter gather from the vines over eight gypsy moth caterpillars or cutworms of any kind, or more than thirty-two spanworms, the infestation should be treated, four spanworms equaling one cutworm in their capacity to do harm. As the worms of many of the species grow larger they cling more and more to the vines or hide under them and so are gathered by the net in smaller and smaller numbers.

The worms that float ashore during flooding treatments seldom give any trouble. Usually most of them thrash themselves to death in the water or die from exhaustion or infection if they crawl ashore.

Bogs should never be burned off to control insects unless the vines are so deep and snarled that their renewal is desired. Even then it is often better to mow them.

Cranberry insect problems present so many conditions that it is hard to cover them all fully in bulletins. Chances to check two or more pests with one treatment should always be looked for. Those that occur commonly are indicated in the discussion of the various insects. The insect control chart issued yearly by the extension services of Plymouth and Barnstable counties is helpful here.

CRANBERRY INSECTS IN MASSACHUSETTS

(Revision of Bulletin 239, 1928)

By Henry J. Franklin

Research Professor in Charge of the Cranberry Station at East Wareham

Two general bulletins on cranberry insects have been published by the United States Department of Agriculture.[1] Both were based on work done mainly in New Jersey. Cranberry insect problems in Massachusetts vary widely from those in New Jersey, for several of our important pests are nearly or quite unknown in that State and a difference in methods of culture and in climate affects the situation a good deal.

The possible value of a paper of this kind may be judged if it is recalled that there are about fifteen thousand acres under cranberry cultivation in Massachusetts,[2] that this fruit is the leading export crop of the State with a gross annual value of from four to sixteen million dollars,[3] and that insects destroy fully a fifth of the crop yearly.

Every effort has been made to arrange this paper so clearly and simply that cranberry growers may find it not only informing but thoroughly usable. It is amply illustrated, and the color plates and tables for the identification of the various species should be particularly helpful. It is divided into seven parts, as follows:

Part I.—*Worms or wormlike forms attacking the foliage, buds, flowers, or fruit.*

Part II.—*Forms not wormlike attacking the foliage or fruit.*

Part III.—*Insects attacking the stem.*

Part IV.—*Insects attacking the roots.*

These four parts describe the various pests, their life histories, and the injuries they do, and give the controls found most effective.

Part V.—*Insects and other animals beneficial to cranberry growing.*

Cranberry flower pollination is treated here, and the predatory enemies and insect parasites of cranberry pests are discussed.

Part VI.—*Insecticides and paraphernalia used in fighting cranberry pests.*

Spraying and dusting apparatus, the insect net, and insecticides are discussed here.

Part VII.—*Relation of uplands to bog insect conditions.*

Both harmful and beneficial insects are considered here.

This bulletin presents only Part I.

Acknowledgments: The writer acknowledges his many obligations to all who have helped him in the studies, the results of which are assembled here; especially to the cranberry growers, who everywhere have given him the freedom of their bog properties and every encouragement. Thanks are due the Cape Cod Cranberry Growers' Association for the kodachromes from which the colored plates for this bulletin were made, and for other services rendered.

[1] U. S. Dept. Agr. Farmers' Bul. 178, by J. B. Smith (1903); and U. S. Dept. Agr. Farmers' Bul. 860, by H. B. Scammell (1917).

[2] Mainly in Plymouth, Barnstable, and Bristol counties, but also in five others.

[3] This is greater in some years than the value of the commercial apple crop of all New England.

PART I—Worms or Wormlike Forms Attacking the Foliage, Buds, Flowers, or Fruit

This section includes a majority of the cranberry pests. The worms may be classified by the following table:

With much hair covering most of the body............hairy worms (p. 45).
Without much hair............1

1. Legless or green and much flattened or working only inside the berries............miscellaneous pests (p. 51).
With legs, not flattened, and not confined to working in the fruit............2

2. With habit of sewing the leaves together with silk............fireworms (p. 5).
Not sewing the leaves together............3

3. The hind half of the body with only four legs............spanworms (p. 36).
The hind half of the body with more than four legs............4

4. With a prominent sharp horn on the back near the hind end............apple sphinx[4].
With no such horn............5

5. Green, without stripes along the sides............cranberry sawfly (p. 63).
Not green, or if green, with noticeable side stripes............cutworms (p. 21).

FIREWORMS

These are relatively small worms and they wriggle vigorously when disturbed, moving forward or backward with equal celerity. They sew together with silk the leaves among which they feed and so form nests to protect themselves from parasites and other foes. They usually begin this webbing soon after they hatch, by sewing together three or four leaves at the tip of a single upright as shown in fig. 8. The later webbing varies somewhat but usually draws several uprights together finally. The worms often injure the foliage so that it turns brown and looks as though a fire had burned the vines—hence the name *fireworm*.

Five kinds of fireworms do material harm on Cape Cod bogs. They are discussed below in the order of their importance. They may be distinguished as follows:

Head black............1
Head not black............2

1. Body striped............hill fireworm (p. 17).
Body not striped............black-headed fireworm (p. 6).

2 Body with conspicuous white spots along the back and sides............spotted fireworm (p. 19).
Body without such spots............3

3. Body with dull reddish lines along the back and sides............red-striped fireworm (p. 12).
Body pale yellowish, without reddish lines............yellow-headed fireworm (p. 11).

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[4] *Sphinx gordius* Cram. These caterpillars grow to be about two and a quarter inches long. As they mature they are smooth and green, but sometimes strongly shaded with pink or purple, with seven parallel stripes slanting downward forward on each side, each composed of a red line bordered above with rather deep brown and below with white. They are ornamented also with many minute brown circles. They mature in August and September, and cranberry pickers often find them in their scoops. They almost never do much harm and may be controlled readily with the derris spray advocated for the cranberry fruitworm (p. 56). The gray moths expand three inches or more and are not uncommon on the bogs in late May and June. See Mass. Agr. Expt. Sta. Bul. 327:32, 1936.

Black-Headed Fireworm [5]

If we consider all the cranberry growing sections of the country, this is the most harmful cranberry insect; and in Massachusetts only the fruitworm and the root grub *(Amphicoma)* do more damage. Means of control, however, have now developed so that much injury by it suggests poor management.

On Cape Cod, this insect rarely harms seriously a bog that has not been flooded during the winter, and its infestations cling more tenaciously to large compact bogs than to small areas. The water kills or drives ashore its enemies, such as spiders and parasites, and protects its eggs from winter adversities. The foes of the pest are, of course, slower in again reaching the center of a large compact bog in effective numbers than they are in reaching that of a small one. So an infestation developing on a large bog always gets serious on the middle part first.

Distribution and Food Plants

This fireworm is very destructive in Nova Scotia, Massachusetts, New Jersey, and Wisconsin and on Long Island and the coast of Oregon and Washington.[6] It has been found in Maine and California. It is not known to feed on anything but cranberry.[7] It generally attacks Howes and Smalley Howes vines more than Early Black.

Character of Injury

The newly hatched worm of the first brood usually begins by burrowing into the under side of an old leaf, the new growth of the season not yet having put out, and works as a leaf miner, casting out on the lower surface a small mass of refuse (fig. 1). An area on the upper side immediately over these castings is lighter colored than the rest of the leaf, and the first hatching of the insect often may be detected most easily by these light patches.

If the hatching begins early, the young worms, on leaving their mines in the old leaves, mine the terminal buds just as they are swelling to start new growth, and sometimes ruin most of them before being discovered.

As new shoots appear, the worms proceed to sew three or four of their tip leaves together. If the worms hatch after the new growth develops, they usually go directly to the new tips without mining the old leaves. The webbed tips generally are the first work noticed by growers (fig. 2).

The worm usually leaves the tip it has sewed up within a few days and either webs leaves farther down on the shoot or goes to another upright the new growth of which it sews up, commonly webbing in one or more other uprights. If the worms are very abundant, two or three often work together and include several uprights in their nest (fig. 3). They feed freely on the new leaves and flower buds in their nests, often destroying the whole crop prospect and turning the bog brown.

During the interval between the two broods, the vines put forth more new growth and recover considerably from their injury.

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[5] *Rhopobota vacciniana* (Pack.). The writer is not convinced that this species is the same as the European holly feeder, *R. naevana* (Hubner), and hesitates to follow Heinrich (U. S. Dept. Agr. Bul. 1032, p. 45, 1922) and McDunnough (Memoirs, So. Calif. Acad. Sci. Vol. 2, p. 50, 1939) in this.

[6] Only on the Pacific coast does this fireworm thrive generally on bogs not flooded during winter. It probably was not present there till it was introduced from the East (U. S. Dept. Agr. Bul. 1032, p. 4, 1922). See also copy of letter of Charles D. McFarlin to E. R. Peterson, 9/22/1906, in Middleboro library.

[7] *Vaccinium macrocarpon* Ait. and *V. Oxycoccus* L.

The work of the second brood varies more than that of the first. It may be more severe or less severe, depending on how much the hatching is suppressed and how freely the worms die of disease. If the hatching begins while the vines are in flower, the small worms may work mostly in the blossoms, especially in the ovaries which they excavate to form tiny cups, and web the foliage only in their later stages. Usually they go to the tips when they hatch and sew the leaves together, but this tip-webbing is more gradual than that of the first brood. They usually web together several uprights at last and may make nests even larger than those of the first brood. Whether they web much or not, they reduce the crop in proportion to the amount of infestation by scoring the berries or working in them somewhat as the fruit worm does. Sometimes they work almost exclusively in the berries. This brood may greatly reduce the crop possibilities for the next year, for the tips of the injured uprights usually fail to form normal fruit buds. Many of the chewed leaves soon drop and the vines recover somewhat in the fall, mainly by putting out some tip growth, but the uprights are often rather bare.

Description and Seasonal History

THE EGG

This pest winters as a partly developed worm embryo in the egg, some of the eggs having been laid by second-brood moths and some by first-brood moths, the hatching of the latter having been suppressed. The eggs (figs. 4 and 5) are very flat, disklike, light yellow, and about a thirty-second of an inch in longest diameter. They are laid singly, nearly always on the backs of the leaves of the new growth. Often several are placed on one leaf. The leaves of delicate uprights deep among the vines generally have more than their share.

Most of the eggs on the leaves in late fall often vanish while under the winter flood, and they evidently perish when they disappear in this way, for the infestation always is reduced the next spring when this happens. Usually, however, most of the eggs stick to the leaves until spring and hatch. If an infested bog is left unflooded for the winter and the vines are winterkilled, the dead leaves drop in the spring and the fireworm eggs on them usually dry up and fail to hatch.

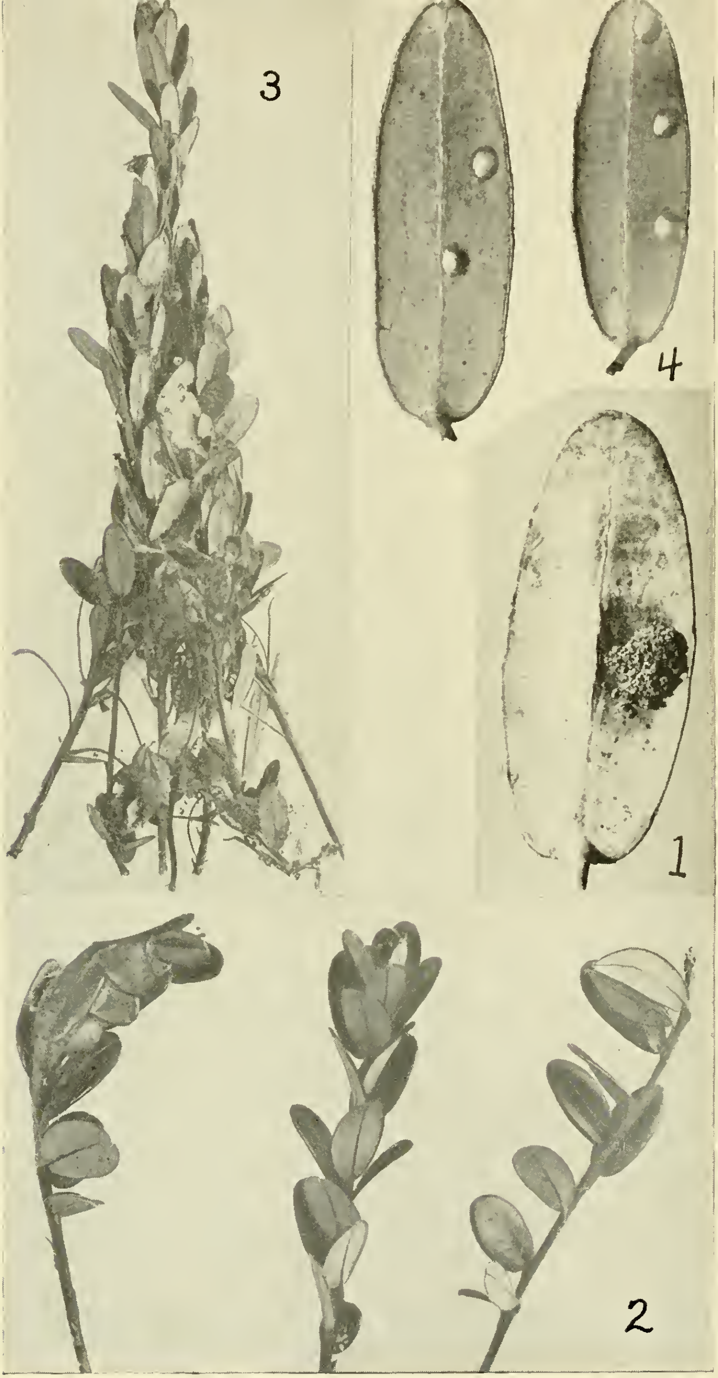
Hatching normally begins about the middle of May, but sometimes starts the first week in May, and occasionally is delayed until the first of June, even on bogs drained of the winter flowage early in April. The hatching period often lasts but three weeks on thinly vined bogs if the weather is warm, but it may continue six weeks among rank vines in cool weather.

The black head of the worm may be seen through the shell for a day or two before hatching occurs. When the worm emerges, the eggshell is left as a thin shiny whitish scale on the leaf.

The first brood of moths lay their eggs in late June and July. Many of these eggs do not hatch till the next spring. Because of this, the hatching period of the second brood of worms on any given bog often lasts little more than a week. If the winter water is held till late May, the deferment of the hatching of this brood is sometimes nearly complete.

THE WORM

The worm (fig. 6) is greenish or pale yellowish, with a shining black head and neck, and is about a third of an inch long when full-grown. First-brood worms generally take two and a half weeks to mature, but those of the second brood mature in about twelve days. The second brood sometimes works till well into August, even on bogs bared of the winter water in April.



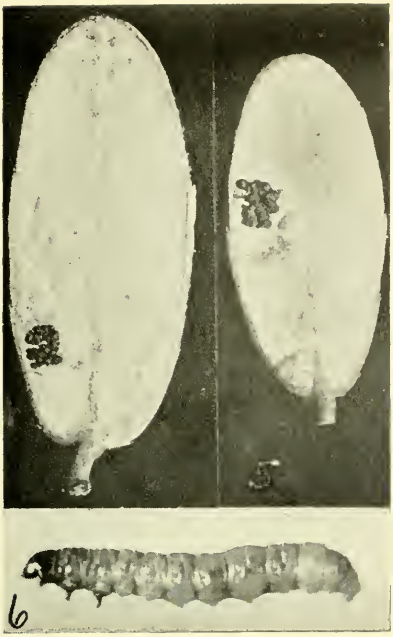
BLACK-HEADED FIREWORM

Fig. 1 Cranberry leaf with pile of castings over mine of newly hatched worm. Much enlarged.

Fig. 2. In middle, uninfested cranberry upright; at right, upright with the first webbing; at left, more advanced webbing.

Fig. 3 Nest of webbed cranberry uprights.

Fig. 4 Eggs on backs of cranberry leaves. Much enlarged.



7

BLACK-HEADED FIREWORM

Fig. 5. Cranberry leaves with fruiting bodies of a fungus (Venturia compacta Pk.) often mistaken by growers for its eggs. Much enlarged.

Fig. 6. Larva. Considerably enlarged.

Fig. 7. Moth. Much enlarged. (From U. S. Dept. Agr. Farmers' Bul. 860.)

THE PUPA

The mature worms generally leave the vines to pupate on the sand or in the trash beneath them. The pupa often is naked but usually is in a light case of silk and sand or fallen leaves. If water happens to be standing under the vines, the worms pupate among the webbed foliage. They used to do this quite generally in Wisconsin, probably because most of the vines there were poorly drained. The pupa is light brown at first, but it gets almost black before the moth emerges. The pupal period of the first brood is nearly two weeks, and that of the second brood about a week and a half.

THE MOTH

The moth (fig. 7 and Plate One, fig. 6) is dark grayish brown and so small that it is often mistaken for a fly when in flight. It expands somewhat over three-eighths of an inch. The forewings are marked with gray-brown and silver-gray bands. The female may lay eggs within a day after it emerges. The moths fly little during the day unless it is warm and very cloudy, but they are flushed up easily. At dusk they fly and hover freely just above the vines.

Treatment

CESSATION OF FLOODING

If a badly infested bog is not flooded at all for three years, it generally becomes free of this pest, and sometimes it will do so in a year. This treatment is not advocated because of the danger of winterkilling and of a great increase of fruitworm infestation.

REFLOODING

Complete flooding for ten hours, during the night or when the weather is cool, as soon as the small worms of the first brood become numerous, usually about May 30, is often very effective. Generally it is necessary to repeat this treatment once or twice, as soon as more worms appear, to get satisfactory control for the season, this often eliminating the second brood. Flooding for much longer periods is not advocated because of possible injury to flower buds. Delay of the flooding to insure completion of the hatch generally allows too many of the first worms to pupate and develop a second brood.

DUSTING

Dusting with 50 pounds of clear pyrethrum dust (0.9 percent pyrethrins or better in killing power) to the acre is a very effective control for the worms of either brood. They can be treated as well and much more cheaply with 50 pounds of 5 percent DDT dust to the acre. These dusts may be applied whenever the worms seem too abundant.

SPRAYING

The following is an excellent spray for either brood: 7 pounds of derris (4 or 5 percent rotenone) powder and 2 pounds of soap in 100 gallons of water, 400 gallons to the acre. Cheaper, and equally effective, 2 pounds of 50 percent wettable DDT in 100 gallons of water, 400 gallons to the acre, is advocated.

Pyrethrum soap makes an excellent spray for the first brood, but it tends to stunt the small cranberries that are usually present when the second brood of worms appear.

The second brood must be treated as soon as hatching is general, usually five or six days after the first worms appear, for the following reasons: (1) Because of its partial suppression, this brood is usually well bunched in hatching: (2) the worms are killed most easily when small; (3) if treatment is delayed, the worms may injure the tips so that they will not bud well for the next year; and (4) the worms that enter berries are not easily reached with a spray or dust.

Fig. X. Remains of a Black-Headed Fireworm, Killed by Fungus, on the Under Side of a Cranberry Leaf.

Outbreaks of a disease[8] sometimes wipe out the second brood on many bogs. If spraying is contemplated or in progress, it is well to watch for this, for the epidemic may make treatment unnecessary. The general abundance of the fungus that causes the disease may be learned by leaving fifty of the worms in a moist chamber[9] over night. By morning the fungus will appear on most of the diseased worms as a fluffy white mold, and around them as a ring of white spore dust. Professor W. H. Sawyer, Jr., found this fungus absent or inactive on the bogs with fireworm infestation notably resistant to control but generally abundant on other infested areas. He found further that the bogs on which it is scarce are generally large, well-managed areas that have been flooded, sprayed, and resanded regularly. Evidently it is killed out, directly or indirectly, by late-spring or summer flooding or by spraying or sanding, for no evidence has been found that fall flooding or the winter flood, even when it is held late, affects it. The fungus passes the winter in the form of resistant spores among the chaff on the bog floor.

Moderate infestations of this fireworm must be treated as though they were severe. Even slight ones should be given due attention, especially on large bogs. They should be treated at least once during the season.

Yellow-Headed Fireworm[10]

This pest never harms bogs that are flooded completely during the winter on Cape Cod and seldom does elsewhere, for the wintering moths cannot endure submergence. It is attacked by parasites much more than the black-headed fireworm. They do not reduce the first brood much, but they decimate the second so that, however severe the infestation, the first brood of the next year seldom does much harm. There are two broods in Massachusetts, three in Iowa and Wisconsin, and three or sometimes four in New Jersey.

Distribution and Food Plants

This fireworm is known widely as an apple pest throughout the United States and southern Canada. It also feeds on pear, plum, rose, huckleberry, swamp blueberry, glaucous willow, and sweet gale. It is worse as a cranberry pest in New Jersey than elsewhere. It is much less generally destructive on the Cape than the black-headed fireworm.

Character of Injury

The small worms of the first brood feed on the old leaves at first, usually sewing the surfaces of two adjacent ones together and working between them. Otherwise this species works much like the black-headed fireworm (fig. 8), but it tends to gather more uprights into its web (fig. 9) and often does more intensive injury, not only browning the bog but often leaving only bare uprights in the fall. The worms work in the berries and score them as black-headed fireworms do (fig. 10).

Description and Seasonal History

The moths that appear in the fall (Plate One, fig. 4) are reddish gray, but they gradually lose the red tinge and become slate color.[11] They are small but considerably larger than those of the black-headed fireworm. They winter on

[8] Caused by *Entomophthora sphaerosperma* Fres. This fungus also attacks other insect species. Prof. Sawyer grew it abundantly on various culture media. He did his field work on this disease in cooperation with the Cranberry Station at East Wareham and studied it further in the Laboratories of Cryptogamic Botany at Harvard University. Attempts to control this fireworm by distributing the culture-grown fungus in a spray or otherwise were unsuccessful.

[9] A clear smooth tumbler inverted over a glass plate and containing a little moist cotton is handy for this.

[10] *Peronea minuta* (Rob.).

[11] Form *cinderella* Riley.

the bog and surrounding upland, hidden in the vines or other shelter, but fly on warm days. They lay during April. The eggs look like those of the black-headed fireworm and are laid singly, mostly on the backs of the leaves. They hatch during the first half of May.

Newly hatched worms of the first brood usually have dark heads but they soon change and commonly are distinguished from the black-headed fireworms by the yellow color of the head. The body is pale yellowish. The mature worms are about half an inch long (fig. 11). They pupate in silken cells among the webbed uprights, mostly early in June.

The pupa is light brown at first, but it grows blackish as the moth develops. It is from a quarter to nearly a third of an inch long and has a prominent and distinctive knob at its head end (fig. 12).

The summer moths appear late in June and fly about three weeks. They are clear orange (Plate One, fig. 5), but otherwise like those of the winter brood. They may be flushed up in clouds on badly infested bogs. They lay eggs during most of their flight and generally disappear about July 10. The eggs usually begin to hatch about July 8 to 10. The worms continue to appear for some time and develop more slowly than the first brood, some of them not maturing till September. They pupate like the first brood, the pupal stage lasting about a month, and the gray winter moths appear in September and October.

Treatment

FLOODING

Complete winter flooding, especially if the water is held into May, is a sure control.

SPRAYING

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water, 300 gallons to an acre, is very effective. It should be done for the first brood about May 22, and for the second brood about July 12. The first-brood treatment will check the gypsy moth also if that insect threatens. A single spraying, well timed for either brood, should be enough for a season, for the parasites of this pest generally need only occasional help to keep it down.

The moths may be killed early in April with a spray of 1 quart of 40 percent nicotine sulfate and 4 pounds of fish-oil soap in 100 gallons of water. This treatment is advisable if there is no prospect of much gypsy moth infestation, for it will save spraying in the growing season, with its mechanical injury to the vines.

Red-striped Fireworm. [12]

This insect never infests bogs that are flooded completely all winter. It is less important than either of the fireworms already discussed, but it occasionally develops a severe infestation on a dry bog. It sometimes works with the yellow-headed fireworm.

Distribution and Food Plants

This New Jersey and Massachusetts pest has not been recorded as harming bogs elsewhere. It ranges from Maine and Quebec to Virginia and western Texas. Swamp blueberry and dwarf blueberry are its favorite food plants. They usually harbor large numbers of the worms in the fall everywhere in the eastern part of the State. It also attacks deerberry, low blueberry, dangleberry, black huckleberry, dwarf huckleberry, male berry, fetter bush, leather leaf, and trailing arbutus.

Character of Injury

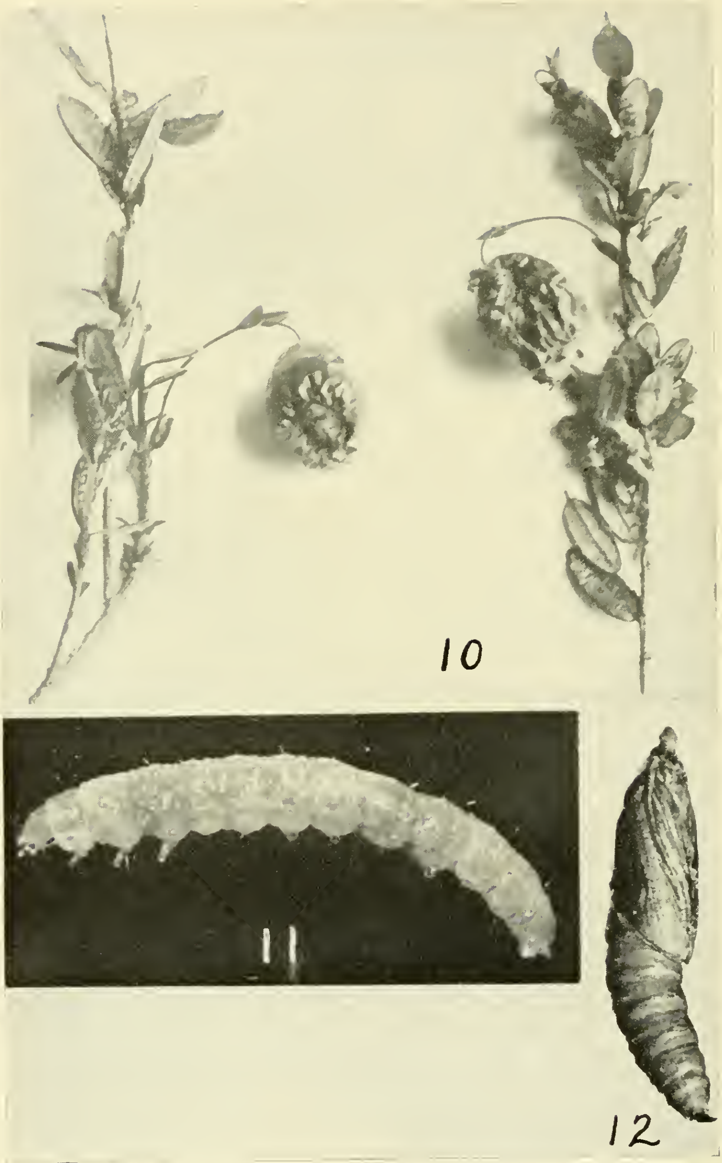
Some of the newly hatched worms go directly to the tips of the new growth,

[12] *Aroga trialbamaculella* (Cham.).

YELLOW-HEADED FIREWORM

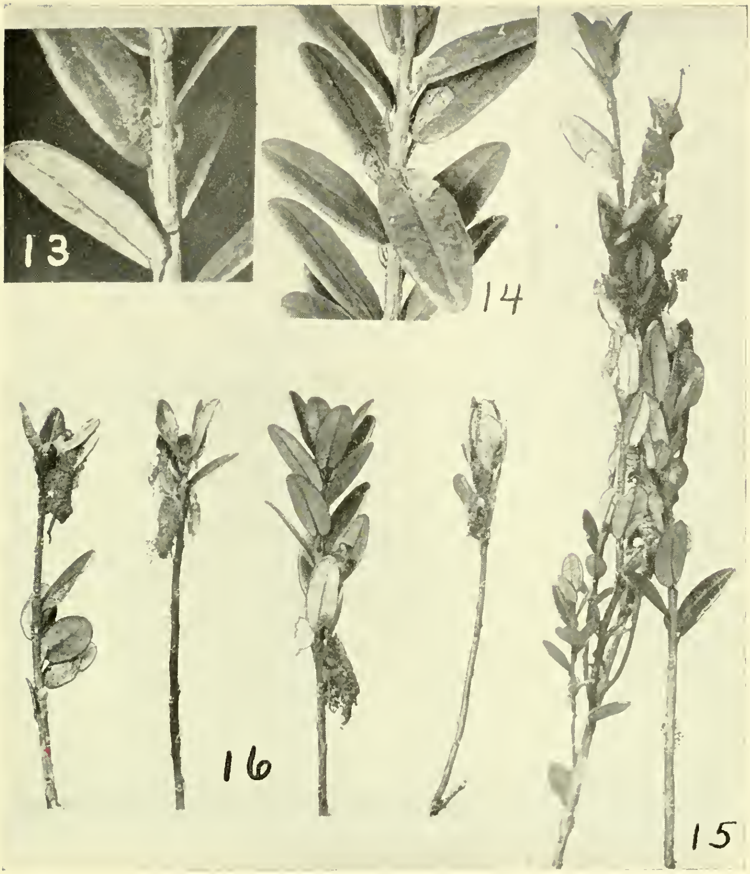
Fig. 8. Cranberry uprights with tips webbed by young worms.

Fig. 9. Nests of webbed cranberry uprights.



YELLOW-HEADED FIREWORM

Fig. 10. Work on berries.
Fig. 11. Caterpillar. Much enlarged.
Fig. 12. Pupa. Much enlarged.



RED-STRIPED FIREWORM

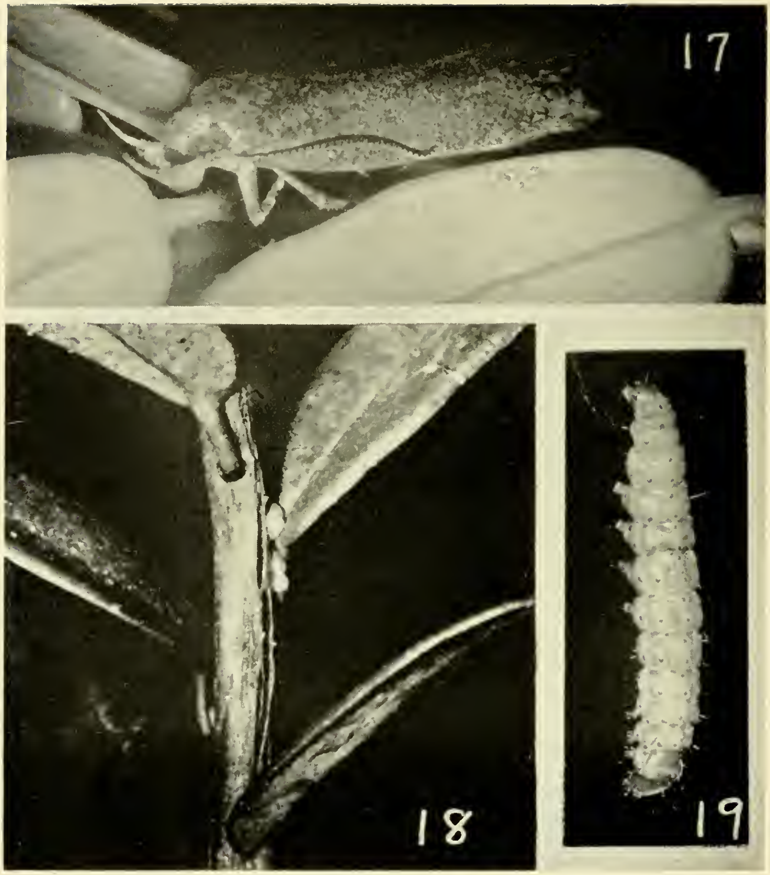
Fig. 13. Mine of young worm covered with castings.
Fig. 14. Cranberry leaves mined at base by newly hatched worms, with castings removed.
Fig. 15. Nest of webbed cranberry uprights.
Fig. 16. Cranberry uprights with tubular cases made by worms in webbed nests.

but many first mine the basal part of the blade of the old leaf between which and the stem the egg was held, entering it from the upper surface and covering the entrance with a mass of green castings (figs. 13 and 14).

The webbing begins among the terminal leaves but is not very conspicuous there. As the season advances it is extended farther and farther down the shoot and often two or three uprights are sewed together (fig. 15). This species webs its nests more closely than the other fireworms do, and forms in them a characteristic irregular tubular case of silk covered with brown castings (fig. 16). The worms are parasitized considerably, but their nests are a better protection than those of other fireworms and they keep much more concealed in them.

Description and Seasonal History

Most of the worms leave their cases during late September and October and go down into the trash and surface sand of the bog floor to remain dormant



RED-STRIPED FIREWORM

Fig. 17. Moth. Much enlarged.
Fig. 18. Cranberry upright with eggs between stem and base of leaf. Much enlarged.
Fig. 19. Larva. Considerably enlarged.

until the next spring. A few remain in their nests, many of which break off and drop during the winter. They pupate one after another during most of May and June. The moths usually appear from soon after mid-May until into August, those found toward the last being adults of a second brood.

THE MOTH

The adult is mostly dark brown, but has a white face, large rusty palpi, a few white dots on the forewings and white spots on the legs (fig. 17 and Plate One, fig. 3). It expands about nine-sixteenths of an inch.

These moths usually keep quiet among the vines during the day, but they flush fairly easily. They have a darting flight and hide even more nimbly than those of other fireworms, often going into the litter under the vines when pursued.

THE EGG

The moths lay eggs from late May to early August, the second brood laying toward the last.

The eggs are irregularly ellipsoid and about a fortieth of an inch long. They are very plastic and pearl white when laid, but turn pinkish or yellowish before hatching. They usually are wedged in between the vine and the petiole or the base of the blade of a leaf (fig. 18), or are placed among the bracts of an opening terminal bud, but are deposited also under loose bark. They usually hatch from mid-June to mid-August, the egg stage lasting about sixteen days in early June and about nine in late July.

THE WORM

The newly hatched larva is pale greenish yellow, with the head and cervical shield brown. As it grows, its head becomes yellowish, and dull reddish lines appear running the length of the back and sides. The mature worm (fig. 19) is fully three-eighths of an inch long and is more slender and agile than other fireworms.

All the worms that hatch in June pupate in their nests after mid-July, the moths emerging at the end of July and early in August. Most of those that hatch after the first of July continue as worms till the following May as already noted. The insect is therefore partly one-brooded and partly two-brooded.

Treatment

A spray of 1 1/3 quarts of nicotine sulfate and 4 pounds of fish-oil soap in 100 gallons of water, applied 400 gallons to the acre about August 6, eradicates this pest.

Hill Fireworm [13]

Considerable outbreaks of this pest are not rare. They seem to occur always on bogs that have been flooded during the winter. The worms in most cases attack vines in the hills of new plantings for a year or two after they are set. Sometimes they seriously infest old, heavily vined areas, and such infestations continue year after year unless they are treated effectively.

Distribution and Food Plants

This species ranges from Canada to Florida but is more common in the South. It has been reported as attacking cranberries only in Massachusetts and Rhode Island. It also feeds on the foliage of the swamp blueberry.

Character of Injury

The young worms often begin their work by channeling the cranberry stems towards and to the tips, so causing them to drop over. Some of them sew up cranberry tips like other kinds of fireworms, but include more frass. As they grow, they often completely defoliate the hills of new plantings, leaving a thick mass of their frass and dropped leaves on the sand around the base of the plants. One to three worms work on a hill, and they make very extensive loose tubes of silk and frass, producing these materials in remarkable abundance and incorporating sand freely with them on and near the ground. These tubes (fig. F) are formed mainly on and around the lower parts of the plants, and the worms hide and work in them. Runners on the sand between the hills are also attacked at times.

The worms are sometimes found abundant in the thicker clusters of vines of a heavily vined bog, mostly in their tubes of silk and frass, well down among the vines but in a zone three to six inches above the bog floor. They may do rather serious damage there by devouring the under leaves and blossoms.

Description and Seasonal History

THE EGG

Most of the eggs (fig. A) are laid during the first half of June and on the

[13] *Tlascala finitella* (Wlk.).

HILL FIREWORM

Fig. A. Eggs. Enlarged.

Fig. B. Mature worm.
Fig. C. Cocoon.
Fig. D. Pupa.
Fig. E. Moth.
} All somewhat enlarged.

Fig. F. Work of Worms, their tubes and frass.

stems of the new cranberry growth. They are oblong-oval and yellow or reddish at first, the largest being very nearly a millimeter long. They become bright crimson within a day and a half and remain so up to within half a day of their hatching. Their usual incubation period is five to six days.

THE WORM

The worms (fig. B) work in June and July and till the middle of August. They have blackish heads and reddish bodies when newly hatched. As they grow larger, the head is black; the cervical shield with a much-broken pale-yellow stripe along its front margin; the body dark brown, marked lengthwise on the back and sides, except toward the hind end, with about eight narrow and broken pale-yellow stripes, these being most conspicuous toward the head end; the venter without stripes; the back and sides with noticeable scattered pale hairs. The full-grown worm is from five-eighths to thirteenth-sixteenths of an inch long

Most of these worms mature and many pupate by August 1. All of them pupate before August 25. They envelop themselves in a cocoon of silk and sand (fig. C), generally on the bog floor, and soon pupate in it.

SPOTTED FIREWORM
Fig. 20. Cranberry uprights with tips webbed by young worms.

THE PUPA

The pupa (fig. D) is slender and about two-fifths of an inch long. Its head end and wing covers are dark olive green. The abdomen is mostly chestnut brown, the caudal segment being dark brown and having a small hook on each side of the apex, recurved ventrad.

THE MOTH

The moths (fig. E) emerge from about August 8 till about September 5; but some of the pupae live through the winter, their moths coming out very late in May and during the first half of June and being somewhat larger than the others.

These moths hide cleverly among the cranberry vines and in the litter under them, but are strong and quick in flight when flushed. They are six to seven sixteenths of an inch long to their wing tips and have a wing expanse of twelve to fifteen sixteenths of an inch. Their further description is as follows: Forewings dark gray above, with cross tufts of black or black-tipped erect scales near the base, about a third of the length from the base and somewhat beyond the middle of each; uniformly smoky below; hindwings pale with smoky front and outer margins; head (except eyes), palpi, and basal parts of antennae dark gray; thorax dark gray above, light gray below; legs dark gray; dorsum of abdomen dark gray with fringes of pale yellow along the hind margins of the middle segments; venter colored similarly but with pale marginal hind fringes on all the segments.

Treatment

Cryolite, 50 pounds to the acre, applied as a dust whenever the worms are prevalent, gives excellent control. Bog flooding has not proved practicable.

Spotted Fireworm [14]

This fireworm is considerably harmful only occasionally and on rather small bogs. It seldom infests bogs that are reflooded regularly. It works like the

[14] *Archips parallela* (Rob.).

SPOTTED FIREWORM

Nests made by worms:
Fig. G. Of cranberry uprights.
Fig. H. On loosestrife.
Fig. I. On marsh St. John's-wort.

yellow-headed fireworm (fig. 20) and sews even more uprights into its nests (fig. G), but rarely browns a bog.

Distribution and Food Plants

This species has been found in Maine, Massachusetts, New Jersey, New York, Illinois, Wisconsin, Minnesota, and Canada. It has been recorded as a cranberry feeder in Massachusetts, Minnesota, New Jersey, and Wisconsin[15]. It also attacks chain fern, sensitive fern, marsh shield fern, common brake, flowering fern, saw

[15] Hardenberg's "Oblique-banded roller (*Archips* species)" was pretty certainly this species (See Wis. Agr. Expt. Sta. Bul. 159:15, 1908).

PLATE ONE

Upper Part: Fireworm Moths and Worm

Fig. 1.—Spotted fireworm moth.

Fig. 2.—Moth of Sparganothis sulfureana (Clem.).
This moth is common on dry bogs in July. The larva has a yellow head and works as a fireworm but never does much harm on bogs except in New Jersey and there locally. It also attacks grape, strawberry, clover, and many other plants.

Fig. 3.—Red-striped fireworm moth.

Fig. 4.—Winter moth of YELLOW-HEADED FIREWORM.*

Fig. 5.—Summer moth of YELLOW-HEADED FIREWORM.

Fig. 6. BLACK-HEADED FIREWORM moth.

Fig. 7.—Mature spotted fireworm.

Lower Part: Cutworm Moths

Figs. 8a and 8b.—BLOSSOM WORM moths, showing variation.

Fig. 9—Fall armyworm moth.

Fig. 10—BLACK CUTWORM moth.

Fig. 11—Spotted cutworm moth.

Fig. 12—ARMYWORM moth.

Fig. 13.—FALSE ARMYWORM moth.

PLATE TWO

Cutworms and Cranberry Shoot Showing Rose-Bloom

Figs. 1a, and 1b.—Mature ARMYWORM.

Figs. 2a and 2b.—Mature spotted cutworm.

Figs. 3a. and 3b.—Mature BLOSSOM WORM.

Figs. 4a and 4b.—Half-grown BLOSSOM WORM.

Fig. 5.—Mature BLACK CUTWORM.

Fig. 6.—Rosy shoots caused by rose-bloom.

Figs 7a, 7b, 7c, 7d.—Mature FALSE ARMYWORM.
The last three figures show its variation in coloration.

Figs. 8a and 8b. Mature fall armyworm.

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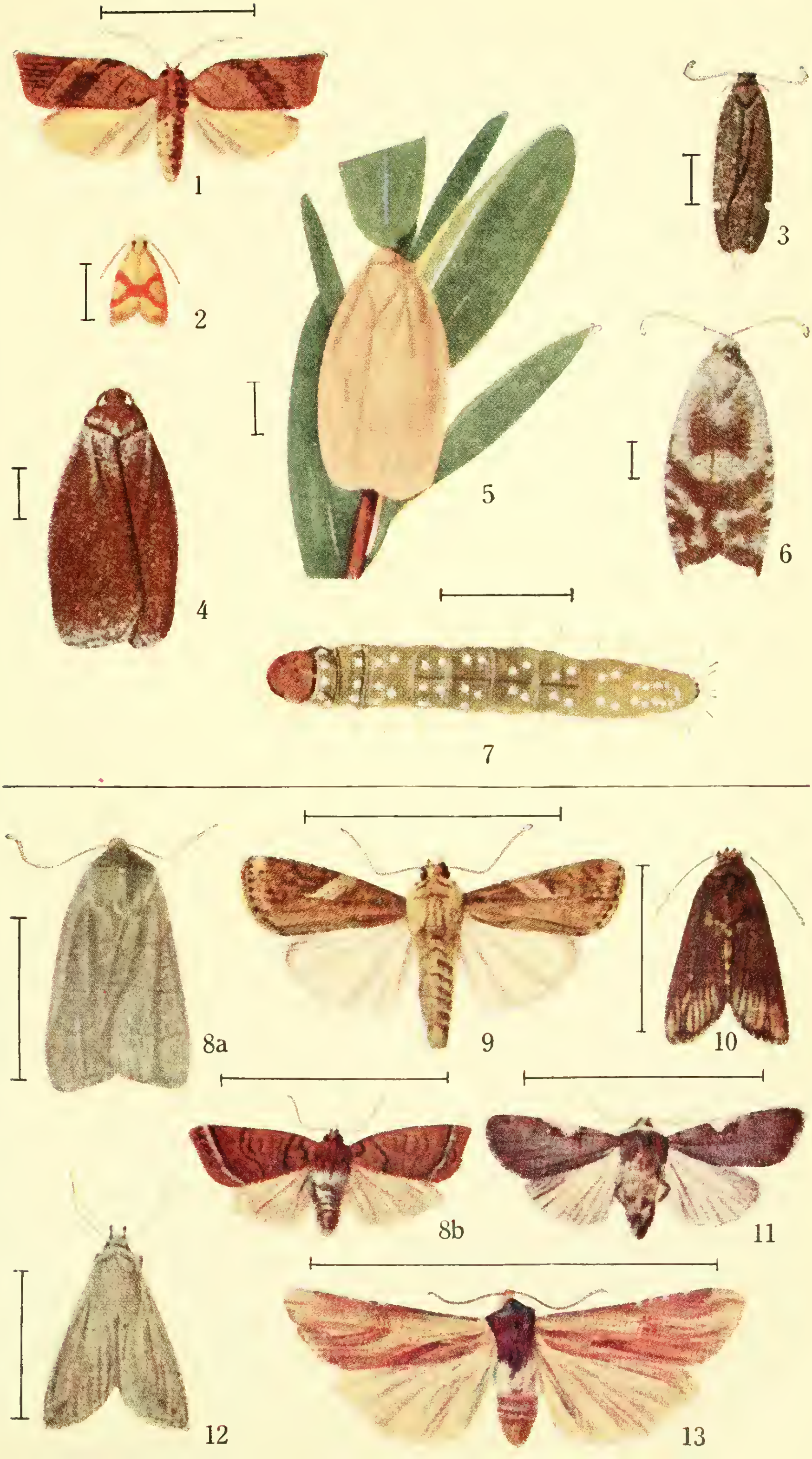
* The names of the more commonly harmful pests are in capitals. Insect size is shown by the length of the lines near the figures.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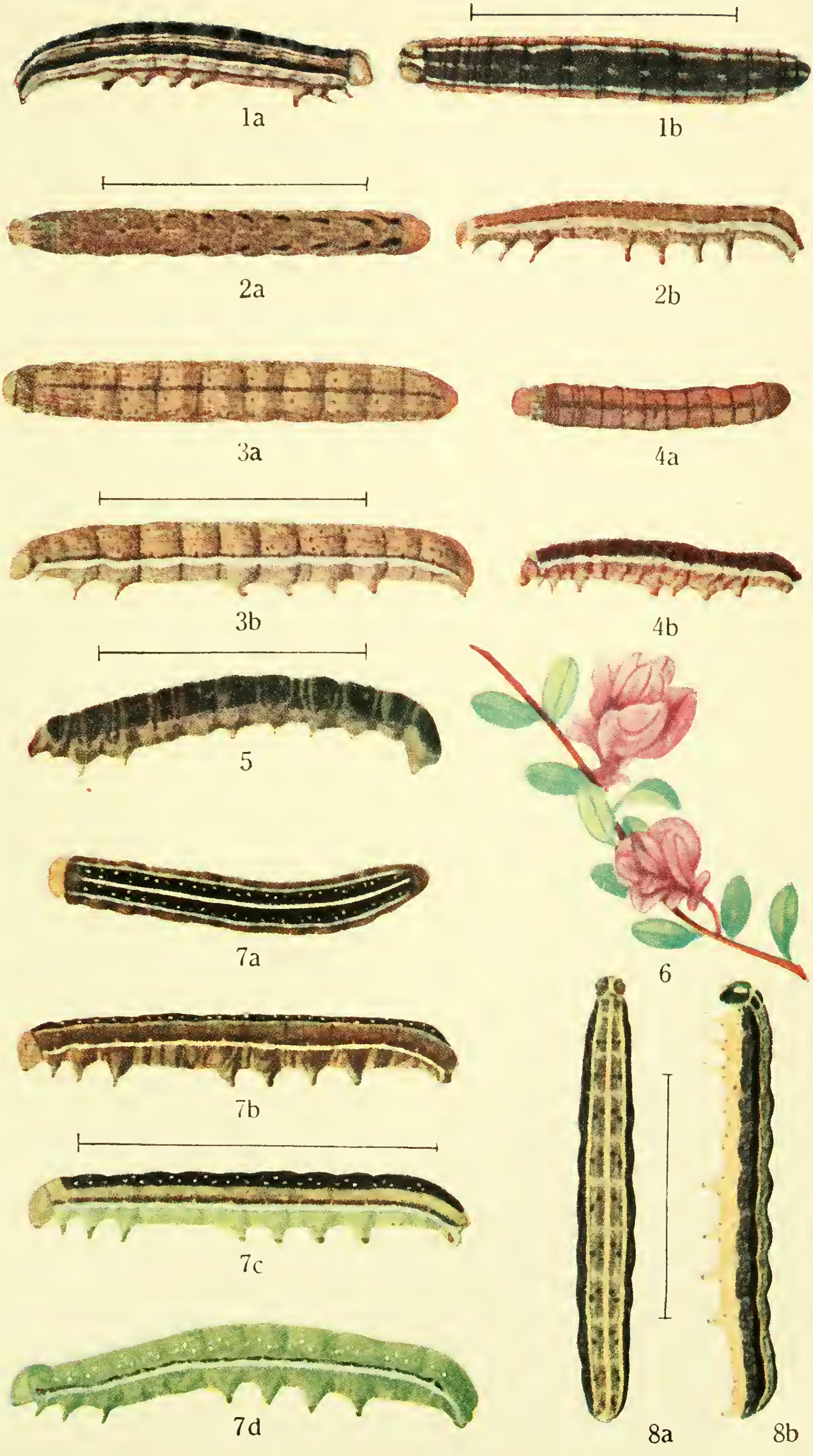
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brier, apple, hardhack, chokeberry, coarse bramble, winterberry, St. John's-wort, sweet pepperbush, swamp blueberry, sheep laurel, loosestrife, sweet melilot, willow, and aster. Loosestrife and marsh St. John's-wort are favorite food plants of the insect (figs. H and I) and, when abundant, probably induce infestations by it. It is also sometimes a rose pest in greenhouses.[16]

Description and Seasonal History

THE WORM

The worms appear on the bogs about the first of June. They mature in late June or early July and pupate in early or mid-July. The moths emerge during the last half of July or early in August. They lay their eggs late in July and early in August. The eggs hatch in about ten days. The worms grow slowly, sometimes enter berries, and are found in steadily decreasing numbers till the first of September, when the last disappear. They are then less than a third grown. They may winter in trash on the bog floor.

The small worms are yellowish white with brown heads. As they grow, the head becomes amber and the body for a time may be somewhat reddish. As they mature (Plate One, fig. 7), the head changes to rather light reddish brown and the body becomes more or less olive green on the back and sides, with conspicuous and somewhat elevated white spots along the whole length and usually one pale hair rising from each spot. They grow to be fully three-quarters of an inch long and pupate among the webbed uprights.

THE PUPA

The pupa is about half an inch long and mostly chestnut brown, but its back is somewhat darker, being almost black toward the front. There is a prominent transverse ridge at the head end, and several rows of small backwardly directed teeth run across the top of the abdomen. Some of the pupae squirm vigorously when disturbed, but they are more often inactive.

THE MOTH

The moth (Plate One, fig. 1) expands about three-fourths of an inch. It is brown with two chocolate-colored stripes crossing each forewing diagonally, one near the middle and the other shading the tip.

THE EGG

The eggs are minute, circular, and flat and partly overlap one another, being laid in flat shiny masses of one hundred to one hundred and fifty. They are lemon yellow at first, but later become orange; and as they near hatching, the brown heads of the worms show plainly through the shells.

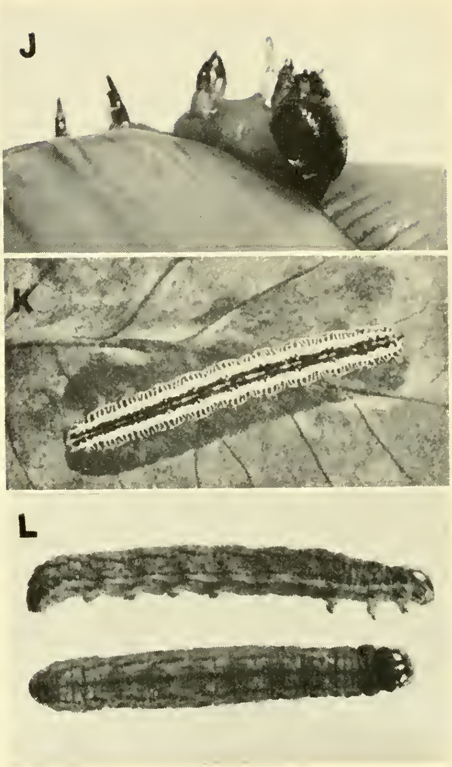
Treatment

The worms are seldom noticed much before they mature, and as they rarely do serious harm it seldom pays to treat them. Complete flooding for thirty hours about June 6 and dusting with 40 pounds of cryolite to the acre in mid-June are good controls.

CUTWORMS

These worms may be distinguished from all others found on cranberry bogs by their possession of a median internal organ in front of the bases of the forelegs which may be extruded by squeezing the fore part of the body (fig. J). They feed openly, never webbing the vines. They are one and a half to two inches long when mature, and without noticeable hair. They feed mostly at night, usually hiding during the day among the vines or in the litter on the bog floor or under pieces of board if such are present. They all belong to the same

[16] Mich. Agr. Expt. Sta. Spec. Bul. 214, p. 75, 1931.



CUTWORM

Fig. J. Showing osmeterium extruded at throat.

ZEBRA CATERPILLAR

Fig. K. Mature worm. (With permission of The MacMillan Company, from O'Kane, Injurious Insects, 1917, p. 171.)

ATLANTIC CUTWORM

Fig. L. Side and back views of the mature caterpillar.

family and, except for differences in coloration, are much like garden cutworms. Most of them are common pests of other crops. All but the false armyworm do injury out of all proportion to the amount of their eating by cutting off flower buds, flowers, small berries, or leaves and dropping them to the ground. The green leaves fallen on the water in the bog ditches are often the first sign of their work observed. The moths of all but the blossom worm ordinarily are night-fliers and seldom seen. They measure an inch and a half or more across their outspread wings. Their eggs (fig. 23) are round, slightly flattened, and marked with many ridges radiating from the summit. The worms generally are severely parasitized.

These insects, except the false armyworm and blossom worm, rarely attack cranberry bogs much unless the winter flowage has been held until late May or later[17] or late-spring and early-summer grub flooding has been done. This may be due to one or all of the following possible causes, given in the order of their apparent probability[18]:

[17] Reflooding for ten days or longer in late May sometimes has the same effect as very late holding of the winter water. If the winter water is let off and the bog is flooded again within a few days, the reflood should be regarded as a continuation of the winter flood as far as its relations to these cutworms are concerned.

[18] Mass. Agr. Expt. Sta. Bul. 192:133, 1919.

1. Egg-laying by the moths after late removal of floods allows the worms as they hatch to find a very tender new cranberry growth, some such special food probably favoring their survival.

2. The moths seem to prefer to lay their eggs on or over damp earth. Bogs drained during the flight of the moths therefore probably invite infestation.

3. By breeding on freshly drained areas the insects may largely escape their natural foes and so develop as they could not otherwise.

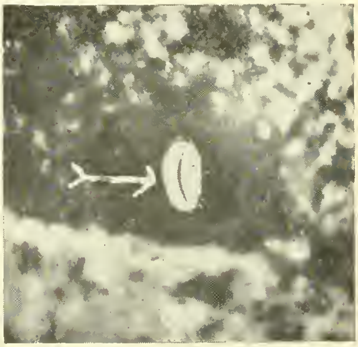
The chances are even that some of these worms will infest a bog if the winter flood is held till the end of May. Sometimes two species attack a bog together under such conditions, and occasionally one species is prevalent on some bogs and another on others. They usually appear within ten days after the water is let off.

The various species of cutworms are hard to distinguish for a time after they hatch, all being then mostly whitish or greenish, but they may be identified after they are half-grown by the aid of the following table:

With very conspicuous yellow stripes..........zebra caterpiller[19].
Not so colored..........1
1. Mostly dark, without definite sidestripes..........black cutworm (p. 31).
With a conspicuous stripe along each side..........2
2. With a row of two to four angular dark spots on each side of the hind part of the back..........spotted cutworm (p. 28).
Without such spots..........3
3. The back reddish brown and not marked with pale yellow dots
cranberry blossom worm (p. 27).
The back mostly dark, grayish, or green..........4
4. Found on a bog not bared of a long flood after May 20
false armyworm (p. 24).
Found on a bog bared of a long flood after May 20..........5
5. With many small round or oval dark tubercles noticeable along the back..........fall armyworm (p. 34).
The back without such tubercles..........6
6. With a broken pale line along the middle of the back..........armyworm (p. 32).
A narrow dark-brown stripe along the middle of the back
Atlantic cutworm[20].

SPOTTED CUTWORM

Fig. 21. Spiracle of caterpillar. Much enlarged.



[19] *Ceramica picta* (Harr.). These worms (fig. K) often hatch in considerable numbers on cranberry bogs, but only a few ever mature there, cranberry apparently being an unfavorable food plant for them, and they never do much harm. They are noticed most in July.

[20] *Polia atlantica* Grote. This brown cutworm (fig. L) attacks cranberry bogs only rarely and locally. See Mass. Agr. Expt. Sta. Bul. 355:39, 40, 1939; and Bul. 369:34, 1940.

The color of the spiracles helps to distinguish some of these worms in their later stages. The spiracles are the respiratory organs placed at intervals along the sides of the body. They should be examined with a good lens. Those of the armyworm and the black cutworm are blackish; those of the spotted cutworm clear yellowish white rimmed with deep brown (fig. 21); those of the blossom worm reddish brown to dark brown rimmed with dark brown; those of the false armyworm yellowish white in the half-grown stages but deep orange rimmed with deep brown as the worm matures; and those of the fall armyworm pale brown with the rim dark brown.

False Armyworm [21]

This worm is not known as a cranberry feeder elsewhere, but it has attacked Cape Cod bogs for many years, probably ever since the industry began. Some years it is hardly noticed, but sometimes it is an important pest,[22] destroying all prospects of a crop on many bogs if it is not checked. It never infests bogs on which the winter water is held till May 15, and seldom harms strictly dry bogs[23] much.

Distribution and Food Plants

This insect ranges throughout northeastern United States and southern Canada, south to the District of Columbia and west to Nebraska, Oregon, and Alberta. It attacks various weeds, grasses, iris, and apple as well as cranberry.

Character of Injury

The young worms often do great harm by eating out the hearts of the terminal buds (fig. 22) before new growth starts. They develop with the new growth and feed more and more voraciously upon it as they mature, devouring leaves, buds, and flowers with equal avidity and sometimes leaving little of the new shoots but the stems, but seldom eating the old foliage much. Their work is more like that of gypsy moth caterpillars than that of any other cranberry pest. They feed freely in the daytime.

Description and Seasonal History

THE EGG

The moths winter[24] and the females lay about six hundred eggs apiece in late April and very early May, placing them in masses of sometimes over a hundred on the stems or the backs of the leaves of cranberry uprights (fig. 23). The eggs are whitish at first but soon turn light yellow and later become reddish brown. They are about a thirty-first of an inch in diameter. They hatch during the second and third week of May, the egg stage lasting fifteen to twenty days.

THE WORM

The newly hatched worms (fig. 24) are whitish and marked with many black spots, each of which bears a slender black spine, these being conspicuous under a lens. They loop much like spanworms but gradually drop this movement. They soon become green with whitish lines along the back and sides, being somewhat darker above than below, and retain this coloration till over a third grown.

The mature caterpillar (Plate Two, figs. 7a, 7b, 7c and 7d) is about two inches long and its head is uniform greenish yellow. Though the arrangement and relative width of the various stripes and lines along the body are

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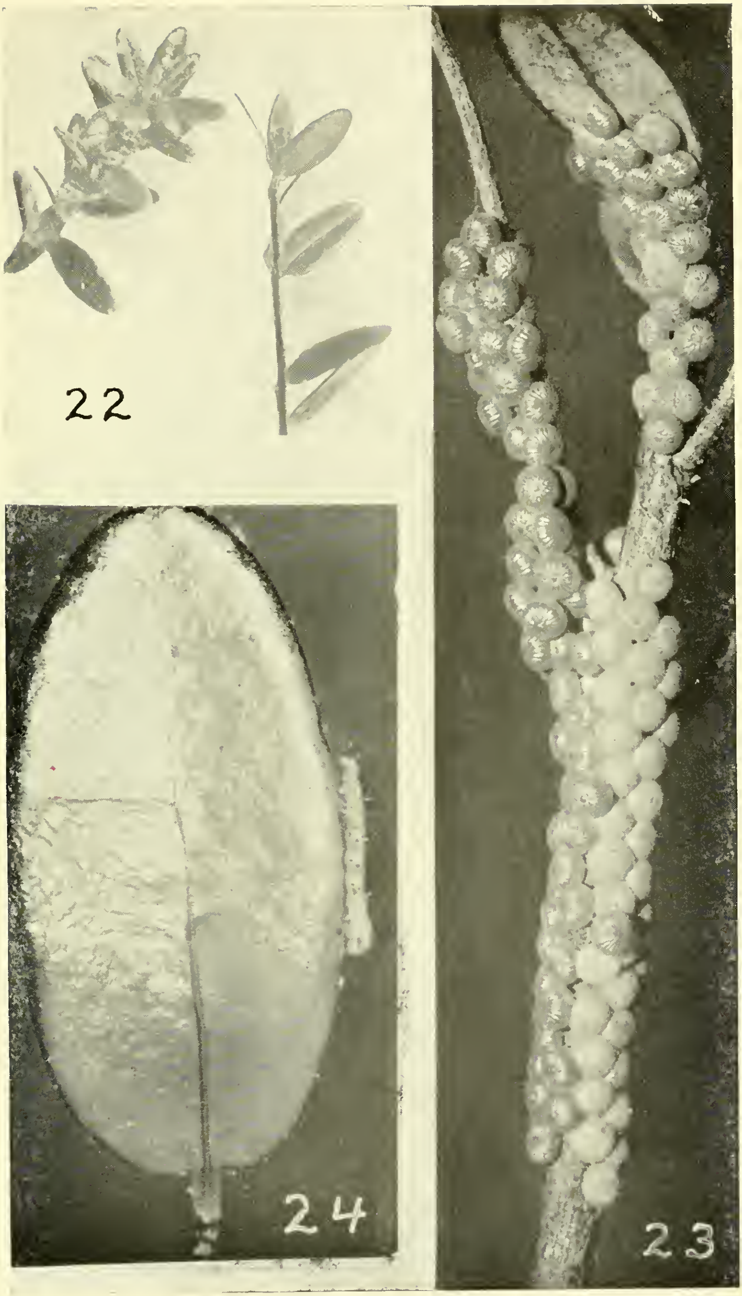
[21] *Xylena nupera* (Lint.). Also known in cranberry literature as *Calocampa nupera.*

[22] As in 1906, 1907, 1940, 1941, and 1942.

[23] The moths seem to prefer damp locations for egg-laying.

[24] These moths, especially the females, may be caught readily at honey baits on tree trunks about the bogs in the milder nights of April.



FALSE ARMYWORM

Fig. 22. Cranberry uprights with terminal buds drilled by young worms.

Fig. 23. Egg-masses. Much enlarged.

Fig. 24. Cranberry leaf with newly hatched worm. Much enlarged.

the same in all specimens, the general color varies from grass green to dark brown. The stripes are as follows: a broad band of varying color runs the length of the back and is divided in the middle lengthwise by a light line; this band is bordered on each side by a yellowish line; below this line on each side is a much lighter stripe extending nearly down to the spiracles; across the spiracles passes a blackish line which is bordered below by a sulfur yellow one. There are light dots at intervals along the back. The body is greenish or flesh-colored beneath. The spiracles are orange, ringed with deep brown.

THE PUPA

The worms mature in late June and go into the ground to remain dormant two to six weeks before pupating. They pupate mainly in late July and early August. The pupae are stout, about an inch long, and dark brown.

THE MOTH

The moths emerge from mid-August till late September. They are (Plate One, fig. 13) light coffee brown with the body reddish sooty brown below and on the back between the wings. The top of the head, the collar, and the abdomen above are pale yellowish brown. The forewings are variegated, with brown, gray, and sooty streaks above and are light brown color. The hindwings are pale brown with a conspicuous dark spot somewhat before the middle and toward the base on the under side. The wings expand two inches or more.

Treatment

FLOODING

On winter-flowed bogs scant of water for reflooding:—Hold the winter water till May 15. This preventive has another advantage. (See p. 12).

On bogs bared of the winter water early and with plentiful water supplies: If the net count (p. 3) calls for it, flood about May 18 for ten hours. Seven hours is enough in windy weather. If the net count is equivalent to not more than twelve cutworms to fifty sweeps, this treatment may be put off till late May or early June when it will check other pests also; but this is not advocated.

SPRAYING OR DUSTING

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water in mid-May is effective. It will not check the worms after they are half grown.

Spraying with 3 pounds of 50 percent wettable DDT in 100 gallons of water, 300 gallons to an acre, or dusting with 50 pounds of 5 percent DDT is effective at any time and also controls gypsy moth caterpillars and the cranberry weevil.

Spraying with 6 pounds of cryolite in 100 gallons of water, 400 gallons to an acre, or dusting with 50 pounds of cryolite to an acre, May 20 to 25, is effective and also makes a good blanket control for the blossom worm, the gypsy moth, and the weevil.

BAITING

A poisoned bait may be used to reduce serious infestations of any of the cutworms discussed in this paper. The formula for its preparation is: Wheat bran 25 pounds, sodium fluosilicate 1 pound, water enough to moisten. Mix the dry bran and fluosilicate thoroughly with the hands, then add the water gradually and stir till the bait is dampened throughout but not too wet to crumble and spread readily. This amount of material should be broadcasted by hand over an acre at sunset. The bait is not effective after it gets stale or has been soaked by rain, so a second application three or four days after the first is often advisable.

Cranberry Blossom Worm [25]

This is a minor cranberry pest in Massachusetts but more important in New Jersey. It is not known to harm bogs elsewhere. It often destroys the crop promise entirely on a small area here and there on the Cape. It is confined to bogs not reflooded regularly in late May or June or after picking.

Distribution and Food Plants

This insect ranges through the Northeastern States from Maine to Illinois. It feeds on blueberry and is said to attack leather leaf also.

Character of Injury

The young worms first nibble the leaves, especially at the margin, or bore into the buds and so spoil them for fruit production. As they grow, they nip off the buds and flowers, dropping them to the ground. They rarely cut off the leaves much, differing in this from the spotted cutworm and the armyworm. They work very little in the daytime after they are half grown. Each worm that matures destroys fully one hundred cranberry blossoms.

Description and Seasonal History

THE EGG

Most of the eggs are laid in October. They are pale yellow at first but soon turn dingy brown. They are fastened singly to fallen leaves (fig. 25) or pieces of dead vine littering the bog floor. They pass the winter, the bog flowage not harming them even when held fairly late. They usually begin to hatch somewhat after the middle of May on bogs drained in April, and hatch mostly in late May and early June where the winter flood has been held till after mid-May.

CRANBERRY BLOSSOM WORM
Fig. 25. Eggs on fallen leaves.

THE WORM

The worms in their early growth are usually considerably green on the front half or so of the back. After they pass their first stages (Plate Two, figs. 4a and 4b), they are reddish brown, with the head light mottled brown and with a whitish stripe along each side of the smooth and well-rounded body. They mature early in July on bogs bared of the winter flood early. They then become pale brown, often look somewhat bloated and act torpid and are nearly an inch and a half long (Plate Two, figs. 3a and 3b). They soon enter the ground or deep trash to remain dormant two to four weeks before pupating.

THE PUPA

Pupation normally occurs in late July and early August, usually in a cell slightly below the surface of the ground. The pupa is brown and about five-eighths of an inch long. It is enclosed in a loose and indefinite cocoon of silk and sand. The moths emerge during September and are active till late November. Pupation may take place in August or early September and the moths emerge in late September and early October on bogs drained of the winter water late.

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[25] *Epiglaea apiata* (Gr.). Some growers call it the "bud worm."

THE MOTH

The moths vary greatly in color. Some (Plate One, fig. 8a) are brownish gray; others (Plate One, fig. 8b) are fox red above and somewhat lighter below. The front wings are crossed by a few fine lines and there are two characteristic subcircular markings placed lengthwise on the middle of the front part of each. The main part of the body is tufted heavily with hair. The wings expand about an inch and a half. The females lay from one hundred to two hundred eggs each. The males fly well and often.

Treatment

FLOODING

The flooding late in May advocated for control of the gypsy moth will destroy this pest if the winter water has been let off in April; and flooding for ten hours about June 10 checks it anyway.

SPRAYING OR DUSTING

A spray of 6 pounds of dry lead arsenate or 6 pounds of cryolite in 100 gallons of water, 300 gallons to the acre, is effective if applied before the worms are half grown. Dusting with 50 pounds of cryolite per acre is also advocated.

BAITING—See page 26.

Spotted Cutworm [26]

For many years this insect has been known to injure small areas of bog on Cape Cod occasionally, but it has not been reported as a cranberry pest elsewhere. There was a marked outbreak in 1923, two hundred acres or more of bog in various parts of the Cape being so badly infested as to lose most of the prospective crop, and a few of the worms and scattering marks of their work being found on most bogs.

Distribution and Food Plants

The spotted cutworm was brought into this country from Eurasia many years ago and now ranges from New England and Canada to Virginia, southern Missouri, Arizona, and the Pacific coast of Oregon and Washington.

It is a very pernicious pest of vegetable and forage crops. The following are some of its food plants: apple, beet, blueberry, cabbage, carrot, celery, chicory, chickweed, clover, corn, cranberry, currant, ferns, goldenrod, grass, Helianthus, lettuce, Lobelia, maple, onion, pear, rhubarb, spinach, strawberry, sweet fern, tobacco, tomato, violet, and wheat.

Character of Injury

In 1923 this insect did much harm on a few acres of one bog bared of its winter flood in April. With this exception, it has been known to attack severely only bogs drained of the winter water between May 26 and June 8. It generally works more on Howes vines than on Early Black. The worms work almost entirely at night. They nip off the blossom buds, flowers, and small berries, severing the stem near where it joins the ovary (fig. 26), and are most active during the blooming. They also excavate partly grown berries (fig. 27) much as katydids do, and cut off many leaves by severing the petiole, apparently eating little of the tissue. The fallen green leaves are seen first in and along the bog ditches and later everywhere under much infested vines. Severe infestations sometimes so defoliate small areas that the bare uprights give the vines a brown tinge at a distance.

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[26] ***Amathes c-nigrum*** (L.).

Description and Seasonal History

The worms live through the winter and pupate in May. The moths emerge in late May and early June and soon lay eggs. The worms that hatch from them mature in late July and early August. They pupate in the soil at depths of one to four inches, usually from the last of July to late August. The pupal stage averages about nineteen days, the second brood of moths emerging from mid-August to mid-September. These moths lay mostly in early September, the eggs hatching in about two weeks to produce the worms that winter.

THE EGG

The eggs are laid in rows or compact masses, one moth laying two hundred or more.

THE WORM

The young worms are pale at first, but they assume their mature coloration before they are half grown. The mature worm (Plate Two, figs. 2a and 2b) is about an inch and a half long and dull gray or brown with greenish or olive-brown tints. It has a whitish stripe along each side and two to four rather conspicuous angular, blackish spots in a row on each side of the hind part of the back. The head is light yellowish brown with a color network of darker brown.

THE PUPA

This is mahogany brown and about three-fourths of an inch long.

THE MOTH

The moth (Plate One, fig. 11) expands about an inch and a half. Its back between the wing bases is reddish sooty gray, with a pale gray or whitish collar in front. The upper side of the abdomen is light brown. The under side of the body is dark gray, with light gray or even whitish sometimes prevailing on the sides and hind part of the chest. The forewings are mostly dull brown above, usually tinged slightly with reddish or bluish. Each has a conspicuous triangular pale patch reaching back from near the middle of its front margin and nearly dividing an equally noticeable dark brown area, also some blackish markings toward the base and a blackish spot toward the outer end and running back from the front margin. The under side of the forewings is light brown. The hind wings are whitish with brown shadings.

Treatment

FLOODING

On bogs that cannot be reflooded.—Prevention: Let off the winter water before May 23.

On bogs that can be reflooded.—If the net count (p. 3) shows treatment is necessary, flood for ten hours at night.

SPRAYING

Spraying bogs while the worms are small never has been fairly tried. A spray of 6 pounds of dry lead arsenate in 100 gallons of water should be effective. The worms are hard to poison after they are half grown.

BAITING

See page 26.

SPOTTED CUTWORM

Fig. 26. Cranberry uprights from which worms have nipped flowers and berries.
Fig. 27. Work of worms.

Black Cutworm [27]

This pest often attacks cranberry bogs seriously when the winter flood has been held till late May or later; also commonly in late July and early August after removal of the long late-spring and early-summer grub reflow. In both Massachusetts and Washington, it also sometimes harms new plantings seriously by girdling vines in the hills at the surface of the ground. The small worms usually begin to appear eleven or twelve days after the water is let off. The black cutworm sometimes works with the spotted cutworm and also with the armyworm and with the fall armyworm.

Distribution and Food Plants

Important outbreaks of this pest have occurred in Arkansas, Indiana, Oregon and India,[28] on lands which, having been overflowed, became drained at a time favorable to egg-laying by the moths. It inhabits nearly the whole civilized world. Apple, asparagus, bean, beet, cabbage, chicory, cotton, corn, grape, grass, onion, potato, spinach, squash, strawberry, tobacco, and tomato are among its food plants. The worms devour each other and spotted cutworms greedily.

Character of Injury

This worm works on cranberry vines much as the armyworm does (p. 32).

Description and Seasonal History

The life history here has not been traced thoroughly. There seems to be much irregularity in it. The insect winters as a worm in various stages of growth and sometimes as a pupa. The moths are active from late May till late October. There are probably two broods in this State, the moths of the first being most abundant in June and July and those of the second in August and September. Egg laying occurs in June and July—probably throughout most of those months.

THE WORM

In its early life this caterpillar usually is mostly a rather indefinite greenish brown or gray in color, the green element being due to the food in the worm rather than to dermic pigment. When more mature (Plate Two, fig. 5), it is mostly dark brown or sooty gray on the back and sides and grayish below. A rather indefinite and inconspicuous broad stripe of somewhat lighter brown usually runs along the back. The head, the neck shield, and the spiracles are mostly black. There are 6 to 8 instars.

These worms have a peculiar disgusting appearance that has been described as "greasy." They are about an inch and a half long when mature and often are very active in the afternoon.

THE MOTH

The moth (Plate One, fig. 10) expands nearly one and three-fourths inches. The head is mostly reddish brown. The collar is sooty gray with a transverse line of black. The front part of the back is sooty gray. The breast is light gray. The hind part of the body is pale brownish above and light gray below. The forewings are mostly sooty above with a few inconspicuous black markings, the outer third of each being light brown. They are pale brownish underneath. The hindwings are pale with brown shades toward the margins.

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27 *Agrotis ypsilon* (Rott.). Also known as the "greasy cutworm."

28 Rockwood, L. P., Jour. Econ. Ent. 18 (5):717, 1925.

Treatment

FLOODING

On bogs that cannot be reflooded.—Prevention: let off the winter water before May 20.

On bogs that can be reflooded—Flood for ten hours at night as soon as the net count (p. 3) shows it is necessary.

SPRAYING OR DUSTING

Spraying with 6 pounds of lead arsenate or 3 pounds of 50 percent wettable DDT in 100 gallons of water, 300 gallons to the acre, is effective while the worms are small.

Dusting with 50 pounds of 10 percent DDT to an acre is advocated.

BAITING—See page 26.

ARMYWORM [29]

This notorious cutworm infests bogs after late draining of the winter water oftener than the others. It may begin its attack within eight days after the removal of this flood if the water is let off any time between about May 20 and about July 10. It never harms a bog drained early unless it is very grassy or is reflooded for ten days or longer in late May.

The moths seem to fly at times with the prevailing winds for many miles in great numbers and alight in a body to lay their eggs in a place favorable to the development of the worms. This accounts for the sudden appearance of this insect in regions remote from any known source of infestation. A few of the moths appear every year over most of the area in which it occurs, but this does not explain the sudden great invasions that come from time to time. It was very abundant in the Cape cranberry region in 1914 and 1919.

Armyworm outbreaks nearly always start in the Southern States. They are noted there by the Bureau of Entomology of the United States Department of Agriculture, which predicts their spread into the North. They are more common after cold, backward springs.

The armyworm feeds mostly in low meadows and among rank-growing grasses. Its movement in armies is not normal, but follows an exhaustion of food which compels it to spread to other places.

Distribution and Food Plants

This originally was an American insect, but now it inhabits most of the world. It prefers grasses, both wild and cultivated, and the grains, such as barley, corn, millet, oats, rye, and wheat. When pressed with hunger a little, it attacks alfalfa, apple, bean, beet, cabbage, cauliflower, clover, cranberry, cucumber, flax, lettuce, parsley, pea, pepper, strawberry, sweet potato, watermelon, and other plants.

Character of Injury

The worms nip off the cranberry leaves more freely than blossom worms and spotted cutworms do, sometimes nearly defoliating the vines. They also commonly cut new uprights nearly off, so that they break over and hang by a thread. They feed mostly at night and on cloudy days, but also travel and feed a good deal in bright weather.

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[29] *Cirphis unipuncta* (Haw.).

Description and Seasonal History

The life history of the armyworm has not been traced thoroughly, for it varies widely in different parts of the country. It seems to have six broods in the South and two in New England. It appears to winter here as a partly grown caterpillar, but probably survives only our mildest winters. The worms mature in the spring and go an inch or more into the soil to pupate. The pupal stage lasts two weeks or longer, and the moths emerge from the ground and fly at night, laying eggs for the next brood. These hatch in a week to ten days. The worms mature in about a month, go into the ground, pupate late in July, and become moths as described for the first brood. The moths appear in August and lay their eggs, and the caterpillars from these hibernate.

It will be seen that the worms feed in the fall and early spring in one brood and in the summer in another. The latter only is destructive.

THE EGG

The eggs are laid in rows or masses of ten to fifty, mostly in the leaf sheaths of grasses and grains or on stubble or straw, usually in moist or shaded spots, and covered with a gelatinous substance. Each moth commonly lays five to six hundred.

THE WORM

The young worms loop like spanworms and spin down on silken threads but soon lose these habits. The maturing caterpillar (Plate Two, figs. 1a and 1b) is smooth and rather dark. A broad dark brown stripe runs the length of the back and usually is divided by a broken pale line running along its middle. At each side of the dark back stripe is a narrower reddish yellow one, then a dark one, and lastly another reddish yellow one. These colors vary somewhat. The stripes are separated by pale yellow lines. The under side of the body is pale greenish brown. The spiracles are black. Each proleg of the four anterior pairs has a noticeable deep brown stripe across the middle of its outer side. The head is yellowish brown with a color network of darker brown. The mature worm is about an inch and a half long.

THE PUPA

This is reddish or chestnut brown at first, becoming blackish before the moth emerges.

THE MOTH

Swarms of the moths often appear about street lights shortly before an outbreak of the worms. Cranberry men sometimes may be warned by this and should know the moth at sight. It usually spreads about an inch and five-eighths and is plain light brown (Plate One, fig. 12). Each forewing has a white speck near the center of the upper surface and a dark shade running back obliquely from the outer angle.

The moths live on the nectar of flowers and the honeydew of certain insects, and sometimes many may be caught with sweet baits at night. As they rarely lay eggs near where they have developed and often fly many miles before doing so, there seldom are two outbreaks a year in any one locality.

Treatment

FLOODING

On bogs that cannot be reflooded.—Consult the Bureau of Entomology of the United States Department of Agriculture as to the probability of an army-worm invasion. If an outbreak is predicted, do not hold the winter water after May 20.

On bogs that can be reflooded.—Flood for ten hours at night as soon as the net count (page 3) shows treatment is necessary.

SPRAYING OR DUSTING

What has been said of the black cutworm in regard to spraying and dusting applies to this worm also.

BAITING—See page 26.

Fall Armyworm [30]

This insect worked havoc in New Jersey in 1916[31] on several bogs bared of their winter water in mid-July. It sometimes injures grasses greatly on Cape Cod, and it appeared in damaging numbers on several widely separated bogs there in late July and early August, 1948, after removal of summer root-grub flowages. It attacks later than the other cranberry cutworms and is the only one, except the black cutworm, likely ever to infest a Cape bog seriously when a long flood is let off after July 20. It will not attack a bog drained much before July.

Distribution and Food Plants

This pest occurs yearly in Central America, Mexico, the West Indies, and South America and its worst outbreaks may originate in those regions. It is evidently a native of tropical or subtropical America. Apparently it cannot survive the winter north of southern Georgia or central Texas. In the years of its great abundance in the South great numbers of the moths fly northward, sometimes for hundreds of miles, and lay their eggs. These hatch and the worms develop into moths which again fly northward before laying. In this way the insect in favorable summers spreads over most of the eastern two-thirds of the United States and even to Canada before fall frosts halt it. It sometimes does immense damage to crops throughout this range. Its favorite food plants are grasses such as quack or crab grass, Bermuda grass, blue grass, Johnson grass, etc. It seriously injures alfalfa, clover, corn, cotton, cowpea, kafir, millet, oats, rice, sorghum, sugar cane, and wheat. It sometimes attacks beet, bean, buckwheat, cabbage, grape, pecan, pepper, peanut, potato, sweet potato, strawberry, spinach, tobacco, tomato, turnip, and other plants. In greenhouses, it is destructive to gladiolus, chrysanthemum, geranium, and dahlia.

The worms eagerly devour cutworms of their own and other species. They work rather freely in the daytime, even in sunny weather.

There usually are five broods a year in the Gulf States, but only one appears in any one place in the North.

When Outbreaks may be Expected

General invasions of this pest occur nearly always after cold, wet springs. In parts of the Mississippi Valley it is called the "overflow worm," for the farmers attribute its outbreaks to the overflowing of the great river. There is evidence to support this belief. Cold and dampness seem to destroy the insect enemies that ordinarily control the pest but do not harm the worm itself. This may explain the outbreaks that occur almost yearly in scattered places in the South after periods of heavy local rains.

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[30] *Laphygma frugiperda* (S. & A.).

[31] Proc. Amer. Cranberry Growers' Assoc. 47, p. 11, 1917.

Character of Injury

The work of this insect is like that of the armyworm (page 32).

Description

THE EGG

The moths lay their eggs mostly at night, in masses of from fifty to five hundred, preferably on grass blades, though they may place them on any plant suitable as food for the young worms. Low-lying fields of grass or small grains often are chosen for this, so the outbreaks usually begin on bottom land. Sometimes the eggs are laid on lawns. They are light gray and always are covered with grayish down from the moth's body. Each egg is much flattened at the base. This stage lasts a week or more in the Northern States.

THE WORM

The newly hatched caterpillar has a black head and whitish body. As they mature, the worms (Plate Two, figs. 8a and 8b) much resemble armyworms and vary greatly in color. The body is striped lengthwise on a ground color varying from buff to dull gray or nearly black. A pale yellow line divides lengthwise the broad mottled-buff stripe covering most of the back. On each side of this broad stripe is a light line, then a dark stripe, and lastly—down toward the legs—a light yellow stripe mottled with reddish. The under side is pale, varying from buff to green, and often tinged with red, especially toward the sides. Tubercles, each with one hair, appear plainly as dark dots, particularly along the back. The head is rather light brown to almost black, is mottled with pale yellow, and always has an inverted, though not conspicuous, white "Y" on the face. The cervical shield varies from light brown to nearly black. The worm matures in about four weeks in the North, becoming an inch and a quarter long.

THE PUPA

The pupa is formed in a cell an inch or so in the ground. It is like that of the armyworm but a little smaller, being one-half to three-fourths of an inch long. It is light green at first but soon turns light brown and finally dark brown. The spiracles with areas partly surrounding them usually appear as dark spots along the sides.

THE MOTH

The moth expands from an inch to one and three-eighths inches and has a pale-brown body. The forewings of some specimens (Plate One, fig. 9) are mottled brown, with one whitish area near the tip and another running back obliquely from near the middle of the front margin; those of others are uniformly dark grayish brown. The hindwings are whitish with a pearly or pinkish luster and edged with smoky brown. An erect tuft of scales on each side of the hind end of the dorsum of the thorax and a similar tuft on the middle of the base of the dorsum of the abdomen are noticeable. A row of dark spots runs along each side of the venter.

The moths are strongly attracted to lights.

Treatment

FLOODING

On bogs that cannot be reflooded.—The Bureau of Entomology of the United States Department of Agriculture notes the more severe outbreaks of this pest in the South and predicts their spread into the North. Growers planning to hold flowage till July should consult the Bureau as to the chance of an invasion.

On bogs that can be reflooded.—Flood for ten hours as soon as the net count (see page 3) shows it is necessary.

SPRAYING OR DUSTING

Spraying with lead arsenate is a standard control in the South. Dust with a 10 percent DDT dust, 50 pounds to the acre.

BAITING—See page 26.

SPANWORMS

These insects, known also as loopers and inchworms, have a striking way of crawling. They stretch out at full length, take hold with the front legs, and then bring forward the hind end close to the front pairs of feet, the body between bending well up out of the way. This habit is due to the lack of several legs that other caterpillars have to support the middle of the body. The hind part has only two pairs of legs.

These worms are more slender than most caterpillars. They are hairless and feed openly, never sewing leaves together. When disturbed they cling to their support by the hind pairs of legs and remain straight and motionless. As they usually are colored to harmonize with their habitual surroundings and often resemble short or broken twigs, this habit tends to save them from their enemies.

These insects commonly attack bogs here and there in Massachusetts, but have rarely been reported as doing so elsewhere. The kinds seen most on the bogs may be distinguished by the following table:

Body mostly pale yellowish or pinkish, with a reddish herringbone stripe along the back........*Eupithecia miserulata* Gr.[32]

Body mostly yellow........chain-spotted geometer (p. 44).

Body mostly green........green cranberry spanworm (p. 38).

Body mostly brown or gray........1

1. With a row of conspicuous irregular reddish-yellow spots along each side........half-winged geometer.[33]

   Not thus marked........2

2. With a pair of noticeable tubercles a little way from the middle of the back........3

   Without such tubercles........brown cranberry spanworm (p. 39).

3. The tubercles in front of the middle of the back........cotton spanworm (p. 42)

   The tubercles behind the middle of the back—big cranberry spanworm (p. 43).

The green cranberry spanworm and the brown cranberry spanworm are far more important pests than the others, and when either of them becomes prevalent it usually stays with the bog year after year till it is treated. They seem never to harm dry bogs much. They attack mostly bogs flowed during the winter and not reflooded much in June. If they are once thoroughly eliminated from a bog, their presence in destructive abundance need not be feared again for several years. Growers should know the moths of these two species, for their abundance indicates coming trouble.

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[32] An unimportant worm that often eats into the green berries and into meadow beauty flower buds.

[33] *Phigalia titea* (Cramer). An unimportant worm, nearly an inch and a half long when mature, rather common in late May and the first half of June on dry bogs and bogs that are not reflooded. It also attacks swamp blueberry, apple, beech, birch, cherry, maple, rose, and elm. Mass. Agr. Expt. Sta. Bul. 339:36, 1937.

GREEN CRANBERRY SPANWORM

Fig. 28. Cranberry uprights from which worms had nipped flowers and berries.
Fig. 29. Egg on litter from bog floor. Much enlarged.

Green Cranberry Spanworm [34]

This species occurs in limited numbers on most Cape Cod bogs and does considerable harm nearly every year. It broke out on many bogs in 1920 and 1921, destroying the entire crop promise on a large acreage. Growers of long experience said it had been similarly prevalent for a time some twenty years before.

Distribution and Food Plants

This moth ranges from Nova Scotia to British Columbia and has been found in Massachusetts, New York, New Jersey, and Wisconsin. No food plant besides cranberry is known.

Character of Injury

When the winter flowage is held till mid- or late May, some of the worms hatch in time to eat into terminal buds like false armyworms (fig. 22). They seldom do much harm in this way. They usually work like the blossom worm, nipping off flower buds and blossoms by severing the stem near where it joins the ovary (fig. 28). When extremely abundant they attack the leaves and sometimes brown a small area.

Description and Seasonal History

THE EGG

There is one brood a year. In late June, July, and early August the female moths scatter their eggs singly among the litter under the vines, laying about 125 each. They usually stick to fallen leaves or pieces of dead twigs (fig. 29). They are greenish white, elliptical, and about a thirty-seventh of an inch long. They are surprisingly rigid and unyielding as they come from the moth's body and, when examined with a microscope, are seen to be thickly studded, except more or less on a central area above and below, with minute round smooth white tubercles (fig. 30). They often become somewhat sunken in the middle as hatching approaches. The winter flood does not harm them even when held late. When it is let off in April, hatching begins from about May 15 to about June 1, depending on the advancement of the season, and may continue till about July 1.

GREEN CRANBERRY SPANWORM
Fig. 30. One egg. Greatly enlarged.

THE WORM

During most of their life the worms (Plate Three, figs. 3 and 4a) are green with several white lines along the back and sides and a narrow light yellow stripe along each side. In their last stage (Plate Three, fig. 4b) the green has a yellow tinge and the whitish lines are obscure except for a pair along each side of the back which often are more marked. They mature from about June 10 to about July 22, becoming an inch long.

[34] *Itame sulphurea* (Pack.).

THE PUPA

The worms pupate in the litter under the vines. The pupa is pale greenish at first but becomes dark brown as the moth develops. It is about a third of an inch long. This stage lasts about ten days.

THE MOTH

The moths emerge irregularly from late June till early August, the males tending to appear first. The male (Plate Three, fig. 2) is pale yellowish. Its head bears long pectinate feelers. Its wings expand a little over an inch.

The female (Plate Three, fig. 1) is sulfur yellow and expands about seven-eighths of an inch. Its wings have noticeable brown spots which vary, but commonly are arranged as follows: The upper surface of each front wing with three against the front margin, one against the hind margin, one in front of the center, and five to seven small ones along the outer border; the under side of the front wing with one in front of the center, some small ones along the outer border, and a streak toward the outer end and parallel with the outer border; the upper side of each hind wing with a spot in front of the center, another against the hind margin, and several toward and on the outer border; the under side of the hind wing with one near the center and often a series running parallel with the outer border. All the wings have brown sprinklings on the under side, and the outer borders on fresh specimens have brown fringes. The moths brush off many of their scales, often losing their markings and even their yellow color. The feelers on the head are threadlike.

The males are more active than the females, but they rest much among the vines, flying less than the males of the brown spanworm. They are flushed up easily and sometimes rise in clouds from a badly infested area. The period of activity of the moths coincides with that of the brown spanworm caterpillars, and when both species abound on the same area, they often are confused in the minds of growers.

Treatment

Reflooding for ten hours and spraying with 6 pounds of dry lead arsenate in 100 gallons of water, 300 gallons to the acre, are both very effective. Three treatments, about May 30, June 12, and June 25, may be necessary because of the long hatching period. The first, especially if flooding is done, often will check other pests also, especially the gypsy moth, the black-headed fireworm, the false armyworm, and the blossom worm. If the infestation is only mildly serious, two treatments, about June 5 and June 25, will suffice.

Regular resanding tends to keep this pest out, for the sand covers many of the eggs so that the worms fail to emerge.

Brown Cranberry Spanworm [35]

This insect attacks some Massachusetts bog severely almost every year. It broke out on so many in 1919 and 1920 that it was one of the most important cranberry pests. It does more harm than all the other bog spanworms together.

Distribution and Food Plants

This insect inhabits Nova Scotia, the New England States, New York, Michigan, Wisconsin, Colorado, Alberta, and Alaska. Its known food plants beside cranberry are: chokeberry, steeple bush, trailing bramble, black huckleberry, swamp blueberry, sheep laurel, leather leaf, sweet pepperbush, white swamp honeysuckle, bearberry,

[35] *Ematurga amitaria* (Gn.). Also known in cranberry literature as *Epelis truncataria* var. *faxonii*.

red maple, scrub oak, willow, wool grass, cotton grass, Juncus rush, lance-leaved violet, swamp loosestrife, marsh St. John's-wort, bugle weed, saw brier, loosestrife, gray birch, and bayberry, the twelve first-named being attacked most.

Character of Injury

Moderate infestations work much like the green spanworm, nipping off the blossoms and small berries, but they attack the leaves more and chew into and eat holes through the flower buds and often excavate the partly grown berries much as katydids do. A severe infestation sometimes turns a whole bog brown and then many of the worms die of starvation.

This worm works so late in the season that when its attack is severe it destroys all chances of a crop in the following year, and sometimes patches of vines fail to recover fully for a year or two.

Description and Seasonal History

THE PUPA

The pupae winter among the litter under the vines, enduring the winter flood even when it is held till June. They are brown and somewhat over three-eighths of an inch long and have no cocoon.

THE MOTH

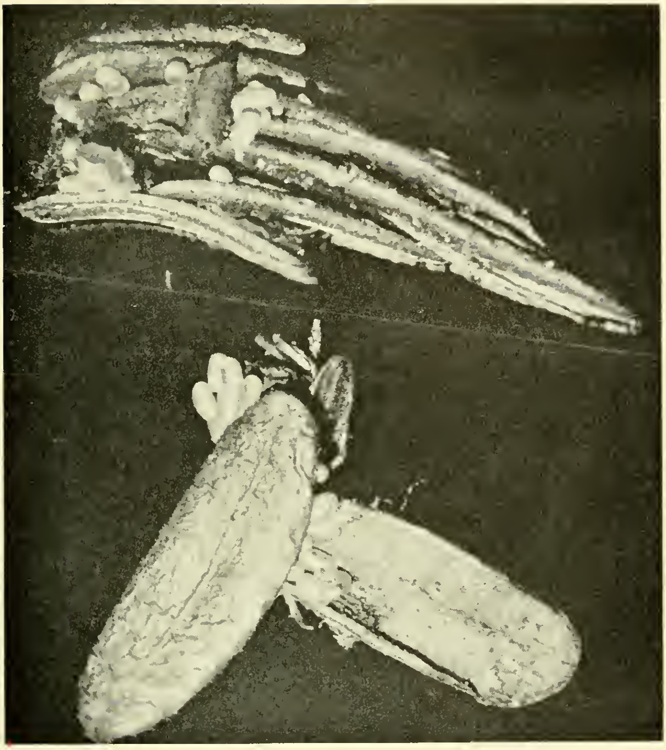
If the winter flood is let off before May 1 and the season is warm, a few of the moths often appear late in May, but they usually emerge mostly during the first half of June and are active till toward its end. Where the winter water is held till late May they emerge mostly in late June and fly into July. They are noticeably protandrous in emerging. The males fly freely, often swarming in clouds over badly infested areas; but the females, heavy with eggs, can only flop along the ground.

The female (Plate Three, fig. 5) is a finely sprinkled grayish or yellowish brown. The wings have vague and variable brown and whitish markings and the hind ones much yellow also on their upper surfaces; and are mostly yellow or yellow and white underneath with liberal general sprinklings of brown. On both their upper and lower surfaces they usually have two or three poorly defined and often more or less broken brown markings running from the front to the hind margin. The back, especially between the bases of the wings, is mostly dingy brown, and the scales on the under side of the body and on the legs are mainly pale yellow. The antennae are threadlike. The wings spread nearly an inch.

The male (Plate Three, fig. 6) spreads somewhat over an inch. The body and head above and the large bushy antennae are dingy brown with a sprinkling of pale yellow. Underneath, the body, head, and legs are clothed mostly with light yellow hair and scales. The front wings are coffee brown above with two or three indefinite and irregular darker brown markings running from the front to the hind margin of each and often with touches of white. The hind wings are mostly deep yellow above with a strong general sprinkling and three rather vague cross markings of brown and with the outer border brownish. Beneath, the wings are deep yellow with a general sprinkling and usually two irregular cross markings of brown.

THE EGG

The female moths lay about three hundred eggs each. They thoroughly hide nearly all of them among the litter on the bog floor, mostly in irregular clusters of sometimes as many as twenty (fig. 31). The eggs are elliptical and about a twenty-seventh of an inch long. They are light green at first but turn yellow. If the winter flood has been let off early, they usually begin to hatch about July 1, but sometimes in advanced seasons by June 20.



BROWN CRANBERRY SPANWORM
Fig. 31. Eggs among litter from bog floor. Much enlarged.

THE WORM

In its early stages the worm is rather light brown with a whitish stripe along each side and another along the middle of the back. The latter tends to persist but becomes obscure as growth proceeds.

The mature worm (Plate Three, figs. 7a, 7b, 8a and 8b) is somewhat over an inch long and is grayish brown, varying greatly in shade, the under half being lighter than the back and the back often having various indefinite markings of darker brown. A whitish stripe often runs along each side just below the spiracles. The spiracles are orange-brown, rimmed with dark brown. The body has no noticeable tubercles and is covered with a fine whitish or sometimes partly brown scurf, seen only with a good lens. The head is indented only slightly and is chestnut brown, commonly marked with darker brown across the top.

The worms mature in late July and early August and change into the pupae that pass the winter.

Treatment

June reflooding interferes enough with the progress of the moths onto a bog and their egg laying there to prevent the development of an infestation where it is practiced regularly. Complete flooding for thirty-six hours as soon as the moths reach the height of their flight often very nearly eradicates a bad infestation, but this cannot be relied on.

It seldom is practicable to flood a bog when the worms are active. A spray of 6 pounds of dry lead arsenate in 100 gallons of water, 300 gallons to the acre, is very effective, especially if applied while the worms are hatching. A second application five to seven days after the first is often necessary.

If the moths have been flying in great numbers, the vines should be examined with an insect net daily from about June 20 till the worms begin to hatch. Then spraying should begin at once and all the infested area be treated in two days, even if it takes several spraying outfits. These worms sometimes give a net count of over 2000 to 50 sweeps, and such an infestation can destroy a fine crop promise within a week after hatching begins.

Cotton Spanworm [36]

The late J. B. Smith gave us what we know of this species on cranberry bogs. He found it in 1883 infesting severely a bog in Cotuit[37]. There is little evidence that it attacked other bogs or has appeared as a cranberry feeder at any other time. Its attack probably was due to unusual abundance, for it broke out as a strawberry pest in Illinois the same year. As it may appear on bogs again, it is discussed here.

Distribution and Food Plants

This spanworm ranges over most of this country east of the Rocky Mountains. It feeds on apple, ash, asparagus, blackberry, clover, cotton, cranberry, elm, geranium, guava, hickory, honey locust, maple, orange, pear, poplar, strawberry, willow, and yellow dock. It attacks asparagus and cotton oftenest.

Character of Injury

The first brood starts near the edge of a bog. The second starts from inside centers where groups of eggs have been laid. The worms were so abundant in the recorded infestation that they browned quite an area. They advanced in masses like armyworms.

Description and Seasonal History

The worms first appear in June and mature late in that month or early in July. They are then about an inch and an eighth long and vary from yellowish to brown or livid gray, being streaked and mottled with lighter and darker shades. There are two low black tubercles on the back about a third of the length back from the head and two smaller ones near the hind end. The head is marked with irregular black cross bands.

The worms go into the ground a little and change into rough brown pupae about half an inch long from which the moths emerge in nearly two weeks.

The caterpillars of the second brood mature in August, beginning to pupate before the ninth but continuing to abound till after the middle of the month. The moths appear at the end of August and in September.

The moth (Plate Three, fig. 12) varies considerably in size, color, and markings. Its wing expanse is from a little less than an inch to nearly an inch and a half. It is ash gray and the wings are crossed by irregular brown lines. The first abdominal segment is white above. The antennae of the female are threadlike, those of the male pectinate.

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[36] *Anavitrinella pampinaria* (Gn.). This insect is officially known as the cranberry spanworm, but there is no sound reason why it should be.

[37] U. S. Dept. Agr., Div. Ent., Bul. 4 (O.S.), pp. 26-28, 1884.

Treatment

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water is advocated.

Big Cranberry Spanworm [38]

Some growers say this species is destructive on considerable areas on rare occasions. A few of the worms often occur on the bogs and sometimes defoliate small patches. They prefer to sever the flower buds and blossoms.

Distribution and Food Plants

The insect ranges from Canada to Florida and Missouri. It feeds on apple, clematis, cranberry, false dandelion, hickory, maple, pear, live oak, and white oak.

Description and Seasonal History

This species winters as a pupa. The moths emerge late in May and soon lay their eggs. These hatch toward mid-June. The worms mature and pupate in July. There is but one brood a year.

THE EGG

The eggs are laid in clusters, often of as many as 432. They are green at first but turn reddish, then black—the last color only two or three days before hatching.

THE WORM

The caterpillars are almost black at first, but as they grow they become chocolate brown. The mature worm (Plate Three, fig. 9) is fully two and a half inches long. Most of its surface is very smooth. A noticeable dark ridge bearing a few low tubercles crosses the back opposite the second pair of legs. The back in front of this ridge and the head are lighter brown than most of the body. The under side between the legs at the hind end is lighter still. The spiracles are yellow, rimmed with black. On the back there are a pair of noticeable tubercles somewhat behind the middle and a moderate double tubercle toward the hind end. The top of the head is rounded and not much indented.

THE PUPA

The pupa (Plate Three, fig. 10) is somewhat over three-fourths of an inch long and a fourth of an inch thick. It is coffee brown and, with the exception of the wing cases, has an irregular sprinkling of dark brown. The spiracles and their surroundings appear as conspicuous black spots along the sides. The surface is dull and rough. This pupa never gets hard and firm as most pupae do, but always yields to the touch.

THE MOTH

The moth (Plate Three, fig. 11) is light gray, dully variegated with rusty brown. The wings, the abdomen, and the legs are sprinkled lightly with black scales. The thorax is whitish beneath and pale brown above. The head is light rusty brown, with the top between the bases of the feelers pure white.

The wings spread about two inches. Their outer edges are irregular and the tips of the front ones are sharp-pointed. A nearly straight line running from near the tip of each forewing diagonally across its upper surface to the hind margin is whitish on the outer side and brown on the side toward the body. A similar line runs part way across the upper surface of each hindwing from beyond the middle of the hind margin. All the wings have a conspicuous dark brown speck somewhat back from the middle of the front margin on each surface.

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[38] *Abbotana clemataria* (S. & A.).

Treatment

Because of the size which these worms attain, their net count should rate as that of cutworms (see page 3). A spray of 6 pounds of dry lead arsenate in 100 gallons of water, 300 gallons to the acre, should be used when they hatch.

Chain-Spotted Geometer [39]

Neglected bogs with a dense growth of birches on the surrounding upland, usually areas that never are flooded, occasionally have this spanworm crawl onto them in such numbers that the vines are browned for some distance from the margin. The worms often are reduced greatly by parasites and a fungus disease.[40] A few of them appear on most dry bogs yearly. Severe local outbreaks occurred in the Cape Cod cranberry region in 1927 and 1934.

CHAIN-SPOTTED GEOMETER

Fig. 32. Worm. Much enlarged.

Distribution and Food Plants

This species ranges through the Atlantic States and southeastern Canada and west to Colorado. Gray birch seems to be its favorite food plant, but it often defoliates alder, ash, low blueberry, dwarf blueberry, swamp blueberry, male berry, wild black cherry, bayberry, sweet fern, black huckleberry, dangleberry, wild indigo[41], red maple, white maple, witherod, sheep laurel, scrub oak, meadow-sweet, poplar, red spruce, tamarack, white pine and willow. It also feeds on raspberry, blackberry, beach plum, locust, goldenrod, sweet gale, hazelnut, poison ivy, juniper, apple, pear, cranberry, rhodora, sedges, grasses, and other plants. It sometimes is an important pest in the blueberry fields of Maine.

Description and Seasonal History

THE WORM

The worms appear in early summer and develop slowly, maturing in late July and early August. They get to be nearly an inch and a half long. As they mature they have the habit of hanging straight and still, head downward (fig. 32), during the day. They seem to feed mostly in the evening or at night. They are yellow, with round black spots on the head, the neck shield, the outer sides of the prolegs, and the very hind end. About thirty-two deep rusty-brown lines run along the body, some above, some below. There is a row of conspicuous white spots along each side, mostly above the spiracles, most of them bordered with one black spot in front and another behind.

THE PUPA

The worms pupate in early and mid-August. The pupa is white, marked with black and yellow,

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[39] *Cingilia catenaria* (Dru.).

[40] Caused by *Entomophthora aulicae* (Reich.).

[41] *Baptisia tinctoria* (L.) R. Br.

PLATE THREE

Spanworms and Harmless Insects Sometimes Mistaken for Them

GREEN CRANBERRY SPANWORM*:

Fig. 1.—Female moth.
Fig. 2.—Male moth.
Fig. 3.—Worm, side view.
Fig. 4a.—Half-grown worm, back view.
Fig. 4b.—Mature worm, back view.

BROWN CRANBERRY SPANWORM:

Fig. 5.—Female moth.
Fig. 6.—Male moth.
Figs. 7a, 7b, 8a, 8b.—Mature worms, side and back views, showing variation in coloration.

Big cranberry spanworm:

Fig. 9.—Worm.
Fig. 10.—Pupa.
Fig. 11.—Moth.

Fig. 12.—Cotton spanworm moth.

Fig. 13a and 13b.—The bog butterfly, Lycaena epixanthe (B. & L.).

This often appears on bogs in great numbers in July and early August and is mistaken commonly by growers for a spanworm moth. See page 51.

Fig. 13b shows the butterfly at rest with wings erect. No important cranberry pest ever rests with its wings held up so.

Fig. 14.—Nomophila noctuella (D. & S.).

A harmless moth common on many bogs, especially from May to mid-July. It often excites suspicion.

PLATE FOUR

Gypsy Moth and Other Pests

Fig. 1.—CRANBERRY GIRDLER moth.

Fig. 2.—Crambus praefectellus (Zinck.).

An unimportant moth common on many bogs in June and early July and often confused by growers with the cranberry girdler. Note the single conspicuous white stripe along the middle of each forewing.

Figs. 3a and 3b.—CRANBERRY SPITTLE INSECT female adults, showing variation in coloration.

Fig. 4.—CRANBERRY SPITTLE INSECT male adult.

Fig. 5.—Cranberry rootworm beetle.

Fig. 6.—Fire beetle beetle.

Fig. 7.—CRANBERRY ROOT GRUB male beetle.

GYPSY MOTH:

Fig. 8.—Caterpillar.
Fig. 9.—Pupa.
Fig. 10.—Male moth.
Fig. 11.—Female moth.
Fig. 12.—Egg mass.

Figs. 13 and 14.—Calosoma sycophanta beetle and larva, predaceous on gypsy moth caterpillars and pupae.

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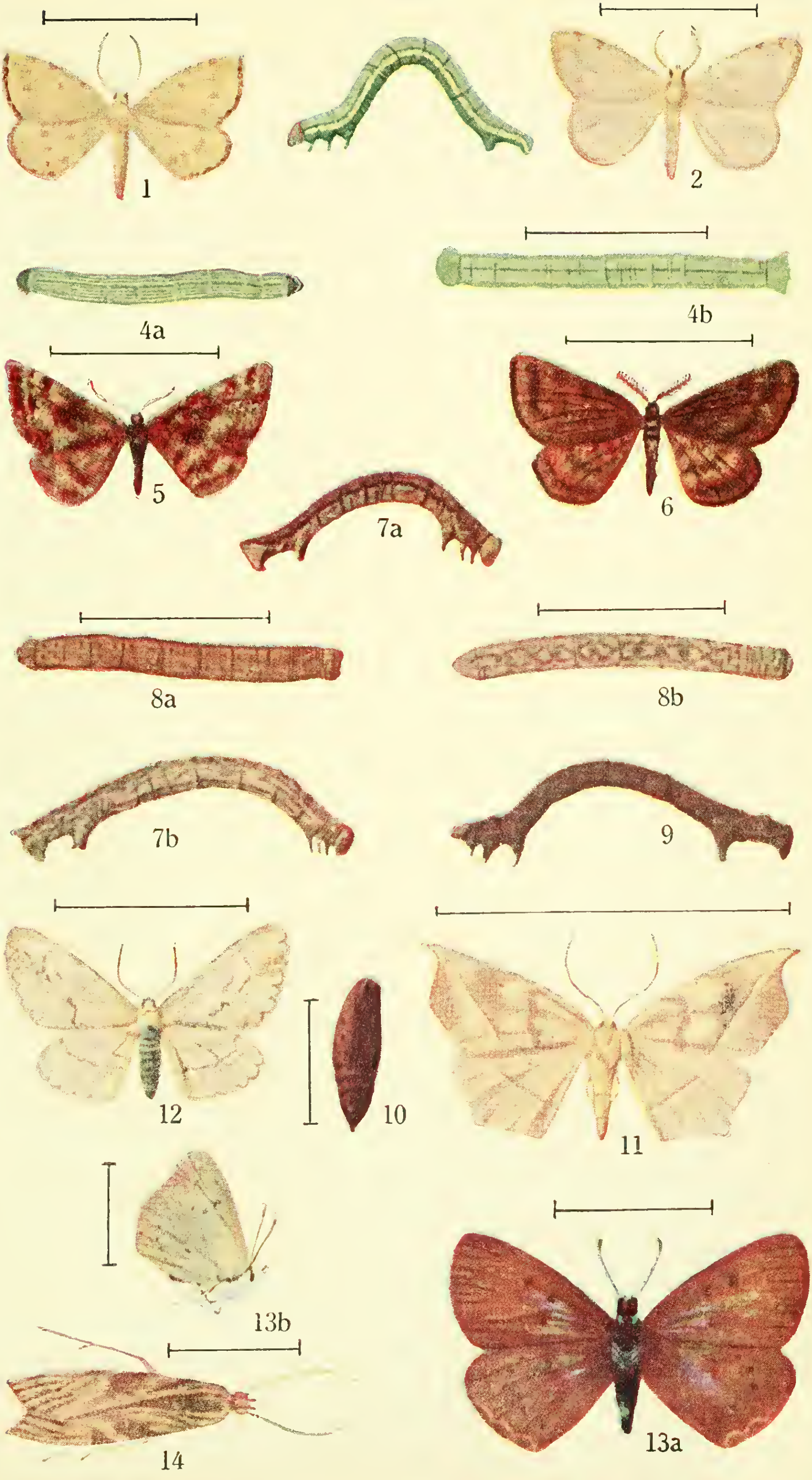
* The names of the more commonly harmful insects are in capitals. Insect size is shown by the length of the lines near the figures.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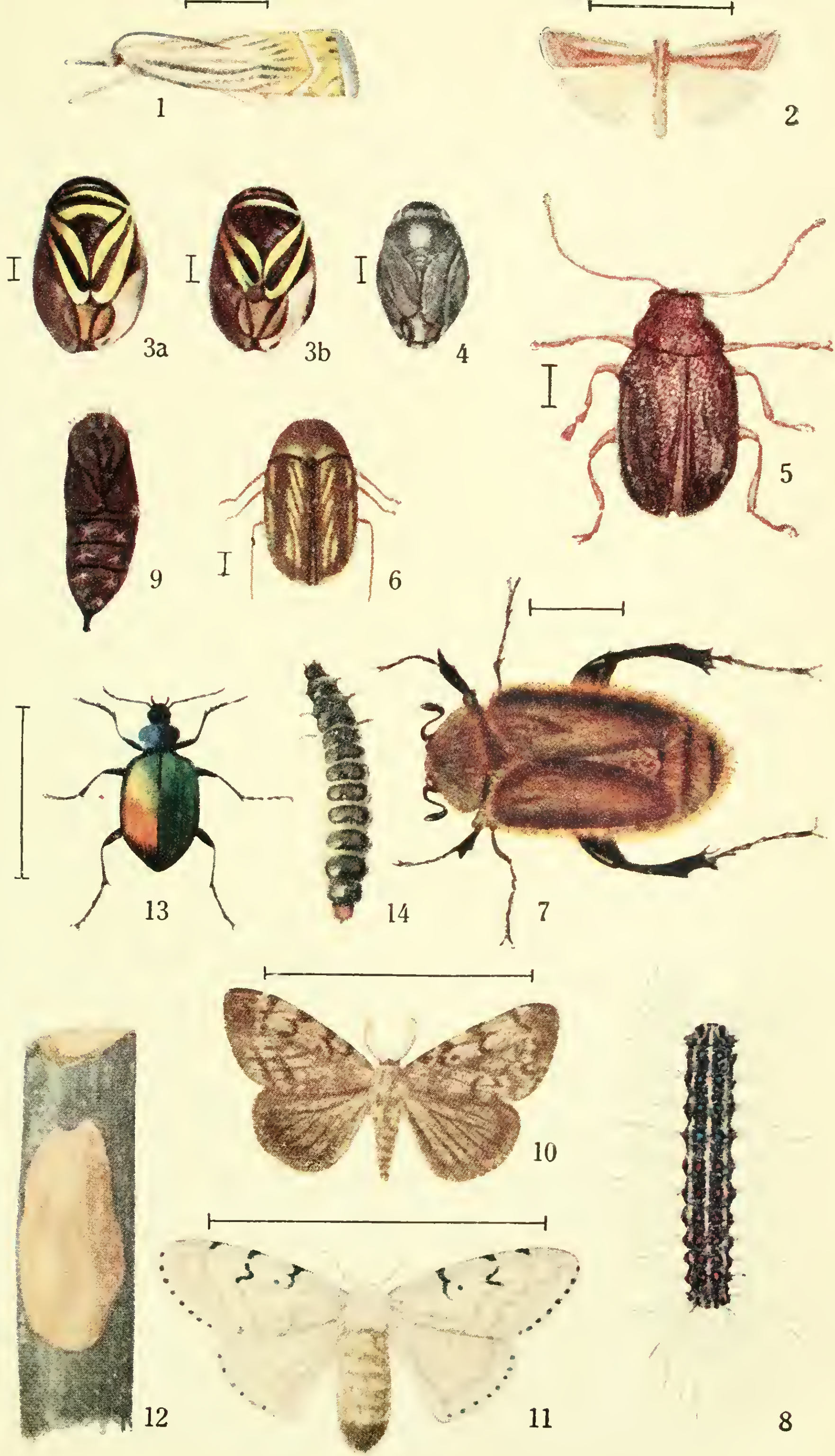
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and is about four-fifths of an inch long. It is formed in a slight but well-made net of yellowish threads among twigs, leaves, or grass (fig. 33). This stage lasts about a month.

THE MOTH

The moths appear in September and very early October. They fly by day, but the males sometimes come to street lights in clouds. The females fly little if not disturbed. Both sexes have snow-white wings marked with zigzag lines and dots of black (fig. 34). The face is deep yellow and there is a patch of yellow in front of the base of each forewing. The antennae of the male are very bushy, those of the female threadlike. The male expands about an inch and a half, the female an inch and three-eighths.

CHAIN-SPOTTED GEOMETER
Fig. 33. Pupae. Enlarged.
Fig. 34. Male moth.

THE EGG

One female sometimes lays as many as 368 eggs. They are attached to the lower surfaces of leaves or scattered indiscriminately on the ground, mainly in the latter half of September. They hatch about the first of the following June. They are greenish yellow at first but become brownish lavender in a few days. They are about a thirty-third of an inch long and are broadly elliptical with one end flattened or somewhat cupped.

Treatment

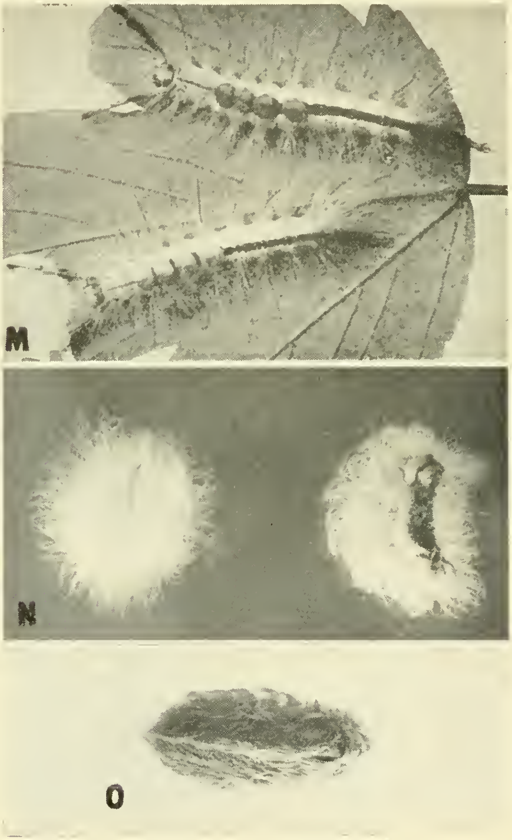
Spraying with 6 pounds of dry lead arsenate in 100 gallons of water, 300 gallons to the acre, is advocated. If this is done on the upland when the worms are small it will prevent trouble on the bog later. Keeping the marginal ditch cleaned out and partly full of water, as advocated for the gypsy moth, secures a bog from infestation.

HAIRY WORMS

These caterpillars have copious hair over much of the body. They are open feeders, never sewing the leaves together. They are like cutworms in the number and arrangement of their legs and in their gait. Several kinds of hairy worms occur in small numbers on the bogs, but only four need notice here. They may be distinguished by the following table:

Head red..white-marked tussock moth (fig. M)[42].
Head not red..1

1. Working in late spring and early summer........................gypsy moth (p. 47).
Working in late July and early August........................*Datana drexelii* Hy. Edw.[43].
Working in late August and in September
crinkled flannel moth (figs. N and O)[44]



WHITE-MARKED TUSSOCK MOTH

Fig. M. Mature caterpillars. (From U. S. Dept. Agr. Farmers' Bul. 1270.)

CRINKLED FLANNEL MOTH

Fig. N. Young caterpillars. Somewhat enlarged.
Fig. O. Mature caterpillar. Somewhat enlarged.

[42] *Hemerocampa leucostigma* (S. & A.). A beautiful caterpillar sometimes rather abundant on dry bogs but never very harmful.

[43] These worms sometimes defoliate small patches of vines but never do great harm.

[44] *Lagoa crispata* Packard. Flattened, slug-like caterpillars covered with a thick coat of hair at first white and finally brown. They feed freely on cranberry foliage but are never seriously abundant on bogs, appearing there only occasionally and on small areas.

Gypsy Moth [45]

This Old World species, brought into Massachusetts in 1868, did not infest the Cape cranberry region seriously till 1913. During 1913 and 1914 it increased vastly there, becoming the important cranberry pest it still continues to be. It usually is most harmful on the outer Cape.

Distribution and Food Plants

This pest ranges widely through Eurasia and North Africa. In our country it still is confined to New England and areas in New York and Pennsylvania. It has hundreds of food plants.

Character of Injury

The young worms commonly attack the terminal buds first, eating all but the outer scales (fig. 35) and often causing great loss before the grower knows his bog is infested. As the new growth develops, the caterpillars greedily devour the leaves, flower buds, and blossoms (fig. 36) and often sever the new part of the stem (fig. 37). They attack the old foliage severely when they are very abundant and have destroyed the more attractive new growth, and sometimes even gnaw bark from the vines.

The work of this insect on cranberry vines is much like that of the false armyworm in all stages. This is true of no other pest.

An infestation of two first-stage worms to the square foot often develops so as to destroy nearly all the new growth, and one larva to the square foot usually reduces the crop materially.

Bogs usually do not yield well till the second year after severe injury by this pest, but vigorous vines often do so the next year.

Description and Seasonal History

THE EGG

The eggs are smooth, globular, about a twentieth of an inch in diameter and pale pinkish brown when first laid. They grow darker within three weeks when fertile, owing to the development of the worms. They are laid soon after the moths emerge, mostly in oval or rounded masses of four hundred to sometimes over a thousand (Plate Four, fig. 12). These are half an inch to an inch and a half long and a third of an inch to an inch wide. They are covered with yellowish hairs from the abdomens of the moths and look like pieces of sponge. They are laid in every conceivable place, but the trunks and branches of trees probably are the most natural locations. They usually are placed within a few inches of the pupal case from which the female moth emerged.

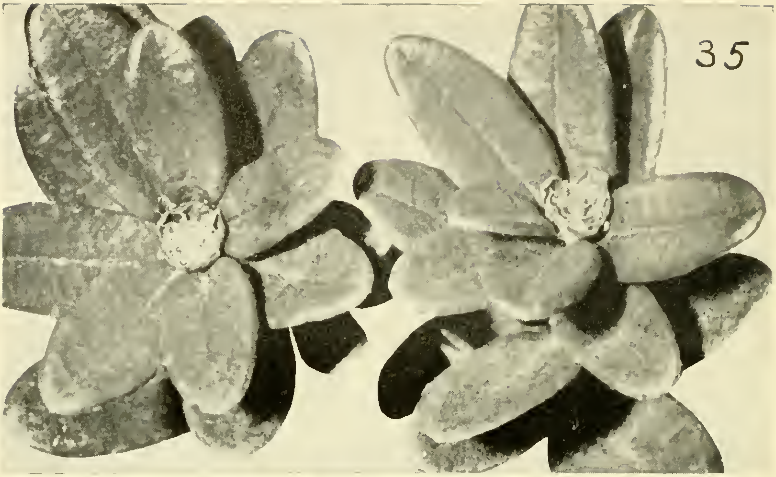
The young worms become fully formed within three weeks after the eggs are laid. They cannot endure a temperature lower than –25°F. and often are winterkilled extensively in northern New England. Some hatch in September in rare instances, but they normally appear from the last of April to mid-June, according to the weather and their position, those in warm sunny places coming out earliest while those in cool shady locations emerge much later, most of them usually hatching between the 12th and the 25th of May.

The winter flowage of bogs does not harm the eggs much as long as it is cold, for they hatch readily afterward if it is let off early in April. If it is held till after May 20, the hatching is negligible.

THE WORM

The caterpillars in their first stage are very dark and, being clothed with long hair and provided with aerostatic hairs, are borne easily by the wind. It sometimes carries them twenty miles or more.

[45] *Porthetria dispar* (L.). See U. S. Dept. Agr. Dept. Bul. 1093, 1922.



GYPSY MOTH

Fig. 35. Cranberry tips with terminal buds eaten out by young worms. Much enlarged.

Fig. 36. Caterpillar and its work.

Fig. 37. Work of worms.

The worms grow rapidly during late May and June and mature early in July. After their first stages are past they are as follows (Plate Four, fig. 8): The head is mostly sooty back, this color being much broken up by irregular light yellow markings, and has a long triangular stripe down the middle of the face and two converging curved lines on the top that are cream-colored and conspicuous. Its surface bears many yellow hairs. The under side of the body is mostly yellowish. The back and sides are rather dark brownish gray, with a light line along the middle of the back. There are eleven prominent tubercles in a row along each side of the back, the first five being blue and the last six red. These bear slender black spines and a few short pale yellow hairs. Tubercles on the sides have more and longer hair most of which is pale yellowish. Two small bright red tubercles without hair or spines, some distance apart on the mid-line of the back toward the hind end, and a conspicuous dark hairy tubercle on each side just behind the head are distinctive. The female worms often get to be two inches long, but the males seldom much exceed an inch.

The caterpillars spin much silk in their first stages and commonly drop and hang by a thread when disturbed. They do not do this when they get larger, but they spin a few threads for support before pupating and often make a scant cocoon.

In their first stages, the worms remain sheltered at night and feed in the daytime, usually being most active from 9 to 11 A. M. and from 3 to 5 P. M. Their habits change as they grow and they feed mostly at night, remaining inactive and more or less concealed during the day unless they are starved.

THE PUPA

Pupation usually becomes general toward mid-July on the Cape, but some caterpillars remain till August. When the worms abound they commonly collect in masses to pupate. The male pupae are from three-fifths to four-fifths of an inch long and the female from three-fifths of an inch to one and two-fifths inches. They are deep brown and bear considerable yellow hair (Plate Four, fig. 9). They usually are found on the sand on cranberry bogs, often covered with litter, but they also occur up among the vines. The pupal stage lasts 7 to 17 days.

THE MOTH

The sexes are very unlike. The male (Plate Four, fig. 10) expands about an inch and a half. Its antennae are bushy and, with the upper side of the body and wings, are dingy brown, the forewings having irregular dark brown markings. The head and under side of the body are yellowish white. All the wings are light brown underneath.

The female (Plate Four, fig. 11) expands about two inches. Its antennae are dark brown and much less bushy than the male's. The hind end of the abdomen is dingy reddish brown. The rest of the body and the wings are nearly white. The forewings are marked irregularly with different shades of brown and all the wings have dark brown spots at regular intervals along their outer margins.

The moths emerge in late July and August. The males are slender-bodied and fly actively by day with a peculiar zigzag flight, but the females are heavy-bodied and sluggish and cannot fly.

How Bogs Become Infested

Bogs become infested in the four following ways:

1. *By the Hatching of Eggs laid on the Bog the Year Before.*—This is a common cause of trouble on bogs that have been neglected, especially dry bogs. These infestations usually defoliate rounded areas.

2. *By Wind Drift of the Worms in their First Stage.*—This is the main

cause of infestation. The uplands around cranberry bogs, often from ten to forty feet high and usually wooded, furnish ideal conditions for wind dispersion. Infestations from wind drift often are thickest near the bog margin and diminish toward the center. They seldom, if ever, develop in round patches.

Often there is a high mortality among the wind-borne larvae after they reach a cranberry bog. It seems to be greatest in their first stage and probably is due mainly to reduced vitality, this making them readily subject to disease and other killing agents. The nature of cranberry foliage as a food may be a factor.

3. *By the Worms Falling on the Bog Margin from Overhanging Trees.*—The uplands around most bogs now are cleared of trees and brush well back from the margin, so the chances of this generally are small.

4. *By the Caterpillars Crawling Across the Marginal Ditch in Their Later Stages.* When the surrounding upland is heavily infested, complete defoliation of the trees commonly occurs, and then the hungry worms often crawl onto the bog.

Treatment

LATE HOLDING OF THE WINTER FLOOD

Holding the winter flood till May 25 kills the eggs laid on the bog the year before and usually catches most of the wind drift. (See pages 12 and 26.)

REFLOODING

The wind drift is generally about over by the last of May, and reflooding about May 29 for twenty-four hours kills the worms before they do much harm unless they are very numerous. A twelve-hour flood kills them after they are a third grown, but if they are abundant, treatment should not be delayed after the above date most years. The date for the earliest springs is May 24 and for the latest June 3. Many of the small worms cling to the vines with a bubble of air as the water rises and never come to the surface. As they grow they lose this habit. This may explain their greater resistance to drowning in their first stages. The larger worms thrash themselves to death on the surface of the water.

Late May is also the time to flood to control rose-bloom. If the water is held thirty-six hours, the swollen pink shoots (Plate Two, fig. 6) caused by the disease collapse and dry up a day or two later.

The flooding also destroys other pests that may be at work, such as false armyworms, blossom worms, black-headed fireworms, and green spanworms.

SPRAYING OR DUSTING

Spraying with 3 pounds of 50 percent wettable DDT powder in 100 gallons of water, 300 gallons to the acre, is recommended whenever the worms are too prevalent. Dusting with 50 pounds of 5 percent DDT dust to the acre is also very effective.

PREVENTION

Keeping the maturing worms from crawling onto the bog is best accomplished by:

(*a*) Removing the trees, especially the oaks, and the brush for 150 feet from the bog margin. This also helps to prevent frosts somewhat by allowing freer air movements across the bog at night.

(*b*) Spraying the upland for 200 feet from the bog margin with the DDT spray already mentioned. This is always advisable if the upland has not been cleared and is thickly infested.

(*c*) Keeping the marginal ditch cleaned out and partly full of water, with a film of kerosene or fuel oil on the water, during the worm-crawl. Sometimes the ditch must be deepened considerably for this.

MISCELLANEOUS PESTS

These pests are placed here because their characters or habits are such that they cannot be grouped with others. The following table distinguishes them:

Mostly green 1
Not green 2

1. Working only inside the berries .... cranberry fruitworm (p. 51).
   Feeding mainly on the blossoms and small berries, slug-like .... bog butterfly[46].
2. With a head; working in the blossom buds .... cranberry weevil (p. 56).
   Headless; working in the tips of the uprights .... cranberry tipworm (p. 60).

BOG BUTTERFLY
Fig. P. Mature caterpillar. Much enlarged.
Fig. Q. Work of worms.
Fig. R. Pupa. Much enlarged.

Cranberry Fruitworm [47]

This worm has been more destructive on the Cape than any other cranberry pest, sometimes taking nearly half the crop; but nature controls it some years so that it does no great general harm. It is usually much more harmful around Plymouth and on the outer Cape than elsewhere, seldom troubling bogs much in Middlesex County and other areas well inland. It often takes all the fruit on a bog without proper winter flowage. It attacks early varieties more than late ones. It is also very injurious in Nova Scotia and Wisconsin, but is less troublesome in New Jersey and on the Pacific Coast.

Many moths probably come onto the bogs from a standing upland infestation most years in Massachusetts and Wisconsin, for new bogs made in isolated locations nearly always become infested in a few years. Infestations on bogs flooded during the winter might die out soon but for this continual invasion.

[46] Production of males is excessive in this species, and the egg laying capacity is relatively low. The worm works in June and sometimes is rather harmful. It can be controlled easily with a spray of lead arsenate. It is about three-eighths of an inch long when full grown. See figs. P, Q, and R, and figs. 13a and 13b of Plate Three.

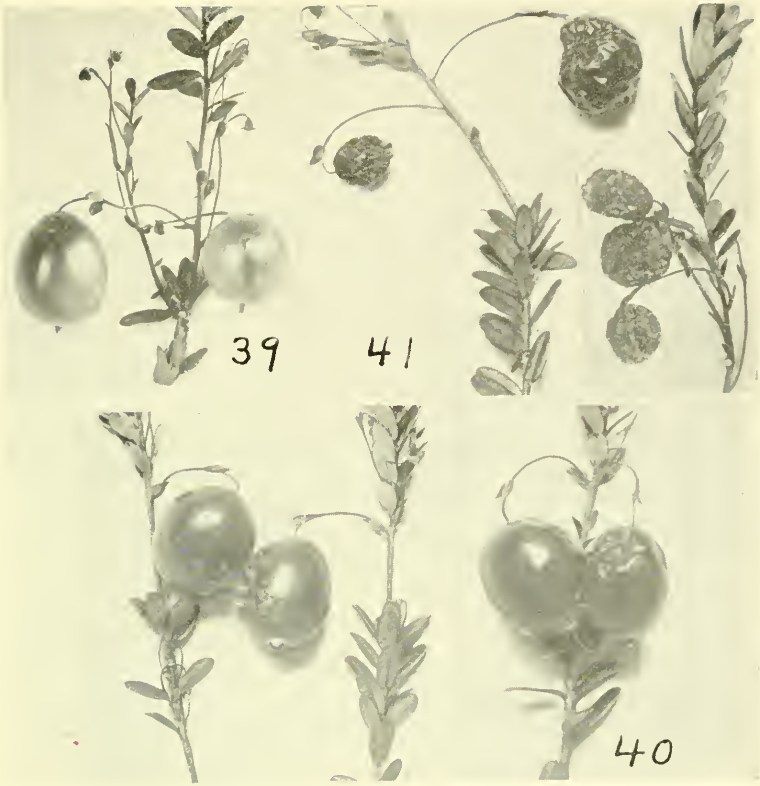
[47] *Mineola vaccinii* (Riley).

In Massachusetts, except in well-sheltered locations, the worms sometimes are winterkilled in their cocoons when not covered with snow or water. The worms freeze in midwinter when exposed in their unbroken cocoons to air with a temperature of –2° to –3° F.

Distribution and Food Plants

This species has been found in Quebec, Prince Edward Island, Nova Scotia, Maine (at Machias), Massachusetts, Rhode Island, Connecticut, New York, New Jersey, North Carolina, Michigan, Wisconsin, Texas, and Washington. It seems to have been introduced in the Long Beach cranberry district of Washington about

CRANBERRY FRUITWORM
Fig. 38. Cranberries cut open, with worms at work.



CRANBERRY FRUITWORM

Fig. 39. Cranberries with worm holes, one closed with white silken curtain.
Fig. 40. How the worms often work from one cranberry directly into another.
Fig. 41. Cranberries shriveled to dry husks because of its work.

1923, and in the Grayland district about 1936 (D. J. Crowley and H. F. Bain). It is not found in Oregon.

The worms infest in the wild the fruits of the mountain cranberry[48] and swamp blueberry and are sometimes a considerable pest in cultivated fields of the latter. They commonly web together several berries of these plants and feed among them. They probably have still other food plants, for they eat dangleberries, black huckleberries, apples, and beach plums freely in confinement.

Character of Injury

The newly hatched larva almost always crawls over the surface of the cranberry from its place of emergence at the blossom end and enters close to the stem or goes to find another berry. If, however, the berry is held with the blossom end up, the worm enters at that end. Its entrance is so small that it is barely visible to the unaided eye. It eats the seeds and usually more or less of the pulp and then leaves the berry to enter a second. One worm destroys from three to six berries, the number varying with their size. Most of the pulp is eaten in all

[48] *Vaccinium Vitis-Idaea* L. var. *minus* Lodd.

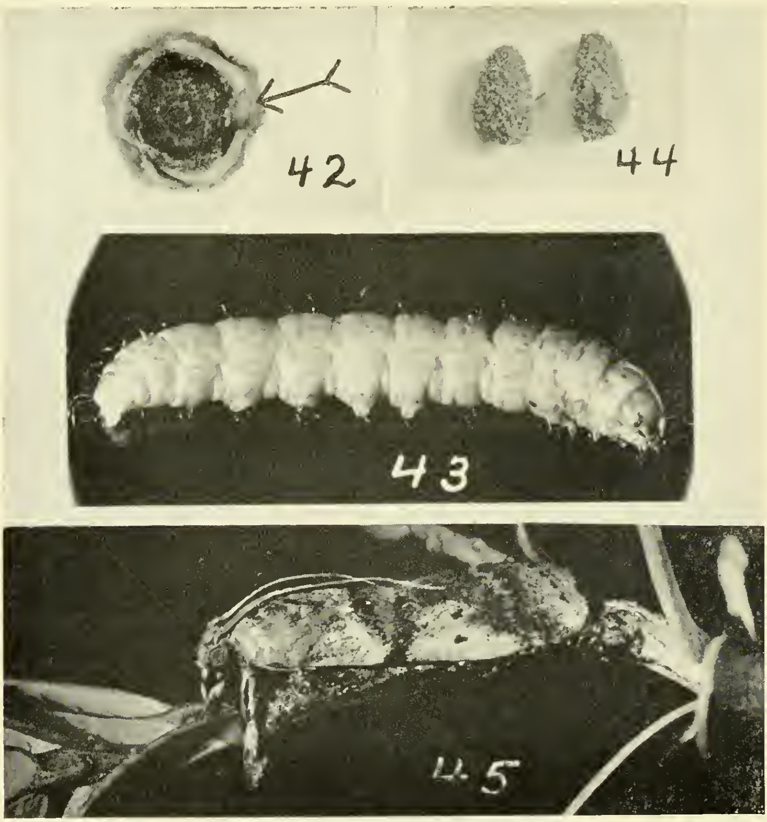
except the last (fig. 38). The entrance to the first two or three is closed by a white silken curtain (fig. 39). After the first berry, the worm is indifferent about the location of its entrance. It often goes from one berry directly into another at their point of contact (fig. 40). The berries turn red prematurely soon after they are attacked, this being the first sign of the work of this insect. They then gradually dry and shrivel and may cling to the vine as husks till the next year (fig. 41).

When the worms mature late many are gathered with the berries and sometimes do much harm among the stored fruit and in shipments, working some years till late October. Here they web the berries into balls in which they feed.

Description and Seasonal History

THE EGG

The egg is generally oval and so plastic when laid that it adapts itself readily to an irregular surface. It appears rather watery at first but soon becomes pale yellow and develops a circling irregular reddish streak in about two days. It

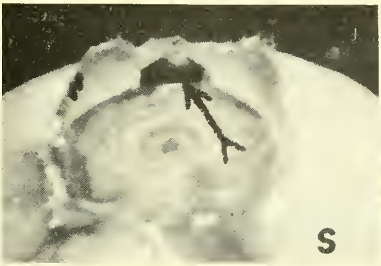


CRANBERRY FRUITWORM

Fig. 42. Egg under calyx lobe of cranberry, showing reddish streak. Much enlarged.
Fig. 43. Worm. Much enlarged.
Fig. 44. Cocoons. Somewhat enlarged.
Fig. 45. Moth. Much enlarged.

usually is placed under one of the lobes at the blossom end of the berry (fig. 42) but sometimes is elsewhere on the surface. More than one or two are seldom found on a berry unless the infestation is very severe. Fig. S shows an egg turned dark by parasitism, and fig. T the shell of a hatched egg.

Egg laying begins when the small berries start to grow and sometimes continues till late August. The normal eggs hatch in about five days and eggs parasitized by *Phanerotoma* or *Pristomeridia* in about eight days.



CRANBERRY FRUITWORM

Fig. S. Egg blackened by Trichogramma parasitism. Greatly enlarged.
Fig. T. Shell of hatched egg. Greatly enlarged.

THE WORM

The normal mature worm (fig. 43) is about half an inch long and is green, often tinged with reddish on the back. The head is yellowish. The parasitized worms seldom become much over a third of an inch long.

The caterpillars are generally most active from about July 12 to about August 30, but often some work in the berries well into September. When through feeding, they go down to the sand under the vines, on or near the surface of which they make oval cocoons (fig. 44) of sand and silk or of fallen cranberry leaves webbed together. Those of the normal worms generally are a little over three-eighths of an inch long, but those of parasitized ones are smaller and frailer. They are not impervious to water, for when submerged they nearly fill up in about five days. The worms in them generally are not much affected by cold water and some live through the winter under bog flowage.

THE PUPA

Pupation occurs within the cocoons in late May and June on dry bogs and bogs drained of their winter water before mid-April. The pupa is pale greenish at first but soons turns yellowish brown and becomes dark brown before the moth emerges.

THE MOTH

The moths occur from very late May till after mid-August. They hide among the vines during the day and are hard to flush, so even when abundant they are seldom seen by growers. They are very active in calm evenings and may be seen at dusk hovering over the vines and alighting occasionally to lay eggs. They have been known to fly 272 feet in one flight and may travel surprisingly far during their life and come to bogs from considerable distances.

The moth (fig. 45) expands about two-thirds of an inch. The forewings are mostly dark grayish brown above with a slight pinkish tinge, each having two whitish areas, one toward the base and one running back from beyond the middle of the front margin, there being two dark dots in the latter. The under side of the forewings and both sides of the hindwings are light brown.

Treatment

WINTER FLOOD

Experiments have shown that the worms in their cocoons generally cannot endure submergence longer than two weeks in water with a temperature above 60° F. Bog experience confirms this, for if the winter flood is held till after May 20, fruitworm trouble is usually much less than on bogs from which the flowage has been let off early. Bogs vary greatly in their tendency to become severely infested, owing probably to differences in their surroundings. Holding the winter flowage late every other year is a good control with some, but others need treatment nearly every year.

SPRING REFLOW

If the winter flood is let off early in April, it is often good practice to reflow a bog from about April 20 to about May 24 to curtail the fruitworm, false army-worm, and gypsy moth.

AUGUST FLOOD

Bogs are sometimes flooded in August to stop the work of fruitworms. This is effective, but it is an extreme measure and is rarely advisable, for the water usually will spoil a considerable part of the crop. Cool weather should be selected for this and the water held for about twenty-four hours.

INSECTICIDES

Insecticides are used very effectively to kill the worms as they hatch, two and sometimes three applications, ten days apart, being necessary, the first made as soon as the vines are half out of bloom. Counts of fruitworm eggs on berry samples gathered from scattered locations on the bog should always be made to determine whether such a treatment is advisable. Such examinations should be repeated every few days until after the first of August. Treatment is always advisable when more than four eggs that are unhatched and not turned black by *Trichogramma* parasitism (figs. S, T, and 42) are found on a hundred berries.[49] Two or three unhatched eggs on a hundred berries justify helicopter dusting, especially where there are prospects of a heavy crop or high prices for berries.

1. *Dust* with 40 pounds of cryolite or 70 pounds of activated derris (2 per-cent rotenone) dust to the acre.

2. *Spray* with 6 pounds of cryolite or 7 pounds of derris (4 or 5 percent rotenone) and 2 pounds of soap in 100 gallons of water, 400 to 500 gallons to the acre, according to the vine growth. The derris spray is an excellent blanket treatment for fruitworms and second-brood blackheaded fireworms, as is also a spray of 3 pounds of 50 percent wettable DDT in 100 gallons of water, 400 or 500 gallons to an acre.

As fruitworm infestations are commonly more severe along the margins than on the interiors of cranberry bogs, it often is best to confine attention to the former when using insecticides to control them.

Cranberry Weevil [50]

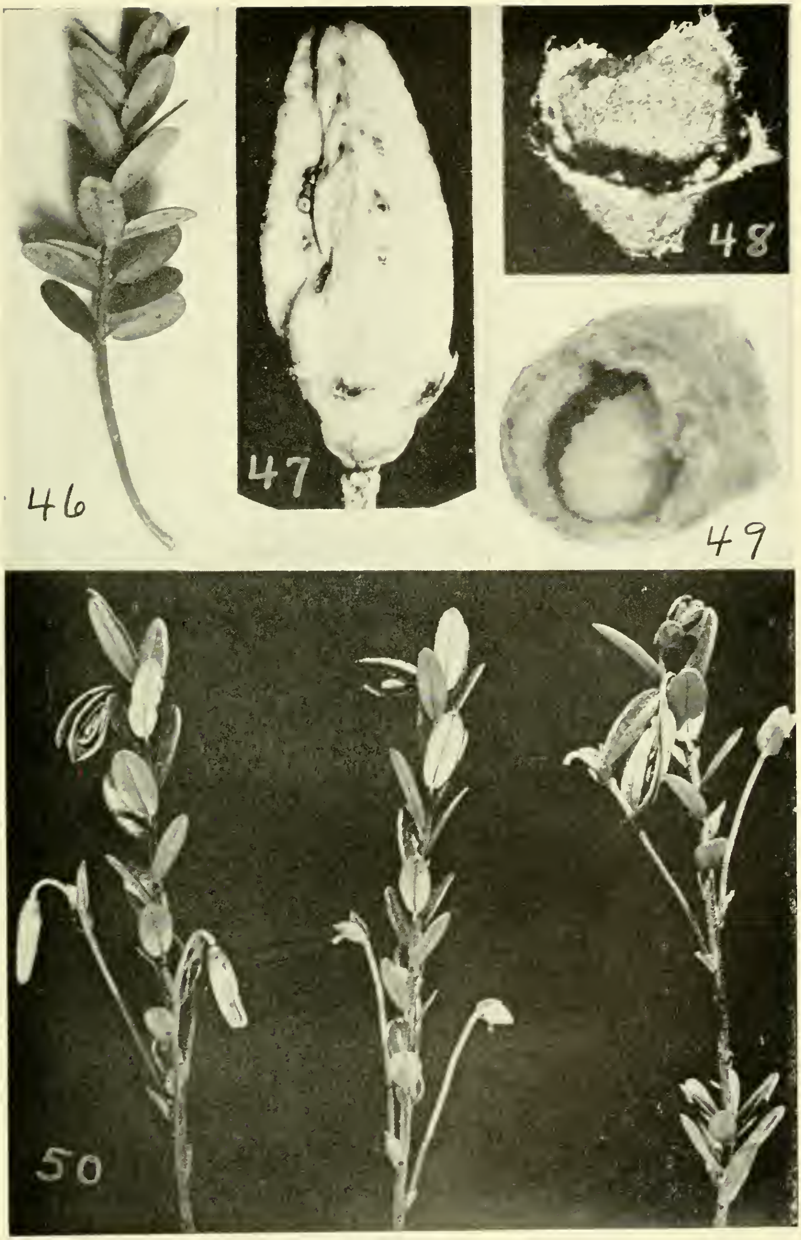
This insect works on dry bogs and bogs that are flowed for the winter but are not reflooded much. It has been a minor pest, doing serious harm only on small areas here and there, but it has become more troublesome in recent years. When it establishes a considerable infestation it usually stays for years unless it is treated.

Distribution and Food Plants

This beetle ranges from Ontario and New England to the Rocky Mountains and

[49] Such a count indicates a potential loss of at least 25 percent of the crop. The examining is best done with a hand lens magnifying about ×14.

[50] *Anthonomus musculus* Say.—determined by W. S. Blatchley and H. C. Fall. The name *A. suturalis* LeC. has been tied to this species erroneously in cranberry literature.



CRANBERRY WEEVIL

Fig. 46. Cranberry upright with holes drilled in leaves by beetles.
Fig. 47. Cranberry blossom bud drilled by beetles. Much enlarged.
Fig. 48. Ovary of cranberry blossom bud excavated by grub. Much enlarged.
Fig. 49. Cranberry blossom bud with ovary removed showing grub in unopened corolla. Much enlarged.
Fig. 50. Cranberry uprights with tips broken down and buds dropped, work of beetles.

Florida. It is found commonly on black huckleberry and the flowers of chokeberry. The grubs work in the flower buds of swamp blueberry, sometimes doing much harm where this is cultivated.

Character of Injury

In the spring the beetles occasionally drill holes in the under side of the old leaves (fig. 46) and in the dormant buds. They turn their attention to the new growth as it develops, drilling into the new leaves and the growing blossom buds freely (fig. 47) and often eating the stamens. New shoots often are killed by this feeding, turning dark as if frosted or breaking over where the stem has been punctured.

The grub devours the pistil and stamens of the flower bud, leaving the excavated ovary (fig. 48) together with the unopened corolla (fig. 49) a mere shell[51]. If this is opened it usually is found to contain either the grub or pupa and some fine brown castings.

Many of the infested buds fall to the ground (fig. 50), some before the egg hatches. The cause is not known, but probably the beetle partly severs the pedicel somehow when it lays the egg. A few of the buds fall because the grubs eat them off from within. Buds that show they are partly cut off by shaking freely when the vines are disturbed indicate surely the presence of this pest.

The beetles of the new brood appear while the berries are small and feed voraciously on them (figs. 51, 52 and 53) and on the more tender foliage for about three weeks, riddling both with holes. Some of their work on the backs of the leaves at this time is very characteristic (fig. 54). This feeding decreases as the season advances and finally they only nibble the leaves occasionally, doing this till into September.

Where abundant, this insect often destroys the entire prospective crop by its work in the blossom buds, and the newly emerged beetles sometimes ruin most of the small berries and by killing the tips of the uprights make a crop the next year impossible.

Description and Seasonal History

THE BEETLE

The beetle (fig. 55) is about a sixteenth of an inch long. It has a slightly curved snout about a third as long as the rest of the body. This bears a geniculate feeler on each side beyond the middle and small jaws at the end. The wing covers are ornamented lengthwise with rows of little pits. Narrow white scales noticeable only under a microscope are scattered over the body and legs and often form transverse patches on the wing covers. When the beetle emerges from the pupa it is light brown, with the head and snout deep reddish brown and the eyes black. It changes to its normal color within two or three weeks, then being blackish with the wing covers, the legs, and the under side of the abdomen mostly deep reddish.

There is one brood a year. The insect passes the late summer, fall, winter, and spring as a beetle and can live under the winter flood. In the fall and spring the beetles hide in the trash under the vines or burrow a little in the sand on cold windy days, coming out only in warm sunny weather. When active they are easily swept from the vines with an insect net, fifty sweeps sometimes gathering over five hundred of them late in July and early in August. When disturbed they either drop to the ground and play possum or fly off a few feet. They start mating toward the first of June.

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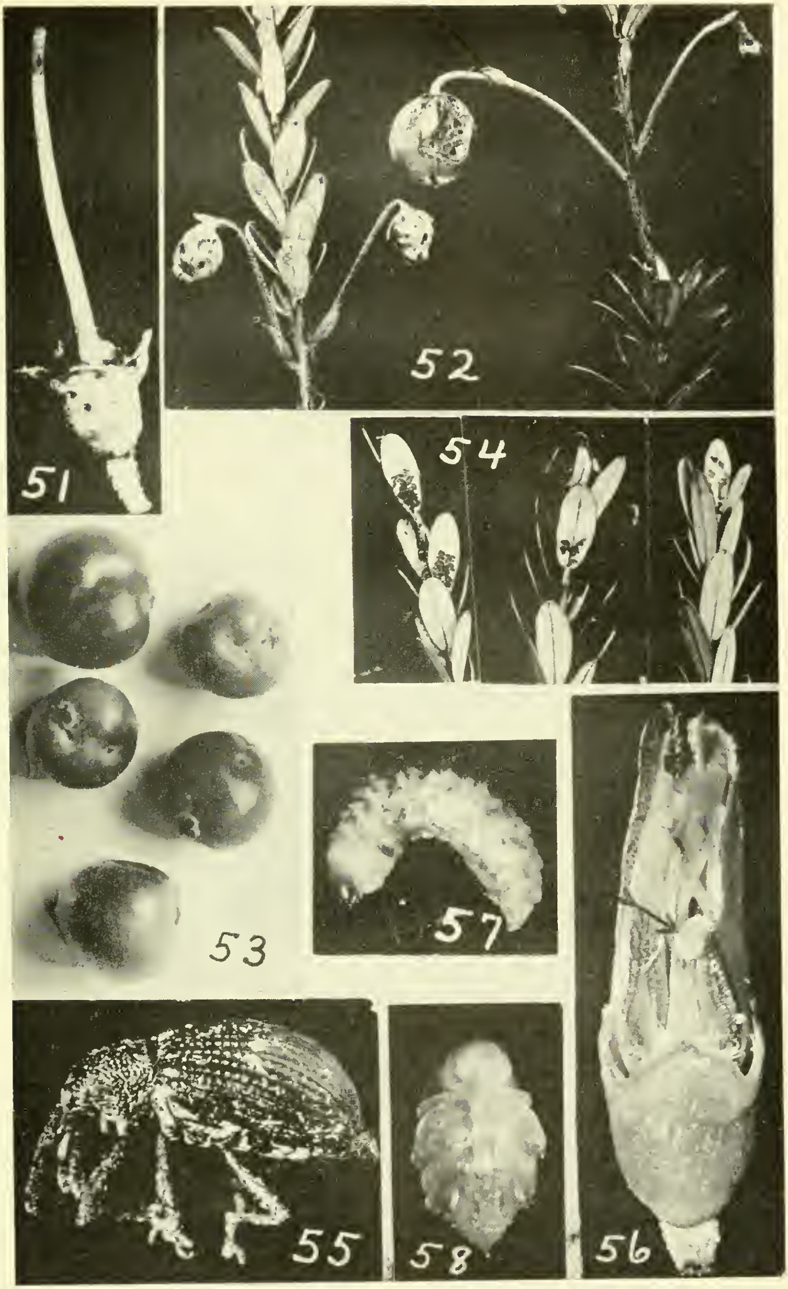
51 The lobes of the corolla of an infested bud always remain closed tightly together and become dry and rigid in that position, a protective cell thus being formed for the insect.



CRANBERRY WEEVIL

Fig. 51. Newly set cranberry drilled by beetles. Much enlarged.
Fig. 52. Growing cranberries drilled by beetles.
Fig. 53. Cranberries with deformities due to drilling of beetles.
Fig. 54. Cranberry uprights showing characteristic work done by beetles on backs of leaves in July and August.
Fig. 55. Beetle. Much enlarged.
Fig. 56. Cranberry blossom bud with part of corolla cut away showing egg among stamens. Much enlarged.
Fig. 57. Grub. Much enlarged.
Fig. 58. Pupa. Much enlarged.

THE EGG

The female beetles begin to lay eggs when the first blossom buds show pink and continue to do so through June. Some lay fifty or more. Only one egg is laid in a bud, the beetle pushing it with her ovipositor into a hole made with her snout. It usually is placed among the stamens near the bases of the anthers (fig. 56). It is smooth, glistening, oblong-ovoid, pale yellowish, and nearly a fiftieth of an inch long. It hatches in three to nine days.

THE GRUB

The normal hatching period is the last half of June. The grubs develop and pupate in the blossom buds. They mature in ten to fourteen days. The mature grub (fig. 57) is whitish and has a yellowish head but no legs. It is about a ninth of an inch long.

THE PUPA

This (fig. 58) is about an eleventh of an inch long and pale yellow at first, but it finally turns brown. The legs, wing pads, and snout lie tightly against the body. This stage lasts about six days. When the beetle emerges, it eats its way out of the bud near the calyx lobes. The beetles usually come out mostly during the first third of July.

Treatment

FLOODING

Ordinary late holding of the winter flood fails to reduce this pest much. A complete flowage for two days about June 1 is effective, especially if 5 gallons of kerosene for each acre of bog is poured onto the water along the windward side soon after the vines are covered.

SPRAYING OR DUSTING

The beetles can be killed readily with a spray of 6 pounds of cryolite or 3 pounds of 50 percent wettable DDT powder in 100 gallons of water, 400 gallons to the acre, preferably on a warm day in the spring after the new growth of the vines starts but before the beetles lay eggs. This is between May 20 and June 1 most years. It may be used to kill the beetles of the new brood at any time from their first appearance till early August, but it should be applied as soon as they appear.

Dusting with 50 pounds of 10 percent DDT to the acre is also effective but is not advocated as a treatment for use in August.

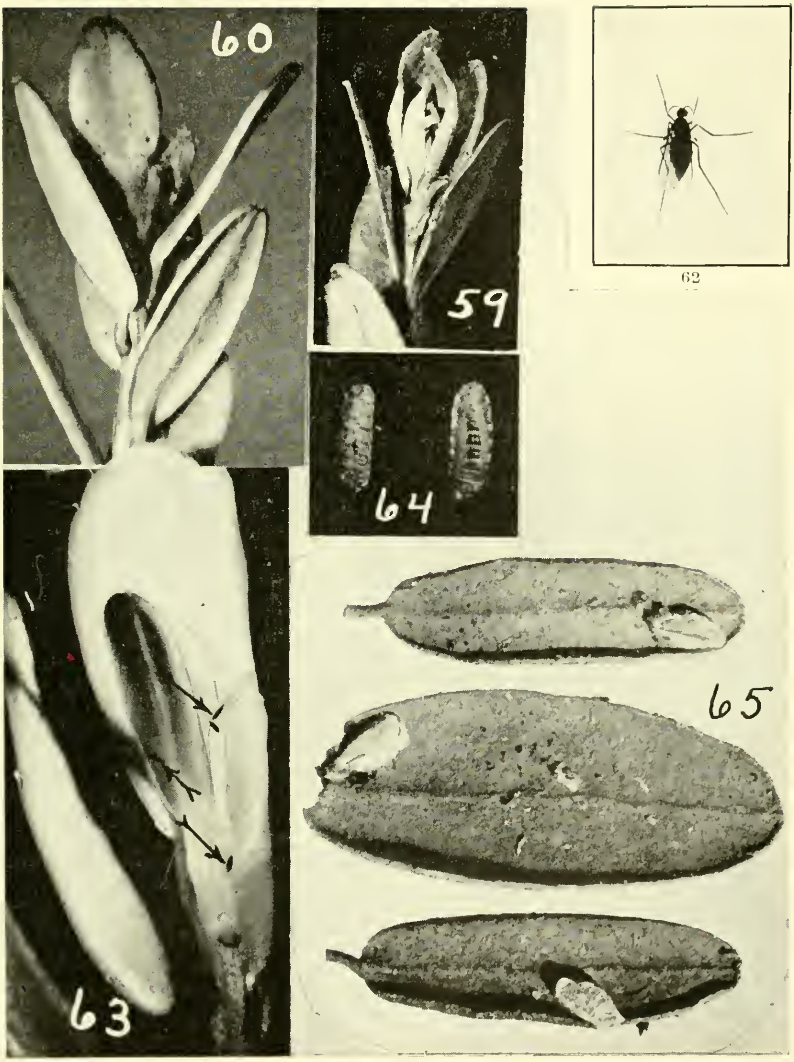
Cranberry Tipworm [52]

Vigorous vines very often recover from the attack of this insect and yield well the next year. Those that fail to do so might have been unproductive anyway. In view of this, it is hard to say just how harmful the pest really is, but it tends to reduce crops and should be controlled. It infests flowed bogs much more than strictly dry ones and tends to attack Howes vines more than Early Black. Flooding kills or drives ashore many of its natural enemies and may protect hibernating worms from winter severities. Frost sometimes reduces an infestation greatly when it kills the cranberry tips.

Distribution and Food Plants

The tipworm is abundant and causes concern in Massachusetts, New Jersey, and Wisconsin. The fact that it is prevalent in the Grayland district and not found elsewhere on the Pacific Coast seems good evidence that it was introduced

[52] *Dasyneura vaccinii* (Smith).



CRANBERRY TIPWORM

Fig. 59. Cranberry tip injured by maggots. Much enlarged.
Fig. 60. Cranberry upright with tip killed by worms of second brood. Much enlarged.
Fig. 62. Female fly. Much enlarged. (From U. S. Dept. Agr. Farmers' Bul. 860.)
Fig. 63. Eggs in tip of cranberry upright. Much enlarged.
Fig. 64. Maggots. Much enlarged.
Fig. 65. Cocoons of second brood on fallen leaves. Much enlarged.

Fig. 61. Cranberry Tipworm. Cranberry uprights attacked by both broods, the branching of the tops being due to the work of the first, the cupped tips to that of the second.

in Washington rather recently (D. J. Crowley). It has been said to infest other heaths and loosestrife.[53]

Character of Injury

The first brood of maggots works mostly during the first half of June. It does little harm for it is seldom abundant and the vines have time to recover. The second brood is much more plentiful and generally appears when the vines are in full bloom. Its work is more serious for it interferes with the development of the terminal buds that should produce the blossom-bearing growth the next year.

Both broods work wholly among the leaves at the tips of the uprights and runners. These become cupped and bunched together characteristically (fig. 59). This is due to the feeding of the worms on their inner surfaces which they rasp with a little horny process on the under side of the body. The inner leaves die (fig. 60) and sooner or later break off. New growth repairs the injury done by the first brood (fig. 61). Side buds usually develop in most of the tips attacked by the second brood, but these are more likely than terminal buds to produce leafy growths instead of flower shoots the next year, especially if the vines lack vigor.

Description and Seasonal History

FLIES AND EGGS

The adults are delicate flies less than a sixteenth of an inch long and expanding less than an eighth of an inch. The male is rather dark and inconspicuous, but the female (fig. 62) has a large bright reddish abdomen. The female lays her eggs near the bases of the terminal leaves (fig. 63). The eggs are watery translucent with scattered reddish pigment and are about a seventieth of an inch long. They are smooth, elongate, usually curved from end to end, and with rounded ends.

WORMS AND COCOONS

From one to five maggots appear in each infested tip. They vary from pale yellowish to orange red and are pointed at one end (fig. 64). They have neither legs nor head. They mature in about ten days, becoming about a sixteenth of an inch long. Those of the first brood make their cocoons in the injured tips and the flies emerge in a few days; those of the second descend

[53] *Lysimachia* sp.

to the ground when mature and there form cocoons in which they live till late the next spring, without much harm from the winter flowage even when it is held late.

The cocoons are whitish, slightly flattened cases of closely spun silk about a sixteenth of an inch long. Those of the second brood usually are attached to fallen leaves or other trash (fig. 65). The maggot changes into a brown pupa and this wriggles out of the cocoon through a slit at one end shortly before the fly emerges.

Treatment

The maggots endure submergence longer than it is safe to have the growing vines flooded.

SANDING

Ordinary resanding every other year during the fall, winter, or early spring checks the pest nicely on most bogs, but it seldom pays to sand so often if a bog has ample frost protection. The sand either smothers the worms in their cocoons or prevents the emergence of the flies. Fertilizer helps weak vines bud after the attack of the worms, especially on sand bottom.

DUSTING OR SPRAYING

Dusting or spraying with DDT materials as soon as scattered cranberry blossoms have opened gives good control by killing the flies as they emerge to lay their eggs. In dusting, 60 pounds of a 10 percent DDT dust to an acre is necessary. In spraying, 3 pounds of 50 percent wettable DDT in 100 gallons of water, 400 gallons to the acre, is advocated.

Cranberry Sawfly [54]

This species occurs only on dry bogs and bogs that are not reflooded regularly. It hardly ever attracts attention, but its long feeding period probably sometimes allows it to do considerable harm. It is one of the minor drains that must be checked to make cranberry culture efficient.

Distribution and Food Plants

This insect has been found in Massachusetts, New York, New Jersey, Illinois and Wisconsin. Cranberry is its only known food plant. The worms scallop the leaves irregularly.

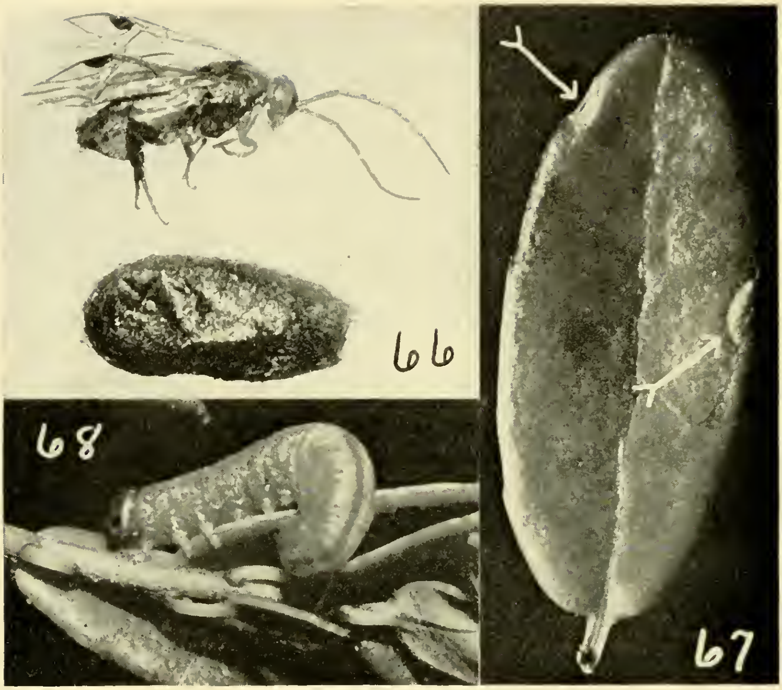
Description and Seasonal History

The worms winter in rather tough cocoons of coffee-brown silk (fig. 66) among the trash on the bog floor, unharmed by the winter flood. They pupate in early May and the adults usually emerge soon after mid-May and lay eggs so that the larvae appear on the bogs again early in June. About five generations occur, the last worms usually entering their winter cocoons in mid-October. The worms develop so irregularly that the broods get mixed by late summer, all stages occurring at once.

THE EGG

The female always perches on the edge of a cranberry leaf to lay and puts her eggs in pockets she makes between the upper and lower surfaces and opening at the margin (fig. 67). The pockets usually are placed singly, but sometimes two or more are near together. One or, rarely, two eggs are placed in a pocket and often protrude a little. They are elliptical, watery greenish

[54] *Pristiphora idiota* Norton.



CRANBERRY SAWFLY

Fig. 66. Cocoon and female fly. Much enlarged.
Fig. 67. Cranberry leaf with egg-pockets. Much enlarged.
Fig. 68. Worm. Much enlarged.

brown, and a little over a twenty-fifth of an inch long. They hatch about a week after they are laid.

THE LARVA

At first the worms are light yellowish green with the head dark brown. They grow darker with age. When mature (fig. 68) they are slightly over three-eighths of an inch long, smooth, green, and without noticeable markings except a narrow internal stripe of whitish pigment running the length of the back on each side of the heart and conspicuous through the skin. Their heads are pale greenish brown with a black dot on each side. They have six pairs of prolegs.

THE ADULT

The flies (fig. 66) are a fifth of an inch long and half an inch across their expanded wings and mostly black, but the females have a broad band across the middle of the upper side of the abdomen and all its under side but the tip brownish yellow.

Treatment

Flooding for 10 hours about June 8 is effective; so also is spraying with 6 pounds of dry lead arsenate to 100 gallons of water early in June.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN 446 FEBRUARY 1948

Septic Tank Studies

By James E. Fuller

This bulletin reports a study of the operating efficiency of septic tanks when sewage is retained for periods less than the 24 hours usually recommended. Management observations and chemical and biological tests gave evidence in favor of the conventional practise of holding sewage in tanks for 24 hours or more.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

SEPTIC TANK STUDIES

By James E. Fuller, Research Professor of Bacteriology

INTRODUCTION

The septic-tank study that is the subject of this report originated as a joint project between the Division of Sanitary Engineering of the Massachusetts State Department of Health and the Department of Bacteriology of the Massachusetts Agricultural Experiment Station. The design, location, and construction of the original tank installation were carried out by the Division of Sanitary Engineering, and the operating supervision was in the hands of their resident engineer in Amherst. They planned to make an operational study of the installation, to make chemical studies of the effluent, and to study the efficiency of different coarseness of fills about the tile lines in the disposal field. The Department of Bacteriology undertook to study the bacteriology of the effluent with particular reference to its content of coliform bacteria, which are accepted as indicators of sewage pollution of water supplies.

Shortly after the installation was completed, and before it was put into satisfactory operation, the engineer in charge was called into military service and no one was available to replace him. Consequently, the whole of the project was taken over by the Experiment Station and assigned to the Department of Bacteriology.

The purpose of the project was to study the effect of the length of time sewage is retained on the efficiency of a septic tank. Employment of a retention period shorter than the usual 24 hours would enable a tank to handle increased quantities of sewage; or it might mean that tanks need not be as large as is commonly recommended for normal household installations. The design of the installation to carry out the study is explained in detail later in this paper.

The function of a septic tank is not well understood by laymen, who often believe that the effluent should be free from bacteria and harmless so far as its capacity to pollute water supplies is concerned. That this is not true is illustrated by the report of a committee representing governmental agencies of the United States concerned with rural sewage disposal (1). The report states: "Contrary to general belief, septic tanks should not be depended upon to remove disease-producing bacteria from sewage." The report adds: "The septic tank should be located where surface drainage from the site is away from all sources of water supply."

Regarding the size of tank and the retention period of the sewage, the report states that a septic tank is intended to retain and permit the bacterial digestion of the solids of the sewage. "The size of the septic tank should be based on the average daily flow into it with a retention period of approximately 24 hours, with due consideration to sewage sludge storage." The perusal of experiment station bulletins from several states, and reference to standard textbooks on sanitation, discloses recommendations for septic tank construction and operation substantially identical with those in the bulletin just quoted.

THE SEPTIC TANK INSTALLATION

The septic tank installation, the supply line, and the disposal field, are shown in diagram I. The installation was located in a field at the State University below a dormitory from which sewage was supplied by tapping a manhole in the main that served the building.

The installation consisted of three chambers, each of 2′ x 3′ x 4′ dimensions with a capacity of 179.5 gallons. In effect there were three separate tanks of identical size constructed in one block. Sewage was diverted from the manhole by means of a dam that permitted approximately the desired quantity to flow and enter a receiving chamber from which it was apportioned to the three tanks in quantities that provided three different retention periods: the recommended 24 hours in one tank, 12 hours in another, and 8 hours in the third.

The first receiving chamber proved to have several faults of design and operation and it soon became obvious that changes would have to be made. About this time the State Department of Health engineer entered the Army and the Experiment Station took charge. Under the new management, the late Professor C. I. Gunness, Experiment Station engineer, designed a new receiving chamber which is shown in diagram II. The chamber was divided, by lengthwise partitions, into two equal compartments, one of which served the north tank (designated as N) and provided a quantity of sewage that would permit a retention period of 8 hours. The other half of the chamber was divided by a cross partition into two compartments that had a capacity ratio of 2 to 1. The larger of these served the middle tank (designated as M) and permitted a retention period of 12 hours, and the smaller compartment served the south tank (designated as S) and provided the conventional retention period of 24 hours. Thus the sewage volume flow ratio for the N, M, and S tanks was 3:2:1.

A tip-bucket extended the length of the receiving chamber with a partition lengthwise through its center which divided the tip-bucket into two sections of equal capacity. These respective sections emptied sewage into the comparable compartments of the receiving chamber. The tip-bucket was hinged at the bottom on an iron rod which ran its length, and was so arranged that when one side tipped to empty sewage into the chamber, the other was upright to receive sewage which was fed to the tip-bucket through a trough above it having a slit running lengthwise to distribute the incoming sewage as evenly as possible along the length of the tip-bucket. A cross section of the tip-bucket is shown in diagram II.

A mechanical counter was attached to the tip-bucket to record the number of tips. Since the capacity of the tanks and of the tip-bucket was known, it was possible to calculate the number of tips required each 24 hours to furnish the desired quantity of sewage to each tank.

A considerable trial-and-error period was necessary to arrive at the correct diversion of sewage from the manhole. At best, the supply of sewage to the tank was irregular. There were several peaks during the day: first, in the morning when the residents of the dormitory were getting up, then at noon when some of them were back at the dormitory for a time, and again in the evening. Another source of discrepancy, during the period of operation of the tanks, was the difference of personnel housed in the dormitory. During the first two seasons (fall and early winter, 1943-44 and 1944-5) Army Air Corps cadets occupied the building, and the third season (fall and early winter, 1945) it reverted to student use and was occupied by girls. The cadets were not in the dormitory during the morning or afternoon, while during the last season some of the girls were in at all times. There were two other sources of discrepancy: the dormitory was unoccupied from May to late September each year; and the heavy snow and hard freezing of midwinter made operation impracticable from January through March because the receiving chamber and collecting wells were not housed, with the result that control of flow and collection of samples were difficult at all times and frequently impossible.

Collection of effluent samples was made from wells provided on the disposal lines as indicated in diagram I. These wells were double "T" joints set with one arm vertical. The lower portion of each vertical arm was plugged with cement to provide a sump, while the upper portion extended up to the surface of the ground and was open at the top. A cross section of the collecting wells is shown in diagram II.

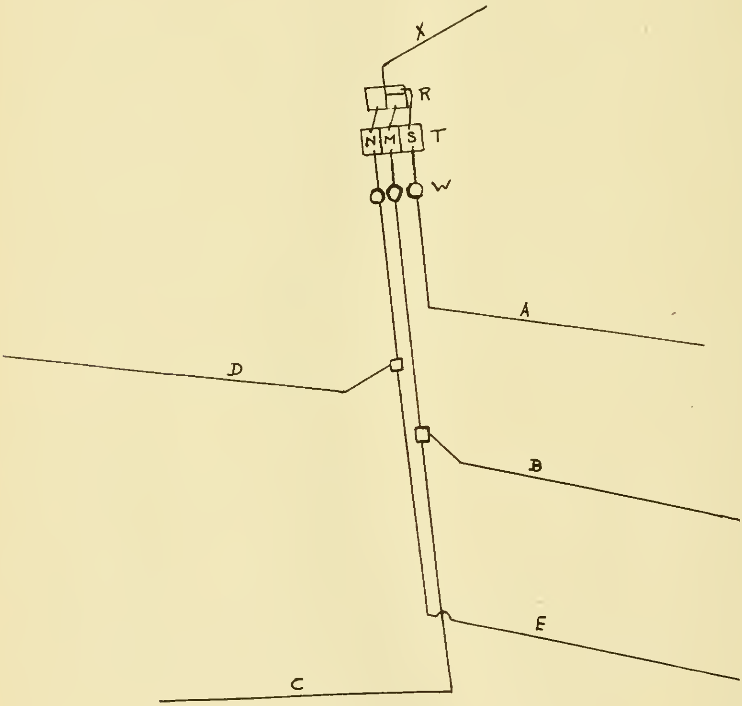


Diagram I. Plan of Septic Tank Installation and Disposal Field.

- X, line from sewer main.
- R, receiving chamber.
- T, septic tanks.
  - N, north tank, 8 hours retention.
  - M, middle tank, 12 hours retention.
  - S, south tank, 24 hours retention.
- W, collecting wells.
- A, B, C, D, E, disposal lines.

OPERATION OF TANKS

Operation of the tanks was begun in September, 1943, and was continued until hard freezing weather and snow in late December made it necessary to discontinue. No data from that period are included in this report because operation was in the experimental stage and a certain amount of trial-and-error procedure was required to detect faults in construction and to make plans to remedy them.

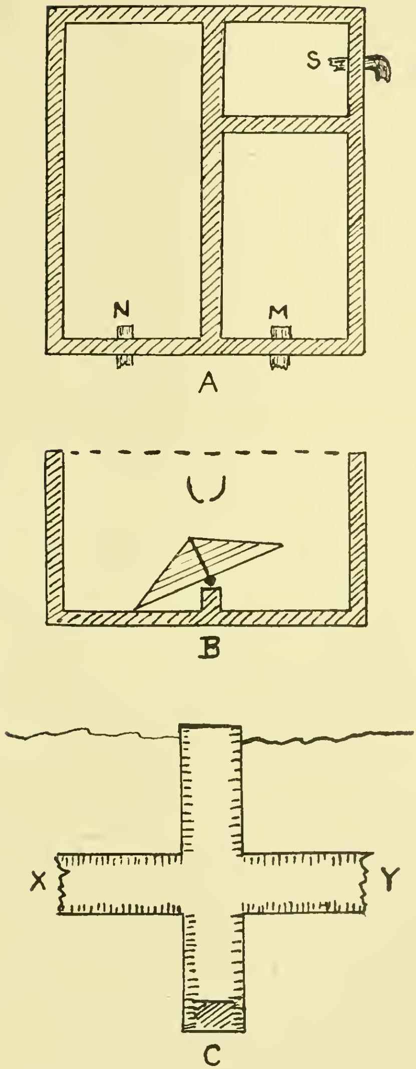


Diagram II. Details of Receiving Chamber, Tip Bucket, and Collecting Wells.

A, Receiving chamber, viewed from above.
N, M, and S, outlets to north, middle, and south tanks.

B, Cross-section of tip bucket.
U-shaped cross-section above is the supply trough from the sewer main.

C, Vertical cross-section of a collecting well.
X-Y is line of flow from tank to disposa' line.
Wavy line is ground level.
Top of vertical tile is open and bottom is plugged with cement to form well.

In the spring of 1944 the tanks were pumped out, the new receiving chamber with the tip-bucket was built, and operation was started as soon as the dormitory was occupied which was in the latter part of September. The installation required attention only about twice each day to record the amount of flow as indicated by the counter on the tip-bucket and to remove toilet paper that accumulated in the manhole on the dam that diverted the sewage to the line serving the tanks.

At the end of four weeks, the accumulation of scum in the north and middle tanks (8 and 12 hours retention respectively) was about 2 inches; in the south tank (24 hours retention), about 1 inch. By December 1, about two and one-half months after operation was started, so much scum had accumulated in the north tank that the outlet was plugged, and the middle tank was nearly in the same state. The south tank had only about 2½ inches of scum. The outlet pipes had vertical "T" arms extending 5 inches below the outlet level, which will give an idea of the accumulation of scum in the north and middle tanks. An examination of the scum in these tanks revealed that it contained considerable quantities of undigested solid matter of the sewage.

Cold weather dictated the closing of the tanks for a time because cleaning was impracticable. In late March, 1945, the scum was removed and operation was resumed. At the end of April the cadets left the dormitory, so no further results were obtained. Some examinations of effluents were made and are reported later.

After the second closing of the tanks the contents were removed and the horizontal "T" arms of the inlet and outlet pipes in the north and middle tanks were exchanged for longer arms that reached 12 inches below the levels of the horizontal inlet and outlet pipes. The tanks were put in operation again in late September, 1945. The scum began to form promptly in all three tanks, and in six weeks was about 6 inches thick in the north tank, 5 inches in the middle tank, and about 1½ inches in the south tank. By December 26, the thickness of the scum was 13 inches in the north tank, 11 inches in the middle tank, and about 2½ inches in the south tank. Again, examination of the scum in the north and middle tanks revealed the presence of substantial amounts of undigested solid matter of the sewage, while there was practically none in the scum in the south tank.

This portion of the investigation gave results in favor of the conventional 24-hour retention period recommended for and commonly employed in septic-tank operation. The rapid accumulation of scum with its content of undigested solid matter in the north and middle tanks indicated that the rapid flow of sewage prevented efficient functioning in them as compared with the south tank which functioned in the usual manner of septic tanks, and the thickness of the scum in the north and middle tanks was all out of proportion to the capacity of the tanks.

DISPOSAL FIELD

The disposal field was laid out in anticipation of the volume of flow from the tanks. The south, or normal-flow, tank was provided with a lateral 50 feet long; the middle tank with two laterals 50 feet long each; and the north tank with two laterals 75 feet long each. Thus, the ratio of the lengths of the laterals was the inverse of the sewage-retention periods of the tanks. These lines are shown in diagram I. The soil of the field was light silty loam. The disposal lines were laid in trenches excavated to a depth of 20 inches. The width was 18 inches at the bottom and 22 inches at the top. The top of the drain tile was 11 inches below the surface of the ground. The trenches were filled with gravel to one inch above the tiles. The remainder of the fill was the soil taken from the trenches.

While the tanks were being operated the disposal lines were watched to observe any evidence of excessive drainage from the tanks. None was observed from the middle and south tanks but, mid-way through the October-to-December period of 1944, the soil about the laterals of the north tank was definitely damp and remained that way until the ground froze late in December. Around the end of the lower lateral, water was visible on the surface of the ground, particularly at the end of the line, and the ground was so soft that one stepping on it would sink in the mud to his shoe tops. The ground water table at the season was not unusually high. The situation during the second season (October to December, 1945) was similar except that the soil around the lower lateral from the north tank was not quite so wet and no water appeared on the surface.

Reference to the surveyor's notes indicated that the drop of the more distant line of the north tank was somewhat sharper than it should have been; but, even so, the results of these observations indicated that the flow from the tank with the 8-hour retention period was too heavy to be taken care of satisfactorily by the length of disposal line provided. If economy of size is sought in the construction of rural septic-tank installations, it would seem advisable to economize on the disposal line rather than on the tank, particularly if only a limited amount of space is available for disposal.

BACTERIOLOGICAL EXAMINATION OF EFFLUENTS FROM TANKS

Samples of the effluents were collected from the wells on the disposal lines previously described and shown in diagram I. The collection schedule is shown in table 1. Samples were collected in sterile glass dippers which were pyrex beakers of suitable size with long wire handles attached to permit them to be dipped into the wells. A separate dipper was employed for each well, and samples were collected into sterile, wide-mouth, glass-stoppered bottles with a capacity of 12 fluid ounces. Samples were taken directly to the laboratory, which was within a few hundred yards of the tanks, and setting up of the bacteriological tests was begun promptly and carried through as expeditiously as possible. In no instance were the samples stored before they were examined.

TABLE 1.— DATES OF COLLECTION OF SEWAGE EFFLUENTS FROM SEPTIC TANKS.

Period I		
	1944:	October 17, 24, 30
		November 8, 14, 20, 29
	1945:	March 30
		April 12, 18, 24
Period II		
	1945:	October 5, 10, 17, 24
		November 1, 7, 13, 20, 28
		December 3, 5, 11, 13, 17*, 19

*Four samples were taken on December 17, at 9 and 11 a.m. and 1:30 and 3:30 p.m., to observe results through one day.

Plate Counts

Plate counts were made as directed in the Standard Methods of Water Analysis (2). Dilutions were made in sterile distilled water, and one ml. quantities were plated. Difco dehydrated nutrient agar was employed as the medium. In trial tests to determine the best time and temperature for incubation, the best growth response was obtained in plates incubated at 30° C. for 48 hours, so this procedure was employed. All counts were made in duplicate from duplicate samples, and the related counts were averaged.

The counts represented the two collection periods: I — October 10 to November 29, 1944, and March 30 to April 24, 1945, a total of ten collections; II — October 10 to December 19, 1945, a total of seventeen collections (see table 1). The counts are summarized in table 2.

TABLE 2.—SUMMARY OF PLATE COUNTS FROM SEWAGE EFFLUENTS.

Counts as numbers per milliliter of effluent.

	South Tank	Middle Tank	North Tank
Period I			
Number of collections	10	10	10
Low count	1,200,000	1,500,000	500,000
High count	7,000,000	5,000,000	5,600,000
Average of counts	3,180,000	2,660,000	2,290,000
Number of counts:			
Under 1,000,000	0	0	1
Over 1,000,000 to 3,000,000	6	8	7
Over 3,000,000 to 5,000,000	3	2	1
Over 5,000,000 to 10,000,000	1	0	1
Over 10,000,000	0	0	0
Period II			
Number of collections	17	17	17
Low count	1,500,000	1,000,000	1,600,000
High count	10,000,000	16,000,000	50,000,000
Average of counts	5,100,000	4.794,000	9,312,000
Number of counts:			
Under 1,000,000	0	0	0
Over 1,000,000 to 3,000,000	6	5	5
Over 3,000,000 to 5,000,000	3	7	4
Over 5,000,000 to 10,000,000	8	2	4
Over 10,000,000	0	3	4

The author is of the opinion that the counts would have little significance in comparing the efficiency of the tanks unless there were marked differences in the results. No such differences appeared in either collection period. One low count from the north tank in Period I lowered the average for that tank for the season. In Period II there were three high counts for the north tank and one for the middle tank. Except for this one low count and the four high counts, the spread of the counts was similar for all three tanks. The high and low deviations just mentioned did not occur a sufficient number of times among the samples to justify drawing any conclusions from them. The results of the plate counts did not appear to afford any evidence to the advantage or disadvantage of any of the three tanks of the installation.

Most Probable Number of Coliform Bacteria in Septic Tank Effluents

Testing for *Escherichia coli* and related species of bacteria, collectively termed coliform bacteria, is the recognized procedure for detecting sewage pollution in water supplies. For that reason the procedure was applied to the effluents from the three tanks to determine the effect, if any, from the three different retention periods on the numbers and types of coliform bacteria present in the effluents.

The procedures employed were those outlined in the Standard Methods of Water Analysis. Difco dehydrated media were employed. Samples of the effluent, diluted suitably to obtain optimum results, were inoculated into fermentation tubes of lactose broth, five tubes for each dilution. After incubation at 37° C. for 48 hours the numbers of tubes showing positive gas production were recorded. Then plates of eosin-methylene blue agar were streaked from these tubes to indicate the types of coliform bacteria present, and all cultures were reinoculated from the plates into lactose-broth fermentation tubes to complete the tests. Cultures were isolated from plates representing the highest dilutions of the effluents giving positive gas tests, five cultures from each sample. These cultures were subjected to differential tests to determine the distribution of types within the coliform group of bacteria. This part of the study is discussed later.

It will be noted that the incubation temperature employed throughout for the various coliform tests was 37° C., while that for the plate counts was 30° C. The reason for the difference was that in isolating and differentiating the coliform bacteria the time required to complete the tests can be shortened considerably by incubation at 37°, while the intent of the plate counts is to obtain growth of as many types of bacteria as possible. Most types, including the coliform bacteria, develop satisfactorily at 30°, and some types require the lower incubation temperature for satisfactory development.

The numbers of gas-positive fermentation tubes were calculated to determine the M.P.N. (most probable number) of coliform bacteria by the "Standard Methods" procedure, with the results summarized in table 3. One result for each tank in each collecting period was much higher than any of the others for the respective tank, so two sets of calculations were made: one set including all results, and one with the extra high figures omitted.

The results show that for the entire set of calculations of period I the middle tank (12 hours retention) had the highest average M.P.N., the north tank (8 hours retention) was second, and the south tank (24 hours retention) had the

Table 3.—Most Probable Number (M.P.N.) of Coliform Bacteria per Milliliter of Septic Tank Effluent.

	South Tank	Middle Tank	North Tank
Period I			
Total number of tests	11	11	11
Low M.P.N.	490,000	790,000	700,000
High M.P.N.	9,200,000	92,000,000	16,000,000
Average M.P.N.	2,997,000	11,450,000	5,273,000
Total tests minus one extra high*	10	10	10
Low M.P.N.	490,000	790,000	700,000
High M.P.N.	5,400,000	9,200,000	9,200,000
Average M.P.N.	2,377,000	3,399,000	4,200,000
Period II			
Total number of tests	18	18	18
Low M.P.N.	70,000	140,000	210,000
High M.P.N.	54,000,000	16,000,000	17,000,000
Average M.P.N.	4,360,000	3,500,000	3,590,000
Total tests minus one extra high*	17	17	17
Low M.P.N.	70,000	140,000	210,000
High M.P.N.	5,400,000	9,200,000	5,400,000
Average M.P.N.	1,420,000	2,770,000	2,240,000

* For each collection period, one M.P.N. value for each tank was much higher than other values for that tank for the same period. Calculations were made with and without these extra high values.

lowest average. For the set of calculations with the extra high figures omitted, the north and middle tanks changed places and the south tank again had the lowest average.

For period II, all tests included, the middle tank had the highest average M.P.N., the north tank second, while the south (normal) tank had the lowest average. The same order obtained for calculations that omitted the extra high M.P.N. figure for each tank.

The individual M.P.N. values from the three tanks were scored for each sampling date, allowing three points for the highest M.P.N., two for the middle value, and one for the lowest. On that basis, for the first operating season, the north tank scored 27, the middle tank 25, and the south tank 14 for eleven tests. The numbers of high, middle, and low scores for the three tanks were as follows:

	High Score	Tied for High Score	Middle Score	Low Score
North tank	5	3	2	1
Middle tank	2	3	6	0
South tank	1	1	0	9

For the second collection period, the scores for eighteen tests were: middle tank, 41; north tank, 38.5; south tank, 28.5. The numbers were larger than for the first period because there were more tests. The numbers of high, middle, and low values were:

	High Score	Tied for High Score	Middle Score	Low Score
North tank	5	1	9	3
Middle tank	8	2	4	4
South tank	3	1	3	11

In one instance all three values were the same and were counted as a tie for high. The results from the scoring procedure show that the south tank had the lowest M.P.N. values for both seasons, which agrees with the averages shown in table 3.

When all the data are considered, the evidence favors the south tank as being more efficient than the other two in eliminating coliform bacteria from sewage. It must be remembered, however, that the north tank received three times as much sewage as the south tank, and the middle tank twice as much. This gives a ratio of 3:2:1. The M.P.N. averages for the three tanks for either operating period are closer than that, which could be taken as an indication that the 8-hour and 12-hour retention periods were relatively as efficient as the normal of 24 hours. Even if that were true, however, the net result would be the liberation in 24 hours of fewer coliform bacteria in the effluent from the south tank than from either of the other two tanks.

Differential Distribution of Coliform Bacteria Isolated from Positive Fermentation Tests

The cultures included in this part of the study were isolated, as was mentioned previously, from eosin-methylene blue plates, five cultures from the highest dilutions of each sample that had given positive gas tests in lactose broth. The cultures were purified according to accepted methods (3) and then were put through the so-called "IMViC" tests (4). These are indol production (I), the methyl-red test (M), the Voges-Proskauer test (V) and growth in sodium citrate C). The letter "i" is included to complete the word.

Indol is produced in tryptophane broth by *Escherichia coli* and related strains of the group and is considered to be a characteristic of coliform bacteria of sewage origin. The same is true of a positive methyl-red test which means that the coliform bacteria of sewage origin will produce sufficient acid in a medium containing dextrose to give a positive acid reaction with the methyl-red indicator. The Voges-Proskauer reaction depends on the production of a substance known as acetyl-methyl-carbinol from dextrose, and a positive test is characteristic of *Aerobacter aerogenes* and other coliform bacteria of non-sewage origin. The same is true of a positive sodium-citrate test which means the capacity of the bacteria to grow in a medium containing sodium citrate as the sole source of necessary carbon. The Citrobacter (5), closely related to *E. coli*, violates this rule because it gets its name from its ability to utilize sodium citrate. Of these tests, the methyl-red test is regarded by many authorities as the most dependable single test for sewage-type coliform bacteria. A positive methyl-red test may occur with any combination of reactions to the other three tests.

TABLE 4. — CLASSIFICATION OF COLIFORM BACTERIA FROM SEPTIC TANK EFFLUENTS EXPRESSED AS PERCENTAGES OF TOTAL CULTURES ISOLATED FROM THE RESPECTIVE TANKS.

	Percentages of Total Cultures		
	Period I	Period II	Both Seasons
South Tan			
Escherichia coli	36.	75.4	56.9
Citrobacte	38.0	4.6	20.4
Methyl-red-positive intermediates	6.9	10.8	8.9
Total methyl-red-positive organisms	81.0	90.8	86.2
Aerobacter aerogenes	0	3.1	1.6
Methyl-red-negative intermediates	19.0	6.1	12.2
Middle Tank			
Escherichia coli	32.7	79.5	59.0
Citrobacter	36.5	1.5	16.7
Methyl-red-positive intermediates	15.4	8.8	11.7
Total methyl-red positive organisms	84.6	89.8	87.4
Aerobacter aerogenes	0	7.3	4.2
Methyl-red-negative intermediates	15.4	2.9	8.4
North Tank			
Escherichia coli	36.5	64.6	52.1
Citrobacter	36.5	3.1	18.0
Methyl-red-positive intermediates	5.8	7.7	6.8
Total methyl-red-positive organisms	78.8	75.4	76.9
Aerobacter aerogene	0	10.7	6.0
Methyl-red-negative intermediates	21.2	13.9	17.1

Results of the differential tests, as seen in table 4, are based on the following group reactions:

	Indol	Methyl-red	Voges-Proskauer	Sodium Citrate
Escherichia coli	+	+	−	−
Citrobacter	+	+	−	+
Aerobacter aerogenes	−	−	+	+

Organisms not conforming to the reactions in this tabulation are termed intermediates. For the purpose of this report the intermediates encountered were placed in two groups, methyl-red positive and methyl-red negative, to relate them to either *E. coli* or *A. aerogenes.*

It may be noted here that the term "Citrobacter" is employed by sanitary bacteriologists for the purposes of sanitary classification but is not recognized in biological classifications.

Reference to table 4 shows that more than 75 percent of all the cultures isolated were methyl-red positive, as was to be expected. Certain differences appeared between the results for periods I and II. In period I the Citrobacter percentages were considerably higher and those of *E. coli* were lower than for period II, but the totals of methyl-red positive cultures were similar for both periods. Also, no *A. aerogenes* cultures were isolated in period I, but they were encountered in period II. The total percentages of methyl-red negative cultures naturally were in accord with those of the methyl-red positives.

The result of the differential studies did not appear to favor any one of the tanks over the other two for either of the collection seasons or for the totals of the two.

CHEMICAL EXAMINATION OF EFFLUENTS FROM TANKS

The chemical examinations of the effluents, reported here, were made in the local laboratory of the Massachusetts Department of Public Health by Mr. Ernest A. Snow, Senior Chemist of the Division of Sanitary Engineering. The scope of the examinations was limited by the time at Mr. Snow's disposal for the work, so it was decided to make the tests that it was fe t would give the best indication the effic ency of the tanks in digesting the solid matter of the sewage. These tests were the determination of the biochemical oxygen demand, commonly called B.O.D., and of the free-ammonia nitrogen in the effluents from the three tanks. The tests were made on the samples collected for the bacteriological examinations of effluents reported in this paper.

Biochemical Oxygen Demand

The test for the biochemical oxygen demand depends upon the fact that oxygen in a sewage suspension is used up in the process of digesting suspended organic matter. Thus, the higher the B.O.D. value in a test, the greater is the amount of undigested matter in the sewage or, in this instance, the effluents from the tanks. The techniques employed for the tests were those of the Standard Methods for the Examination of Water and Sewage (2). Tests were made only in the second operating period, fall and early winter, 1945-6. Results are summarized in table 5.

On the basis of the averages and of the score (explained in note at bottom of table 5) the biochemical oxygen demand for the south tank was considerably less than for the other two tanks, which had values close together. These results indicate that the most nearly complete digestion of the sewage solids took place in the south tank which had the normal retention period; but it should be noted that the B.O.D. values and the scores for the three tanks were closer together than the 3:2:1 volume ratio of sewage passing through them. This could indicate that, considering greater volumes of sewage treated in the north and middle tanks, digestion of sewage solids was relatively more efficient in them than in the south tank.

TABLE 5.—SUMMARY OF BIOCHEMICAL OXYGEN DEMAND TESTS FROM SEPTIC TANK EFFLUENTS.

	South Tank	Middle Tank	North Tank
Number of tests	12*	13	13
Parts per million of oxygen			
Low	78	102	122
High	228	373	493
Average	124	211	221
Score*	15	27	30

* The number of tests represents the number of collection dates. There are 12 tests instead of 13 for the South Tank because the value for one of its tests was so much higher than any of the other values that it was considered a probable error and discarded. The average for this tank was based on the 12 tests. The scores were based on the same 12 tests for each tank: 3 points for the high value, 2 points for the middle value, and 1 point for the low value for each collection date.

The main point at issue, however, is the quality of the effluents, and in this the south tank would have to be considered superior on the basis of B.O.D. determinations. This decision agrees with the amounts of scum that accumulated in the three tanks and with the observation that the scum in the north and middle tanks contained considerable sewage solids which had disintegrated very little.

Free Ammonia Determinations

Free ammonia in the effluent results from the bacterial decomposition of the protein portion of the sewage solids. Consequently the amount of ammonia recovered in the tests and expressed as nitrogen would be interpreted as a direct indication of the relative activity of digestion of sewage solids in the tanks. If the total digestive efficiencies of the three tanks were in proportion to the 3:2:1 volume ratio of sewage handled by the tanks, then the south tank effluent should have shown much the smallest quantity of ammonia. Reference to table 6, however, shows that the averages for the three tanks were nearly the same and that the score for the south tank was only a little lower than the scores for the other two tanks. This agrees with the results of the B.O.D. determinations and with the presence of undigested sewage solids in the scum in the north and middle tanks.

TABLE 6.—SUMMARY OF DETERMINATIONS OF FREE-AMMONIA NITROGEN FROM SEPTIC TANK EFFLUENTS.

	South Tank	Middle Tank	North Tank
Number of tests*	18	18	18
Parts per million of nitrogen			
Low	18.0	13.0	10.0
High	6 .0	48.0	50.0
Average	27.0	28.2	27.0
Score*	30.5	38.5	39.0

* The 18 tests represent 18 collection dates which include the dates represented by the B. O. D. tests of table 5. There are fewer B. O. D. tests than ammonia tests because facilities were not available for making the B. O. D. test on all of the collection dates. The scores are based on a comparison of values for the three tanks on each collection date: 3 points for the high value, 2 points for the middle value, and 1 point for the low value. The fractions are accounted for by the north and middle tanks having the same values on several dates.

BACTERIOLOGICAL EXAMINATION OF DISPOSAL FIELD SOILS

This examination was undertaken to determine the extent to which the coliform bacteria from the effluent had penetrated into the soil, and the permanence of the several species in the soil environment. Soil samples were taken at the points indicated as A, B, C, D, and E in diagram I. Samples were taken on both sides of each disposal line about midway of its length at the level of the tile and two feet from the line. In the first sampling season samples were taken also at two feet and five feet from the end of each line. In the second season samples were taken from both sides of each line as before, but not at the ends. The reason was that, in the cultivation of a field that surrounded the disposal area, the soil at the ends of lines C, D, and E had been plowed practically up to the tile ends and it was felt that the soil was so stirred up that representative samples could not be obtained. Line C was one of two from tank M (12 hours retention) and lines D and E were the two lines from tank N (8 hours retention). Control samples were taken from areas in the same field that received no effluent from the tanks.

The first sampling season was in May, 1945, after the tanks had been in operation through the previous fall and early winter and again in the spring; and the second season was in May and early June, 1946, after the tanks had been operated through the previous fall and early winter (table 1). Reasonable precautions were taken to collect the samples aseptically.

Samples were screened separately through ordinary window screen. Then portions were weighed, air-dried in the laboratory, and re-weighed to establish a basis for making dilutions of the moist soil in terms of dried soil. The samples were kept in closed containers to keep them as nearly as possible in the same condition as when they were taken from the field. Quantities of the samples sufficient to give 10-gram portions of air-dried soil were suspended in dilution bottles containing 100 ml. each of sterile distilled water, giving an initial 1 to 10 dilution. Further dilutions were made from these suspensions.

Since the main interest was in recovering coliform bacteria from the soils, the Standard-Methods procedure (2), as employed for the examination of water and sewage, was followed. This technique is the same as that employed for the study of coliform bacteria from the tank effluents as reported earlier in this paper.

Preliminary trials had indicated that dilutions of 10^1, 10^2, 10^3, and 10^4 were best adapted for the purpose, so five fermentation tubes of lactose broth were inoculated from each of these dilutions of each soil, 1 ml. of suspension to each tube. The inoculated tubes were incubated at 37° C. and read daily for gas production. No tube was discarded as negative until after 72 hours of incubation. Eosin-methylene blue plates were streaked from all gas positive tubes and incubated at 37° C. Cultures were isolated from the plates on which growth occurred and were purified and held on nutrient agar slants for further study. Some of the gas-positive cultures were false-positive tests caused by organisms other than the coliform group. These cultures failed to give growth on the eosin-methylene blue plates. The agar-slant cultures were differentiated later on the basis of the "IMViC" tests.

Tables 7 and 8 give a summary of the results of the fermentation and differential tests. Table 9 is a statement of the results of the fermentation tests, from table 7, expressed as percentages of the numbers of fermentation tubes inoculated from the soil samples of a particular disposal line. Results from the several samples for each line respectively were so much alike that all six sets of results from the first series were combined, and all four from the second series, for each line respectively. Table 10 shows the differential tests of table 8 expressed as percentages of the total numbers of coliform cultures isolated from the soil adjacent to particular disposal lines.

In evaluating the data of the tables the writer takes the position, stated earlier in this paper, that differences in the results obtained for the several disposal lines from the three tanks should not be considered significant unless they were pronounced. That was not true of the data obtained in this study. The results may be summarized as follows.

Gas-Positive Tests

For the first sampling season, the greatest number of positive tests (50 to 65 percent) was obtained at the 48-hour reading. The number of positive tests at 24 hours was about balanced with the number at 72 hours. This meant, therefore, that roughly three-fourths of the gas-positive tests were obtained at 48 hours or later. The control samples gave similar results. *Escherichia coli* from fresh sewage pollution usually gives a positive gas test in 24 hours or less, while the delayed reactions usually are given by non-sewage soil types or by false-positive reactions. On the other hand, the soil types may give positive results in 24 hours. All of this indicates that a majority of the coliform bacteria recovered from the soil were either of non-sewage origin; or that, if they were of sewage origin, their differential reactions had been altered by their sojourn in the soil. This latter possibility has been suggested by several investigators but never proved.

For the second sampling period the percentage of gas-positive results for 48 hours was again the largest; but it was lower and the 24-hour and 72-hour percentages were higher than for first sampling period. The majority of the gas-positive tests were obtained in 48 or 72 hours of incubation as in the first period. There was a considerable discrepancy between 48-hour results from the two lines of the middle tank, but its significance, if any, is not apparent.

The percentage of gas-negative tests was higher in the second period than in the first. In the first period the percentages for one line from the middle tank and one from the north tank were considerably higher than for the other lines. However, the high percentage for the middle tank was for the line nearest the tank, while the high percentage for the north tank was for the more distant line. The percentages of gas-negative tests from the control soils were similar to those from the several disposal lines except for the two high percentages just mentioned.

The percentages of false-positive tests were higher, in general, for the first sampling period than for the second. The distribution of values for the several lines does not lend itself to any particular interpretation. In the first period the highest value was for the control samples and the lowest, about half as great, was for the near line of the middle tank. The value for the other line of this tank, however, was nearly as large as that for the control. In the second period the value for the more distant line of the north tank was the lowest of the series, and that for the control samples was also low as compared to the high.

In general, the results throughout the two seasons were heterogeneous and did not indicate any preponderant values, either high or low, for any of the three tanks. The preponderance of gas-positive values at 48 and 72 hours incubation indicates that the cultures recovered were probably not from sewage but rather were native to the soil.

Table 7.—Summary of Results of Fermentation Tests for Coliform Bacteria in Disposal Field Soils, 1945 and 1946.

	South Tank	Middle Tank		North Tank		Controls
Disposal line	A	B	C	D	E	
Summe of 1945						
Number of tests	120	120	120	120	120	140
Positive tests						
24 hours incubation	17	8	19	14	30	22
48 hours incubation	65	65	40	39	44	54
72 hours incubation	6	15	11	7	11	25
Total positive tests	88	88	70	60	85	101
N gative tests	32	32	50	60	35	39
Analy is of positive tests						
Coliform positives	63	69	36	35	52	61
False positives*	25	19	34	25	33	40
Summer of 1946						
Number of tests	80	80	80	80	80	80
Positive tests						
24 hours incubation	18	16	23	17	6	18
48 hours incubation	27	43	22	29	26	25
72 hours incubation	10	8	13	11	21	21
Total positive tests	55	67	58	57	53	64
Negative tests	25	13	22	23	27	16
Analysis of positive tests						
Coliform positives	40	51	36	43	44	51
False positives*	15	16	22	14	9	13

* False positive tests produced by bacteria not of the coliform group.
Note: South tank, normal 24 hours retention; middle tank, 12 hours retention; north tank, 8 hours retention. Controls were soils from the same area that had not received sewage effluent.

Table 8.—Analysis of Positive Coliform Tests From Table 7.

	South Tank	Middle Tank		North Tank		Controls
Disposal line	A	B	C	D	E	
Summer of 1945						
Total coliform cultures	63	69	36	35	52	61
Escherichia coli	2	1	0	1	1	1
Citrobacter	0	1	0	0	0	0
Aerobacter aerogenes	11	19	13	14	30	31
Coliform intermediates						
Methyl-red positives	20	15	5	6	6	6
Methyl-red negatives	30	33	18	14	15	23
Summer of 1946						
Total coliform cultu es	40	51	36	43	44	51
Escherichia coli	0	1	0	1	0	0
Citrobacter	0	1	1	4	0	0
Aerobacter aerogenes	28	29	24	26	25	38
Coliform intermediates						
Methyl-red positives	2	5	5	3	6	2
Methyl-red negatives	10	15	6	9	13	11

Note: South tank, normal 24 hours retention; middle tank, 12 hours retention; north tank, 8 hours retention. Controls were soils from the same area that had not received sewage effluent.

Table 9.—Results of Fermentation Tests From Table 7. Expressed as Percentages of Number of Tests Made.

	South Tank	Middle Tank		North Tank		Controls
Disposal line	A	B	C	D	E	
Summer of 1945						
Number of tests	120	120	120	120	120	140
Positive tests						
24 hours incubation	14.3	6.7	15.8	11.7	25.0	15.7
48 hours incubation	54.0	54.0	33.4	32.5	36.6	38.6
72 Hours incubation	5.0	12.6	9.2	5.8	9.2	17 8
Total positive tests	73.3	73.3	58.4	50.0	70.8	72.1
Negative tests	26.7	26.7	41.6	50.0	29.2	27.9
Analysis of positive tests						
Coliform positives	52.5	57.5	30.0	29.2	43.3	43.5
False positives*	20.8	15.8	28.4	20.8	27.5	28.6
Summer of 1946						
Number of tests	80	80	80	80	80	80
Positive tests						
24 hours incubation	22.5	20.0	28.8	21.2	7.5	22.5
48 hours incubation	33.7	53.7	27 5	36.2	32.5	31.3
72 hours incubation	12.5	10.0	16.2	13 8	26.2	26.2
Total positive tests	68.7	83.7	72.5	71.2	66.2	80.0
Negative tests	31.3	16.3	27.5	28.8	33.8	20.0
Analysis of positive tests						
Coliform positives	50.0	63.7	45.0	53.7	55.0	63.7
False positives*	18.7	20.0	27.5	17.5	11.2	16.3

*False positive tests produced by bacteria not of the coliform group.

Note: South tank. normal 24 hours retention; middle tank, 12 hours retention; north tank, 8 hours retention. Controls were soils from the same area that had not received sewage effluent.

Table 10.—Analysis of Positive Coliform Tests of Table 8, Expressed as Percentages of Number of Coliform Cultures Recovered.

	South Tank	Middle Tank		North Tank		Controls
Disposal line	A	B	C	D	E	
Summer of 1945						
Total coliform cultures	63	69	36	35	52	61
Escherichia coli	3.2	1.4	0	2.9	1.9	1.6
Citrobacter	0	1.4	0	0	0	0
Aerobacter aerogenes	17.4	27.5	36.2	40.0	57.7	51.0
Coliform intermediates						
Methyl-red positives	31.8	21.7	13.8	17 1	11.5	9.8
Methyl-red negatives	47.6	48.0	50.C	40.0	28.9	37.6
Summer of 1946						
Total coliform cultures	40	51	36	43	44	51
Escherichia coli	0	2.0	0	2.3	0	0
Citrobacter	0	2.0	2.8	9.3	0	0
Aerobacter aerogenes	70.0	57.0	66.6	60.5	57.0	74.6
Coliform intermediates						
Methyl-red positives	5.0	9.7	13.9	7.0	13.6	3.9
Methyl-red negatives	25.0	29.3	16.7	21.0	29.4	21.5

Note: South tank, normal 24 hours retention; middle tank, 12 hours retention; north tank, 8 hours retention. Controls were soils from the same area that had not received sewage effluent.

Differential Tests of Coliform Bacteria

A summary of the results of the differential tests on the cultures from the soils appears in table 8 and the differential tests of that table are expressed in table 10 as percentages of coliform organisms isolated from each tank effluent for each sampling season.

It is significant that, of the coliform bacteria recovered from the soils, very few were either *Escherichia coli* or their close relatives, Citrobacter, which table 4 shows were present in considerable numbers in the effluents and which are considered to be indicative of sewage pollution. The lack of *E. coli* and Citrobacter was observed in both sampling seasons and was consistent with the fact, already mentioned, that a preponderance of the gas-positive tests obtained required 48 or 72 hours of incubation. The percentages of methyl-red positive intermediates were generally lower for the second sampling season than for the first. The highest percentage of these positives in the first season was obtained from the south tank (24-hour retention) and the lowest percentage was from the controls. Accepting the opinion of certain authorities in the field of sanitation, this observation could argue in favor of the 8-hour and 12-hour retention as being more efficient than the normal of 24 hours in removing sewage types of coliform bacteria from the effluents. However, in the second sampling season the lowest percentages of methyl-red positive intermediates were obtained from samples adjacent to the south-tank line and from the control samples. *Aerobacter aerogenes* and methyl-red negative intermediates predominated for all samples and for both sampling seasons. There were no differences that the writer can call significant. In the second season there were more of the *A. aerogenes* cultures than of the methyl-red negative intermediates.

In general, it may be said that the data agree with those for the gas-positive tests and indicate that the bacteria recovered from the soil samples may well have been native to the soils rather than invaders from the septic-tank effluents. This raises a question: what becomes of the sewage-type coliform bacteria when they enter the soil? This will be the basis of a subsequent study.

SUMMARY

The experimental results may be summarized as follows:

1. **Management.** As the tanks were being operated for two seasons it became evident that decidedly too much scum accumulated in the two tanks with retention period of 8 and 12 hours respectively. The layer of scum in each of these tanks formed rapidly and became so thick that the inlet and outlet pipes to the tanks became plugged in about three months and use of the tanks had to be suspended. This was in spite of special construction in the second season designed to permit much greater accumulation of scum than would be anticipated in normal tank operation. The scum in these two tanks contained much undigested solid matter of the sewage. A normal amount of scum accumulated in the tank with 24 hours retention.

The amount of effluent passing from the tank with 8 hours retention appeared to be greater than the capacity of the disposal field could take care of. The ground about the two lateral lines, particularly the more distant one, was waterlogged and water stood on the surface part of the time. This effect may have been influenced in part by the grade drop of the lines.

Thus, from a management point of view, the shorter retention periods would seem to have limitations that would render them unsuitable for practical sewage disposal.

2. **Bacteriological Tests of Effluents.** The total counts of bacteria indicated no advantage for any of the retention periods. The most probable numbers of coliform bacteria favored the normal 24-hour retention period so far as the quality of the effluent was concerned because fewer coliform bacteria were recovered from the effluent. Differentiation of the isolated coliform cultures into the sewage and non-sewage types did not favor any of the tanks.

3. **Chemical Tests of Effluents.** The biochemical oxygen demand test indicated that, with respect to digestion of the sewage solids, the efficiency ratings of the three tanks were closer together than the 3:2:1 volume ratio of sewage passing through the tanks. However, the normal 24-hour retention period would be preferred in practical operation because the tests indicated more complete digestion of solids in the tank. The ammonia tests indicated greater digestive activity in the normal-retention tank and so agreed essentially with the biochemical oxygen demand results.

4. **Bacteriological Study of Soils of the Disposal Field.** Results did not favor any retention period. In fact, so few sewage-type coliform bacteria were recovered from the soil that the question is raised: "What becomes of sewage-type coliform bacteria which are abundant in the effluent but are not recovered from soil which receives it?" This will be the subject of future investigation.

Conclusion. A consideration of the data as a whole favors the normal 24-hour retention period usually recommended for septic tanks. The too-rapid accumulation of scum for the short-time retention periods, and the presence of undigested sewage solids in this scum, would in the writer's opinion outweigh any favorable evidence obtained from the laboratory examinations. The probable need for more extensive disposal fields for these tanks, as compared to the normal-retention tank, would more than balance economy of space or construction costs that might be gained by installing smaller tanks. Even though some of the laboratory evidence indicated that the shorter retention periods were as satisfactory as the normal 24-hour period, the management problems encountered argue in favor of the normal period. Also, the chemical tests and the most probable numbers of coliform bacteria of the effluent indicate preference for the 24-hour retention usually recommended for septic-tank installations.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 447 APRIL, 1948

Cranberry Growing in Massachusetts

By Henry J. Franklin

Massachusetts produces more than half the cranberries grown in the world. It is, therefore, considered desirable to issue a bulletin dealing with the cultural practices of this important crop.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

CRANBERRY GROWING IN MASSACHUSETTS

(A Revision of Bulletin 371, 1940)

By Henry J. Franklin,
Research Professor in Charge of the Cranberry Station

THE cranberry of commerce[1] is native to North America only, although a closely related species[2] grows in northern Europe and Asia. That species, however, has such small berries that it is not suitable for cultivation. Our American cranberry is grown a little in Holland and England, but extensively only in North America. The fruit is used mainly in the United States and Canada, no large foreign market having been developed.

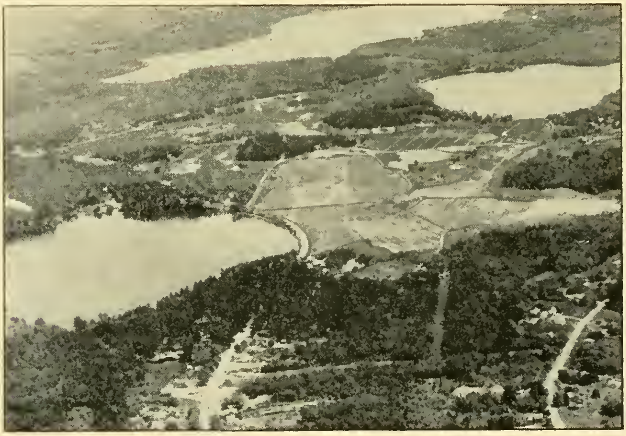


Fig. 1. Cranberry Bogs from the Air.
The bogs in the foreground look whiter than those in the background because they were partly flooded.

Commercial cultivation of the cranberry began on Cape Cod and in Middlesex County a hundred years ago. It paid well from the start and has developed so that this fruit is now the leading export crop of the State, bringing in a gross annual return of from $5,000,000 to $16,000,000. The industry here, except for a few small bogs, is confined to Middlesex, Bristol, Plymouth, Barnstable, Dukes, and Nantucket counties, the Plymouth County crop being more important than the others, with Carver, Plymouth, and Wareham the most productive townships. Cranberries are also grown in Wisconsin, in New Jersey, on the coast of Washington and Oregon, in Nova Scotia, and on Long Island, these districts being named in the order of their importance in the industry.

ACKNOWLEDGMENT is made to the Bureau of Plant Industry of the United States Department of Agriculture for the photographs reproduced in Figures 5 and 6, also for Figure 16; to the American Cranberry Exchange for the photographs used in Figures 2, 3, 7, 9C, 30, 31, 34, 35, and 37; to Cranberry Canners, Inc., for the photographs used in Figures 1 and 40; and to the New Jersey Agricultural Experiment Station for permission to use Figure 22.

[1] *Vaccinium macrocarpon* Ait.

[2] The "moss" or "speckled" cranberry (*V. Oxycoccos* L.)

In Massachusetts, 14,927 acres were under cranberry cultivation in 1946.[3] A New Jersey cranberry survey[4] in 1932 gave a total of 11,944 acres. Wisconsin has about two-thirds of the rest of the acreage of the country, there being about 2800 acres in bearing there (Bain). These figures, however, fail to show how much land is devoted to the industry, for they leave out the sand banks and other upanld around the bogs and the land used for reservoirs.

BARRELS

PRODUCTION OF CRANBERRIES ([redacted]

Year	Massachusetts	New Jersey	Wisconsin	Washington	Oregon	United States Total
1900	200,000	100,000	18,000	—	—	318,000
1901	264,000	110,000	40,000	—	—	414,000
1902	238,000	33,000	46,000	—	—	317,000
1903	226,000	175,000	18,000	—	—	419,000
1904	281,000	83,000	21,000	—	—	385,000
1905	165,000	88,000	18,000	—	—	271,000
1906	264,000	103,000	45,000	—	—	412,000
1907	310,000	121,000	21,000	—	—	452,000
1908	257,000	75,000	12,000	—	—	344,000
1909	402,000	169,000	30,000	—	—	601,000
1910	312,000	241,000	16,000	—	—	569,000
1911	298,000	145,000	30,000	—	—	473,000
1912	354,000	113,000	45,000	—	—	512,000
1913	367,000	101,000	30,000	—	—	498,000
1914	471,000	160,000	33,000	—	—	664,000
1915	257,000	184,000	35,000	—	—	476,000
1916	364,000	169,000	38,000	—	—	571,000
1917	137,000	129,000	27,000	—	—	293,000
1918	218,000	127,000	30,000	—	—	375,000
1919	395,000	155,000	40,000	—	—	590,000
1920	309,000	130,000	33,000	—	—	472,000
1921	208,000	165,000	24,000	—	—	397,000
1922	337,000	205,000	55,000	—	—	597,000
1923	451,000	200,000	35,000	—	—	686,000
1924	339,000	215,000	42,000	9,800	4,200	610,000
1925	447,000	115,000	25,000	15,400	6,600	609,000
1926	438,000	215,000	85,000	16,600	7,000	761,600
1927	385,000	75,000	25,000	21,000	6,000	512,000
1928	348,000	138,000	45,000	22,000	6,000	559,000
1929	421,000	90,000	42,000	11,000	5,800	569,800
1930	395,000	146,000	36,000	3,500	3,000	583,500
1931	460,000	132,000	48,000	9,000	5,000	654,000
1932	415,000	80,000	75,000	7,500	2,300	579,800
1933	506,000	142,000	42,000	4,800	3,900	698,700
1934	290,000	72,000	59,000	18,300	6,000	445,300
1935	332,000	85,000	77,000	17,000	4,500	515,500
1936	346,000	75,000	62,000	16,700	4,600	504,300
1937	565,000	175,000	115,000	18,500	3,800	877,300
1938	325,000	62,000	64,000	15,700	7,500	474,200
1939	490,000	88,000	108,000	12,300	5,900	704,200
1940	322,000	90,000	121,000	25,200	12,300	570,500
1941	500,000	80,000	99,000	36,000	10,200	725,200
1942	572,000	95,000	107,000	27,000	11,200	812,200
1943	492,000	62,000	102,000	24,000	7,900	687,900
1944	159,000	59,000	115,000	30,000	12,700	375,700
1945	478,000	49,000	82,000	36,400	11,400	656,800
1946	553,000	101,000	145,000	42,000	16,100	857,100
1947	485,000	81,000	155,000	48,000	15,700	784,700

[3] Recent survey.

[4] Circular 232, State of New Jersey Department of Agriculture, 1933.

Yields

The average annual acre yield of cranberries in this State ranges from 21 to 41 barrels, but well-managed bogs with proper facilities probably average over 50 barrels in a series of years. The average acre yield is somewhat larger in Wisconsin than in Massachusetts, but elsewhere it is less. The differences are due partly to differing natural conditions for the industry and partly to methods of culture. All of the cranberry bogs in Massachusetts and most of those in Wisconsin are covered with sand. Less than a sixth of the New Jersey acreage is sanded. Most bogs in Massachusetts are kept free from weeds, while most of those elsewhere are very weedy.

The table giving the cranberry production in the chief growing regions since 1900 shows the lead this State has in the industry. Our natural conditions for this crop are so good that this lead will be held a long time. The relative lack of suitable and accessible sand is a handicap elsewhere. The climate is rather unfavorable in New Jersey, promoting more weed and fungous troubles than in other cranberry districts. Wisconsin is well placed in the industry and may be

Fig. 2. Part of a Cranberry Vine with Upright Branches.

a long-term rival in spite of its troubles with drouth and summer frosts; its geographical location gives it an average freight advantage in the delivery of fruit to the markets of the country as a whole; its Searls variety[5], partly because of the large berries, is more productive than any other cranberry variety largely grown; the crop there is harvested more completely and with less injury to the vines than elsewhere by water-scooping.[6] The alkalinity of many of the marshes in parts of Wisconsin is probably a limiting factor there.

Cranberries have been called a luxury, but they are no more so than any of our other fruits. The market for them has kept pace with their production, and prices for good fruit are usually satisfactory. The average season price per barrel has ranged from $11.71 to $31.10 in the last several years. Some growers fear the supply of cranberries may sometime exceed the demand. This may come to pass temporarily, but important new uses are being found for this fruit and the market for it is being largely extended and stabilized by canning. Moreover, the effective producing cranberry acreage of the country is hardly greater now than it was twenty-five years ago. Good cranberry bogs will, therefore, be attractive investments for some time to come. Though the cranberry acreage of this State is not much greater than formerly, its production has increased considerably, probably largely because of reduction of losses by insects and frosts.

Fig. 3.
Cranberry Flower Buds and Flowers.

THE CRANBERRY PLANT

The cranberry plant is a trailing vine with many upright branches and roots along it (Fig. 2). Both the runners and the uprights have leaves, but only the latter bear fruit. The leaves are evergreen but turn brownish in winter. The vines make a mat all over the surface of a cultivated bog (Fig. 31B). They blossom in late June and early July, and the fruit ripens in September and October. The flowers (Fig. 3) depend mostly on insects for pollination; and while wild bees are usually plentiful, it probably is good insurance to keep bees for this purpose. The set of fruit is not affected by night coolness short of frost during bloom.

[5] Searls, also called Searls Jumbo, is the main Wisconsin variety (p. 27). Over a third of the cranberry acreage of the State, however, is in unselected native vines.
[6] Mass. Agr. Expt. Sta. Bul. 293, 1933, p. 23.
The general experience of cranberry growers in the State of Washington, where sprinkling systems have been used on the cranberry bogs everywhere in recent years, is that irrigation by sprinkling on hot days helps greatly by preventing sun scalding of the berries and definitely improves their storage qualities (D. J. Crowley).

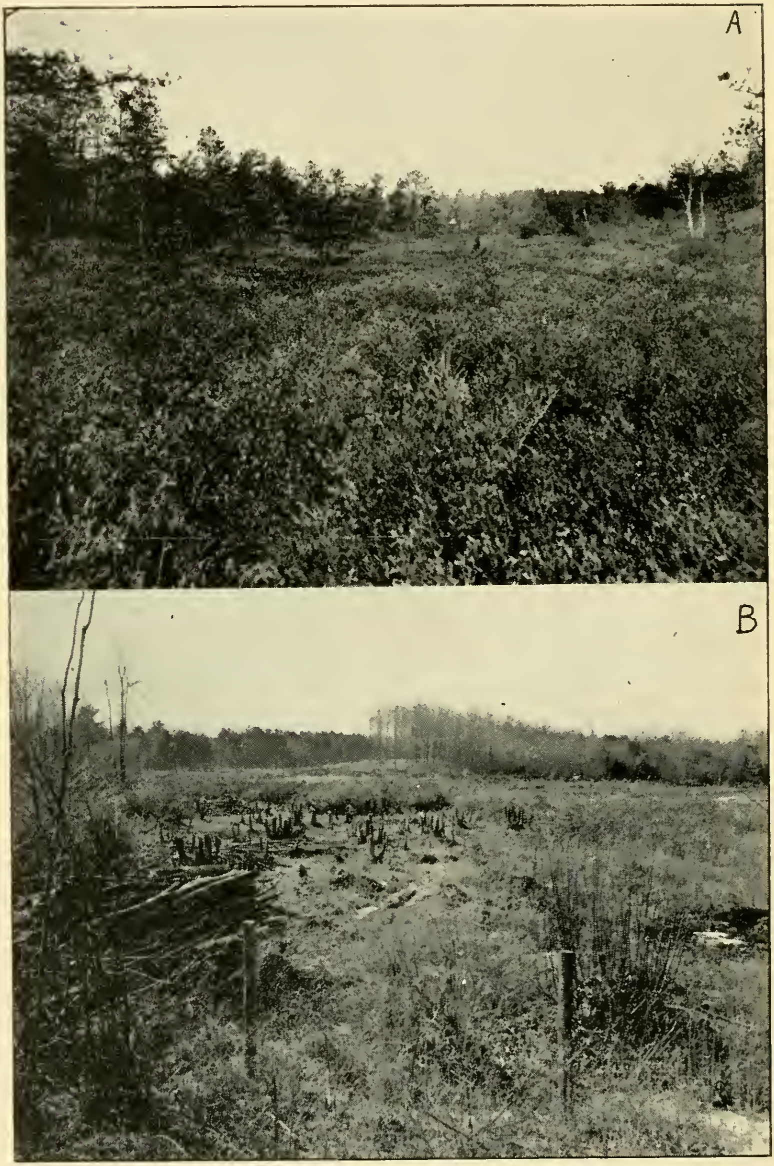


Fig. 4

A. A Leather Leaf or "Brown-Brush" Swamp, excellent land for cranberries.

B. Maple Swamp being cleared and prepared for growing cranberries, with stumps cut high for easy pulling.

THE ESSENTIALS AND PREPARATION OF AN IDEAL CRANBERRY BOG

Land

Cranberries in cultivation, as in the wild, do best on swamp land of muck or peat. The depth of this soil need not be great, a few inches of peat or one layer of turf over sand or clay often giving good results. It does not appear that any peat is essential, for vines grown on sand alone—so-called "hard bottom"—often produce fair crops when fertilized. The soil must be acid. The plants found growing most commonly on good cranberry soil are: sphagnum moss, wild cranberry, leatherleaf ("brown brush") (*Chamaedaphne calyculata* Moench.), sheep laurel (*Kalmia angustifolia* L.), red maple (*Acer rubrum* L.), and cedar (*Chamaecyparis thyoides* BSP.).

Fresh meadow and freshened salt marsh sometimes are made into cranberry bog without turfing, the grass being laid down and covered with about five inches of sand and the vines set out without other preparation except grading and ditching. Swales and pond bottoms may be used. Such bogs are built cheaply and usually do well. Brush swamps (Fig. 4A) are preferable to wooded ones, for it costs less to clear them. If timbered land is used, the tree stumps must be pulled or dug out (Fig. 4B), and taken from the bog. Cranes equipped with mats and clam-shells (Fig. 8B) are best for this on small and medium bogs, but winches may be better on large areas. Dynamite is often used to blow out stubborn stumps, but the filling of the holes made in soft land is costly.

Location

A cranberry bog should be on or near a stream large enough to flood it at any time. If the stream is too small, its capacity for flooding must be increased by making a reservoir above the bog location.

A water supply for flooding as much as may be necessary at any time, especially for flooding by gravity, adds greatly to the value of a cranberry property. It is often difficult and costly to arrange for such a water supply in developing a new bog. In this State there are special laws favorable to cranberry growers in this connection. The water of state ponds is often used, under the direction of the Department of Public Works.

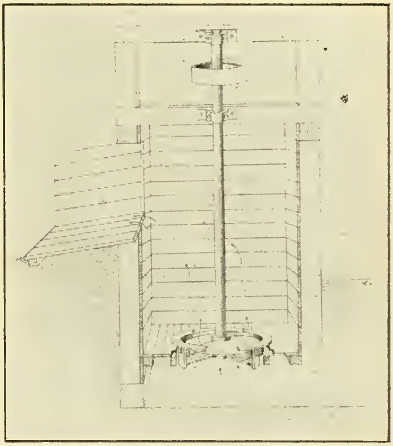


Fig. 5. A Common Bog Pump Installation.

Many fine bogs are flooded by pumping from streams or ponds at lower levels, over a third of the acreage in this State being treated in this way. The service of reservoirs is often greatly extended by pumping the water used in flooding back into them again and again. Electric motors or automobile engines are used in most bog pumping plants. The latter are generally preferable, for they are much cheaper to install and operate, are more easily repaired, and are as reliable. Several makes of propeller and reversed-turbine pumps are used (Fig. 5), and they vary greatly in efficiency. Repair service is an important item to be considered as well as efficiency. The pumping plants in use range in lift from 1 to 24 feet, averaging nearly 6 feet. Their horse power averages about 30 and their capacity probably about 6000 gallons a minute. A pump delivering 10,000 gallons a minute will flood 14 acres in 10 hours if the bog is not over a foot out of level.

Stop-waters in bog ditches often help greatly in efficient use of limited water supplies in frost flooding.

The bog should not be shut in by high uplands and woods, for open locations are less frosty.

Fig. 6. Cranberry Root Systems.
The plant to the left came from poorly drained, that to the right from well-drained land.

The Form and Size of the Bog

Other things being equal, small bogs pay better than large ones. Long narrow bogs, after a certain size is reached, are more profitable than compact ones. The care of large compact bogs and the harvesting of their crops are disproportionately costly, because it takes more time to wheel sand to the center of the bog and to bring the berries from the center; also, most of the bog operations call for more tramping over, and consequent injury to, the vines on large blocky areas. Another factor limiting the success of large bogs is the greater prevalence of the black-headed fire-worm on them. Flooding favors this insect by destroying a fungus that often attacks it severely and by killing or driving from the bog most of its enemies, such as spiders and parasites, at the same time protecting its eggs from the adversities of winter. The natural foes of the pest take longer to reach the center of a large compact bog again in effective numbers than to reach the center of a small one. If, however, a large bog is long and narrow, none of the factors mentioned are unfavorable.

Drainage

A bog should be well drained during the growing season. Poor drainage favors weed growth and the rose-bloom disease and probably promotes infestations of the black-headed fireworm and diseases which cause berries to rot both on the bog and in storage. It also curtails the growth of cranberry roots (Fig. 6). The land below the bog should go down rapidly, so that the water may be drawn from the ditches quickly at any time.

A ditch should be cut entirely around the bog and other ditches dug across it (Figs. 7A and C), dividing it into sections. The marginal ditch prevents upland growths from working onto the bog, keeps many crawling insects off, and is some protection from forest fires. It should be 3 feet wide and 2 feet deep. Cranes (Fig. 8B) are often very helpful in digging the ditches and flooding canals and in loading sanding cars. The ditches may be dug with dynamite.

If the drainage from the bog is good, the cross ditches are not important unless the area is great or the bottom close or springy. They hasten the distribution of water over the entire area in frost flooding and irrigating. Without them, the water tends to pile up for a time at the end of the bog where it is admitted. They usually should be 100 feet or more apart, and are made about 2 feet wide at the top, 1 foot wide at the bottom, and 18 inches deep. One of them (Fig. 7B) should be wider than the others and run lengthwise of the bog, in the path of the direct flow from the water supply to the outlet, to hasten flooding and draining. No more ditches should be made than are necessary because they waste land and interfere with bog operations. Tile drains are useful if the bog is hard to drain.

Grading

The soil thrown out in ditching may be used in grading. The grading is done by the water line in the ditches. All bogs should be made level, so they may be flooded quickly and with little water, and no swamp that cannot be so graded with moderate expense should be used unless the water supply is very ample. If the swamp is large and much out of level, it is often best to divide it with dams into separate areas (Fig. 7C), each nearly level, at different elevations according to the lay of the land. This greatly reduces the amount of water required for flooding. A crane reduces the cost greatly where much grading has to be done (Fig. 8B).

It should be remembered in building a bog that the deeper any cranberry flood is, the more it harms the vines.

Preparation of Land

After the land has been cleared of trees and brush and ditched and drained, it is "turfed" or "scalped" (Fig. 8A). The turf is cut in squares of handy size with turf axes (Fig. 9B) and these are turned upside down with turf hooks (Fig. 9A) and allowed to dry. They are then broken up easily with a grading hoe (Fig. 9C) and all pieces of roots found in them are burned. Care must be taken at this time to remove from the soil the roots of ferns and of all plants likely to give trouble later as woody weeds, such as horse brier, poison ivy, leather leaf, hardhack, sheep laurel, and chokeberry.

All work on the land up to sanding should be completed late in the summer or in the fall.

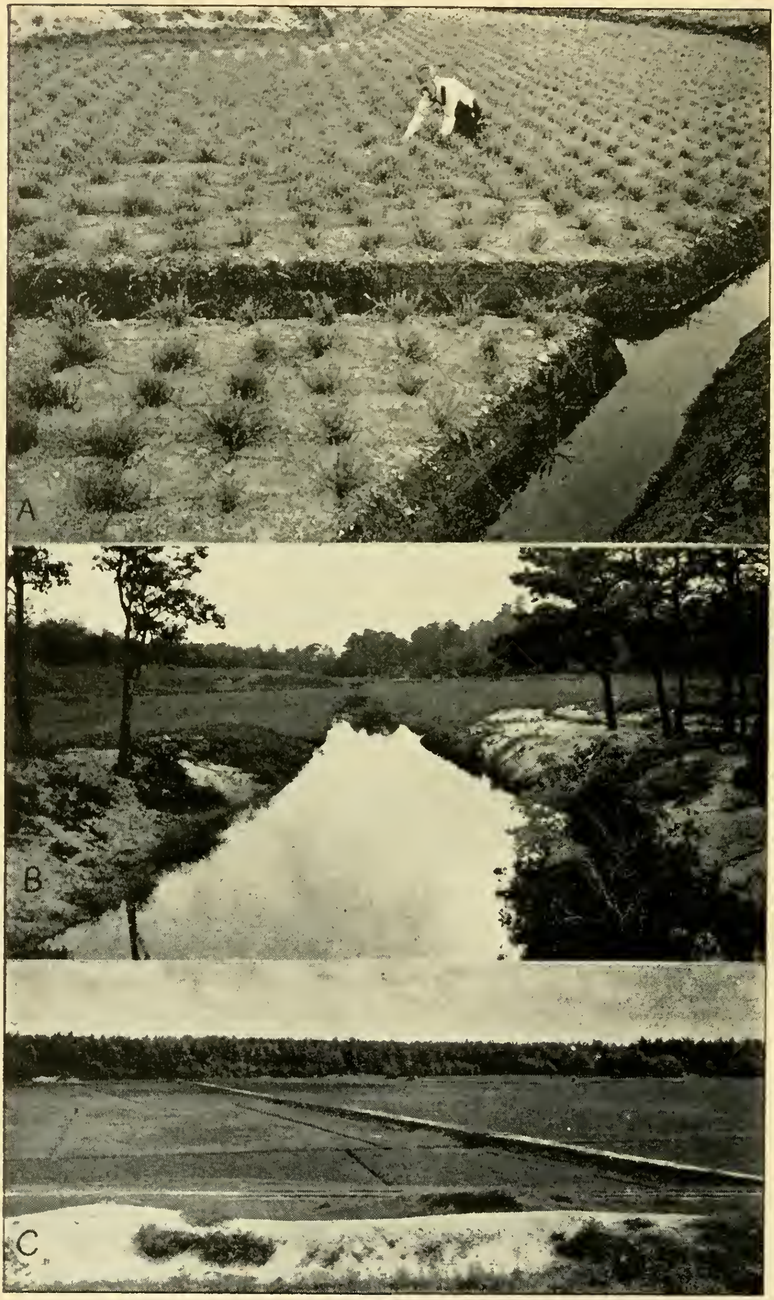
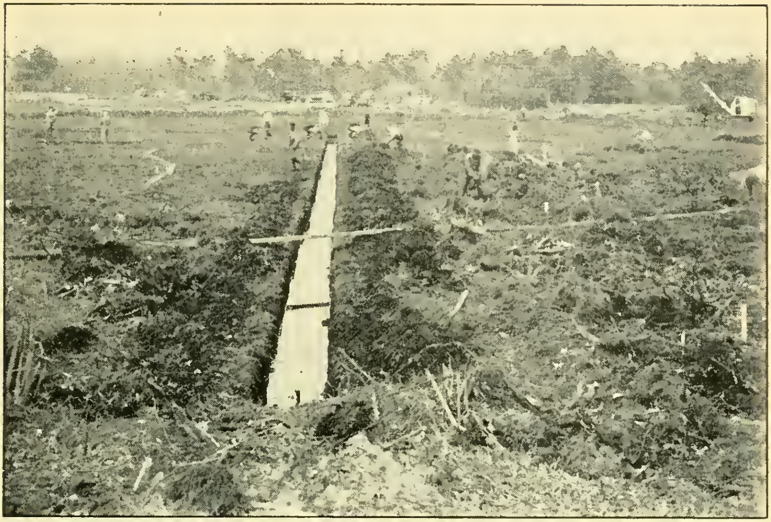


Fig. 7.
A. A Cranberry Bog in the Second Year from Planting, showing the marginal ditch and a cross ditch.
B. Bog with a Good Main Ditch for handling flowages quickly.
C. A Bog Divided with Dams into three Separate Flooding Areas.

Fig. 8. Bog Construction.



A. Turfing.

B. Crane.

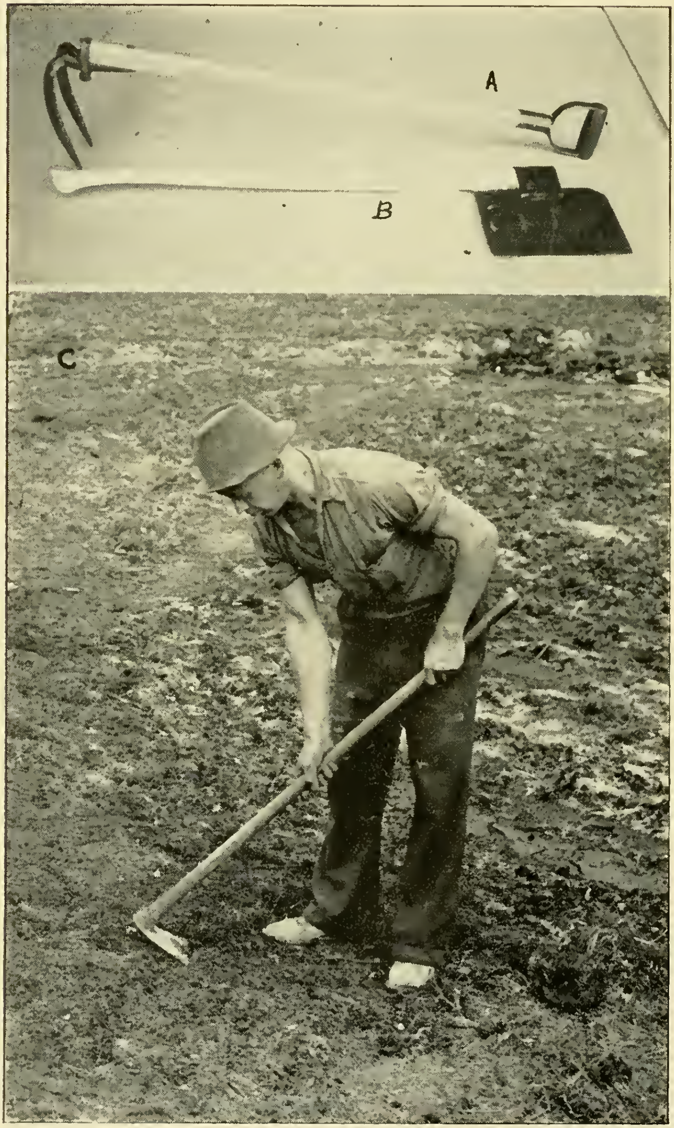


Fig. 9. Tools Used in Preparing a Bog.
A, Turf hook; B, Turf axe; C, Grading Hoe.

Dams[7]

The reservoir and bog dams (Fig. 7C) usually have a wide core of sand walled on both sides with turf. Sometimes the turf is necessary on only one side. The turf walls are built layer on layer with some sand between the layers for ballast, the pieces of adjoining layers overlapping. The turf is often taken from the upland near the bog; but when the swamp itself is scalped, the turf obtained may be used partly in facing the dams.

A trench deep enough to reach below all tree roots should be dug along the middle of the dam location and filled with sand to make a good connection with the soil for holding water. If the dam is to cross very soft land, it must be sheet-piled lengthwise in the middle with matched boards or planks. It should have sloping sides and be widest at the bottom, with dimensions according to the head of water. The wider it is the better it will resist muskrats. It should be a foot higher than high water to keep waves from wearing a hole through the top. It may also serve as a roadway. It is well to ditch the bog a few feet from the dam, making a berm.

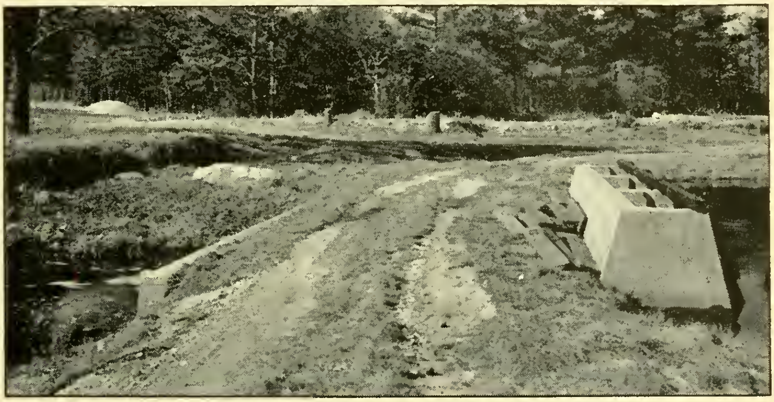


Fig. 10. A Covered or Trunk Gate.

A gate[8] for the passage of the water must be built in the dam—a job which requires an experienced gate builder, for it must be made properly and carefully. It often pays to make the gate of reinforced concrete, but redwood or kyanized cedar lumber is better on soft land. A continuous cross sheet of matched piling under the middle of the gate and extending out into the dam on each side of it is necessary, and two or three sheets may be needed if the water held is to be deep and the soil under the gate is soft or disturbed by springs. A stream of water from the hose of a power sprayer, delivered under high pressure through a piece of iron pipe with its tip compressed to a very narrow slit, helps greatly in driving the piling by loosening the soil.

The most experienced growers prefer the covered or trunk gate (Fig. 10). It is much stronger than the open gate (Fig. 11B) and rots less when made of wood. A concrete bulkhead opening into piping (Fig. 11A) is advisable in some places.

The outlet gate must be large enough to carry off the water of the heaviest rains and of flowages quickly.

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[7] R. B. Wilcox (Proceedings of the 78th Annual Meeting of the American Cranberry Growers' Association, 1948, pp. 25, 28, and 32).

[8] Commonly called a "flume" by the growers.

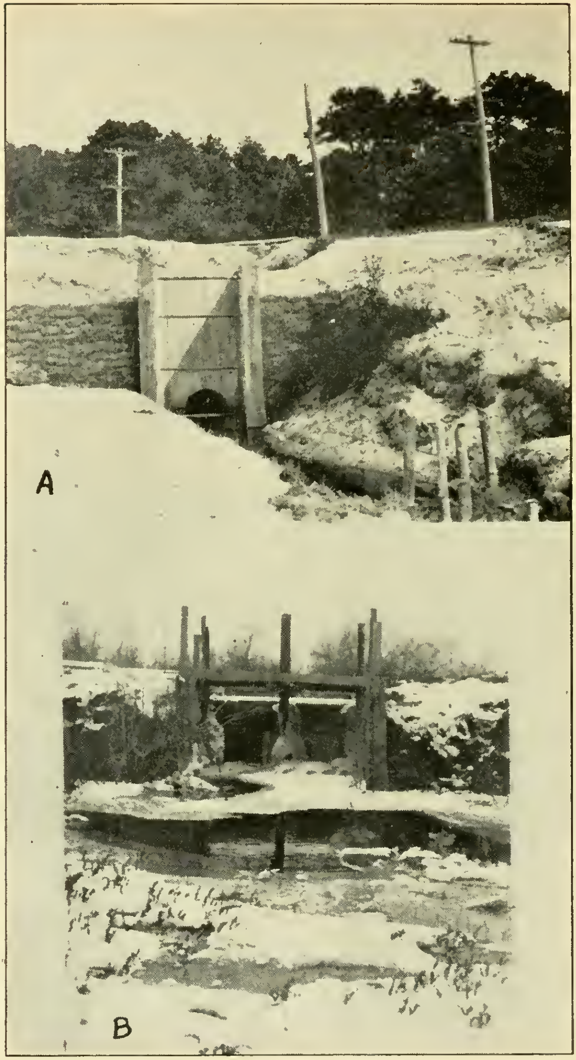

Fig. 11.
A. A Bulkhead and Sewer Pipe Water Gate.
B. An Open Gate. The upright timbers extend well above the top of the dam to permit building the dam higher if this is found desirable.

Sand

Sand is used as a mulch before the vines are set and for resanding in after years. Fine sand promotes the growth of moss and allows weeds to thrive more than coarse sand. Sand screened from gravel is very satisfactory.

On Cape Cod, where sand abounds around the swamps (Figs. 19B and 28), it usually is carried on to the bog over a line of planks by men with special wheelbarrows that have a pneumatic tire and balance the load over the wheel (Fig. 12);

but railroads with gasoline locomotives and cars (Fig. 13) are often used on large areas. In Pacific County, Washington, where the sand underlies the swamps and is not available elsewhere, growers pump it up in water with a centrifugal pump and send it through piping, in some cases over half a mile.

The early bog makers on the Cape put on five or six inches of sand before planting. Some still do this, but the more experienced use only three or four inches. The vines grow faster with this smaller amount, the bog getting vined over and reaching full bearing sooner. Small stones in this sand do no harm.

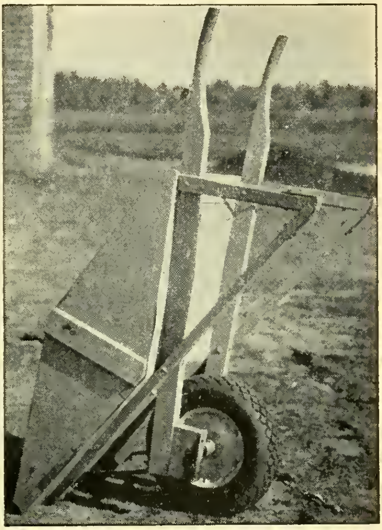

Fig. 12.
Wheelbarrow Used in Sanding Bogs.

A sanding rim may be made around the margin when the bog is built if the upland is mostly sand. This makes a good roadway and gives shorter hauls for resanding in after years than do scattered sand holes. A bulldozer is very useful for opening sand holes, making flooding canals, and building roads around the bog.

The sand helps check weeds and moss; it gives the cranberry roots a medium to grow in which can be drained and aerated far better than peat, so promoting their growth; it serves as a mulch and so ameliorates drouth; and it gives out heat at night so as to afford some protection from frost. Its pH is about 4.5 on most bogs in this State.

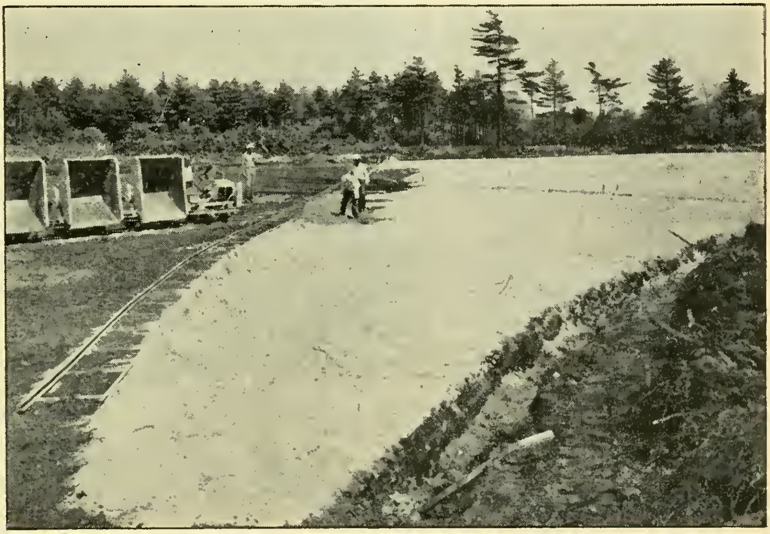

Fig. 13. Sanding a New Bog with Gasoline Engine and Cars.

Fig. 14. Berries of Cranberry Varieties.
A, Early Black; B, Howes; C, McFarlin.

Varieties

Early Black and Howes are the varieties most grown on the Cape, together making up 93 percent of the whole acreage. They are productive, well known to the trade, good keepers, and usually can be picked easily with scoops. Early Black berries (Fig. 14A) make fine sauce, but Howes (Fig. 14B), unless picked very late, are only fair in that respect. Early Black berries are highly valued for canning and for cocktail juice because of their dark red color, and the variety will keep its lead a long time for that reason. Howes berries have a higher pectin content than those of any other cultivated variety, and this makes them very desirable for canning. Howes ripen late and so interfere with proper fall flooding.

Fig. 14. Berries of Cranberry Varieties.
D. Bugle.

Bugle (Fig. 14D), Centennial, Centerville, Holliston, Matthews, McFarlin (Fig. 14C), and Smalley Howes are all fancy berries and prime for the table. McFarlin and Smalley Howes have found more favor than the rest of these varieties, the former being grown widely in Wisconsin and on the Pacific Coast. Round Howes is perhaps the most productive variety.

McFarlin, Shaw's Success, and Early Black are quite resistant to false blossom; most of the other varieties are not.

Varieties with fine vines, short upright branches, and low seed counts and without a noticeable bloom on the fruit are generally superior in production and disease resistance.

A large number of new varieties, selections from the wild and crosses between cultivated varieties, are being tested for future planting by the Bureau of Plant Industry of the United States Department of Agriculture.

The varieties vary in ripening, the earliest usually becoming well colored the first week in September and the latest the third week in October. Some berries color well in storage; others will not redden much unless left on the vines. Most cranberries are first green, then whitish, then pink, then light red, and finally

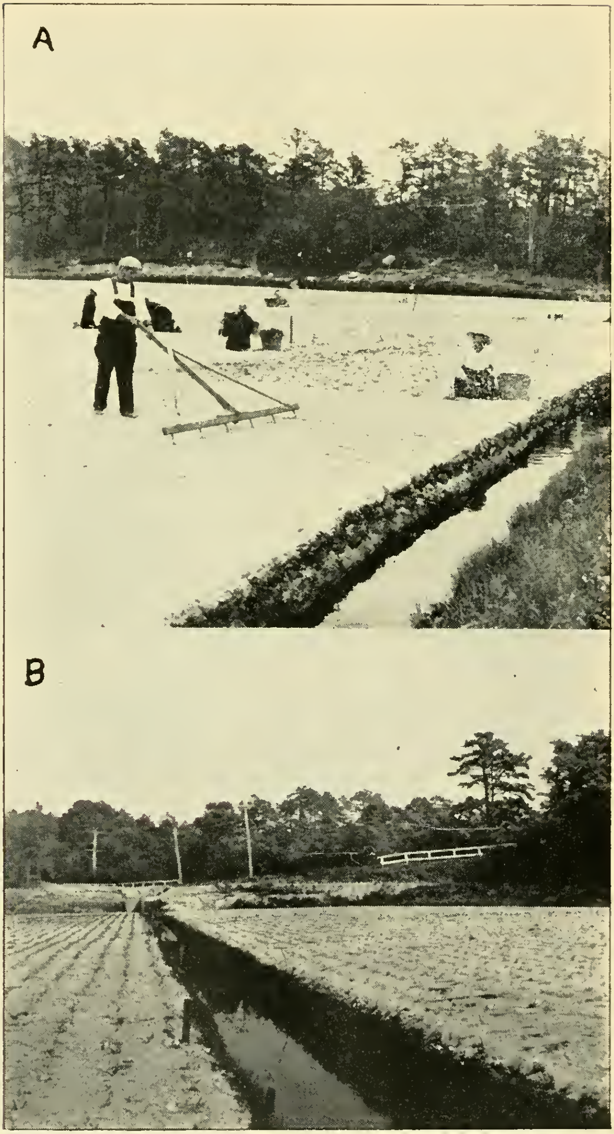

Fig. 15.
A. Marking Rows for Planting Cuttings.
B. A Newly Planted Bog.

dark red. Some of the wild berries are white when ripe, and some cultivated ones get so dark red that they are almost black. The different kinds of berries vary in form, being pear-shaped, fusiform, oval, or round. The round berries are most easily sorted.

No flooding area should have more than one variety. Some of the leading varieties have insect or disease troubles which are especially bad with them, and planting other varieties on the same flooding area complicates controls.

Fig. 16. Growth of Cuttings Set Two Years Before.

Few roots have started from the part of the stems in the peat, most of them growing in the sand covering. The two inches just above the bend were in the peat.

Vine Settings

The sanding should be done in April or May, for the vines set easier and grow better if they are put in before the sand packs. The bog should be marked for uniform planting in hills by drawing a marker with four or five teeth across it both ways (Fig. 15A). The vines may be planted in late April, May, or early June, early May being best. They should be set eight to ten inches apart each way (Figs. 15B and 7A). With this spacing it takes seven to twelve barrels of cuttings to plant an acre, according to the condition of the cuttings and the efficiency of the setters. The closer they are set, the better they will anchor themselves against the pull of picking scoops. Fairly close planting seems to favor high yields.

The cuttings should be taken from a bog in good condition, free of variety admixtures, fireworms, gypsy moths, rose bloom, and false blossom, and with a record for producing good crops of sound fruit. If it failed to yield well the year before, all the better. The vines should be cut with a scythe and planted, if possible, soon after they are cut. If they must be planted in late May or later, they should be cut about May 10 and kept cool and moist till they are used. They may be stored loose under a tarpaulin in a cool shed and turned over and sprinkled every few days, or they may be spread out well in a stream or pond. They will lose their leaves and may die for want of oxygen if they are kept long in water in bags or bales.

Bogs from which vines are cut recover much faster if the cuttings are taken before growth starts. Experienced growers often refuse to cut vines for sale after the new growth appears. If the cuttings have a lot of new growth, much of it is likely to die, and further growth will be slow for a time if it does. One who buys such vines cheats himself by paying for much unnecessary bulk.

If many vines are set in a bunch, those in the center die and are wasted. Two or three to a hill are enough. They must be pushed well into the sand but need not go into the peat beneath, for most of their roots will grow in the sand (Fig. 16). A wooden or iron dibble is used to press them in (Fig. 17). They need not stick up from the sand more than an inch. It often pays to hire professional vine setters.

Bogs are sometimes planted by scattering the cuttings along the ground and discing them in. This saves labor but wastes planting material. Such plantings do well.

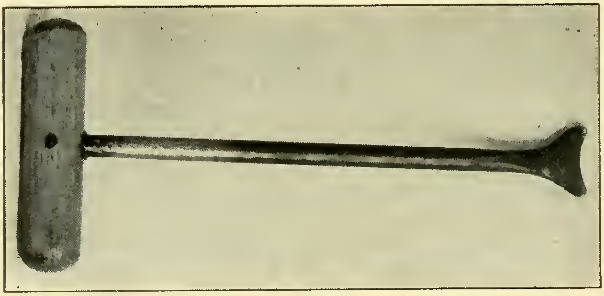

Fig. 17. Dibble for Planting Cuttings. It is eight to ten inches long.

PRESENT COST OF BUILDING CRANBERRY BOGS

	Cost per Acre
Land	\$ 10 – \$ 100
Clearing, ditching, turfing, grading, and sanding	800 – 1800
Ten barrels of vines at \$10 per barrel	100 – 100
Planting vines	50 – 200
Incidentals (tools, dams, head-gates, buildings, etc.)	400 – 800
Total	\$1360 – \$3000

The cost depends on the natural conditions and location of the swamp, on the ability and experience of the man who oversees the work, and on wages. A good bog, well located and built, planted with the right varieties, and given good care, should be nearly permanent. There are bogs on the Cape ninety years old and still in good condition. To own and properly manage a cranberry property requires a considerable investment and special experience which it takes years to acquire.

CARE OF A NEWLY PLANTED BOG

Water should be put on right after planting, held near the surface a day or so to wet the vines and pack the sand around them, and then drained to the bottoms of the ditches. If the bog is flowed again the first season, it should be only for a day or two to wet the sand or control insects.

New bogs should be flooded for the winter as soon as the ground begins to freeze, for frost in the soil heaves new sets out. The surplus water must be let off at times of thaws or heavy rains in winter or early spring. If this is neglected with the vines frozen into the ice, the raising of the ice will pull them out of the ground.

The first three years the winter flowage should be let off about May 5. Earlier removal exposes the plants to possible frost heaving.

More weeds grow on a bog the first two or three years than later, for the vines have not grown enough to crowd them. They give relatively little trouble afterward if they are kept down then. A grower should know the weeds he has to fight at this time, for it is enough to mow the tops of some kinds (most rushes), and some (rice cut-grass) can be checked by good drainage, while others must be rooted out or killed with salt (ferns, brambles, hardhack, leatherleaf, and sheep laurel) or kerosene (grasses and sedges). Upland weeds often appear on new plantings; they need not be heeded, for they will die in the winter flood. Weeds along the ditches may be treated with dry salt.

After the first year and before it comes to bearing, the new planting should be flooded several times each season to check insect pests.

Constant roguing is necessary the first three years to remove plants of odd varieties and hills with false blossom.

The new bog should be resanded with two thirds of an inch of sand right after the first crop is gathered to make the vines develop a strong root system and become well anchored.

It costs $400 to $800 an acre to care for a new bog till it crops.

CARE OF A BEARING BOG

A new planting usually comes to bearing the fourth year, and its care thereafter is described below.

The Use of Water for Flooding

Cranberry vines often winterkill, sometimes to the ground, when exposed for a week or more to drying winds with the soil around their roots frozen. This is due to desiccation, the plants being unable under these conditions to replace the water given off by the leaves. It usually occurs before midwinter but may occur at any time from early December to late March. Flooding for the winter is the best protection.

The winter flowage should go on as soon as the sand surface remains frozen all day, usually about December 1 on the Cape. The water should be held just deep enough to cover the vines. It is often best to let the highest parts stick out a little when a bog is much out of level. The vines are as well protected frozen into the ice as any way, though sometimes they are pulled badly if they are not well anchored and if the ice is thick and is lifted by water. Heavy ice sometimes does some harm by breaking off the vines where it cracks; this injury appears in the spring as though a cleaver had severed the vines and cut into the ground beneath them

If the bog can be reflowed, the winter water should be let off about April 1 at least every other year. It may be held till May 23 (June 1 on the outer Cape) the other years[9] (except on bogs well inland, where, because of higher spring temperatures, late-holding seems to be more dangerous to the crop) to control the fruit worm and false armyworm, reduce weeds and fungous diseases, and promote vine growth. It must not be held so late if it is deep over much of the area or the vines are over vigorous. It may be held till about May 20 rather regularly on bogs that cannot be reflowed. Holding after May 23 invites cutworm infestation. Algal scum often develops in the flood water when it is held late. This sometimes dries to form paper over the vines after the water is let off and is then harmful (Fig. 18). It can be prevented from forming by dissolving 6 pounds of copper sulfate to the acre-foot in the flowage about the first of April. Coarse crystals of the chemical in a burlap sack may be towed in the water behind a canoe or fine crystals may be scattered on the bog ice late in the winter. Changing the flood water early in April, exposing the bog to air a week or more, also usually prevents this trouble.

Fig. 18. Cranberry Bog Covered with "Paper" from Algal Scum.

Bogs used to be flooded regularly early in June to check insect pests. This is advisable one year in three but is a dubious annual practice for it carries fungous infection to the new growth and sometimes reduces the crop seriously by drowning the flower buds. This flood should go on in the night and also be taken off at night if the weather is very warm, for if tender growing vines stand in water long, exposed to a hot sun, they may scald. The flower buds are less likely to be hurt by the flooding if the weather is clear while the water is on, for light is necessary to the photosynthesis by which the plants give oxygen to the water. Cloudiness with a high water temperature is especially dangerous, for the warmer it is the faster the plants respire and the greater their need of oxygen. The complete

[9] It probably is better to let the winter flowage off at the end of March, reflood about April 20 and hold the water till May 23, than to hold the winter water late. This serves all the purposes of late holding, airs the vines, and gives time to work on the bog.

flood should not be held on a bog over twenty-four hours unless the weather is definitely clear and cool and should not be held over twenty hours if the bog has a bad record of injury by June flooding. Ten hours is long enough for most insect pests, but the blunt-nosed leafhopper and the spittle insect require 24 hours.

A partial flood must be put on if frost threatens in May or June. Two or three inches of water under the vines is enough, for heat will pass from the water to the air and keep the vines from freezing. If water must be saved and it remains cold, the water may be held over on the bog from one night to another for several successive days up to about May 10 and for a day at a time occasionally after that.

Cranberry winter buds are not hurt by a temperature of 25° F. till they swell to a diameter of more than 2 mm. They usually will endure temperatures down to 20° till the end of April. Temperatures above 29° seem never to do much harm. Often 28° is reached in the time of tenderest growth without injury, but the greatest depression in such cases is brief.

Flooding should not be done during or after the blooming period, for it will blast the blossoms and promote rapid development of the fungi that rot the fruit.

Frost in September and October often necessitates flowing again, but the berries and vines will endure more frost then, and longer chances may be taken than in the spring. The water may be held over on the bog from one night to another occasionally, as in the spring, if it seems necessary. Cranberries usually will stand 28° F. in the whitish stage before ripening, but 26° often harms such fruit greatly. Freezing begins among ripe Early Black and Howes berries at or slightly above 22°, no softening following exposure to 23°. Ripe Howes and McFarlin berries are so resistant that under bog conditions often only 10 percent are injured at 16° and only 20 percent at 14°. Sometimes, however, 25 percent are softened by 18°. The loss of Early Black berries at these temperatures is much greater.

Frost flooding always does some harm: in the spring tending to reduce production, and in the fall tending to impair the keeping quality of the fruit and interfering with harvesting. For this reason and because unnecessary frost flooding wastes limited water supplies, accurate forecasts of frosts are very important. The Weather Bureau sends out special warnings to the cranberry growers, which are supplemented by those of the Cranberry Station of the Massachusetts Agricultural Experiment Station.

As soon as the crop is gathered, the bog should be flooded for a week to water the disturbed roots and float off fallen leaves, berries, and other trash.[10] This controls the cranberry girdler when it is done late in September. No flooding is necessary after this till the water goes on for the winter.

Some bogs can be flowed only for the winter and some are not flowed at all. They generally are not so profitable as those with plenty of water, but some of them pay well under good management.

Sand and mud wash into the ditches and growing weeds and floating materials help to fill them so they must be cleaned out every few years.

Irrigation

Bogs are too wet oftener than too dry. They do, however, often suffer from drouth, especially in August, the berries being reduced in number and size and retarded in ripening and the vines dying in severe cases. Practice varies in bog

[10] If much of this material lodges on the vines, it is very harmful. There should be catch basins around the bog margin to receive it from the flood. If no catch basins have been made, the trash must be raked from the water where the wind drives it ashore.

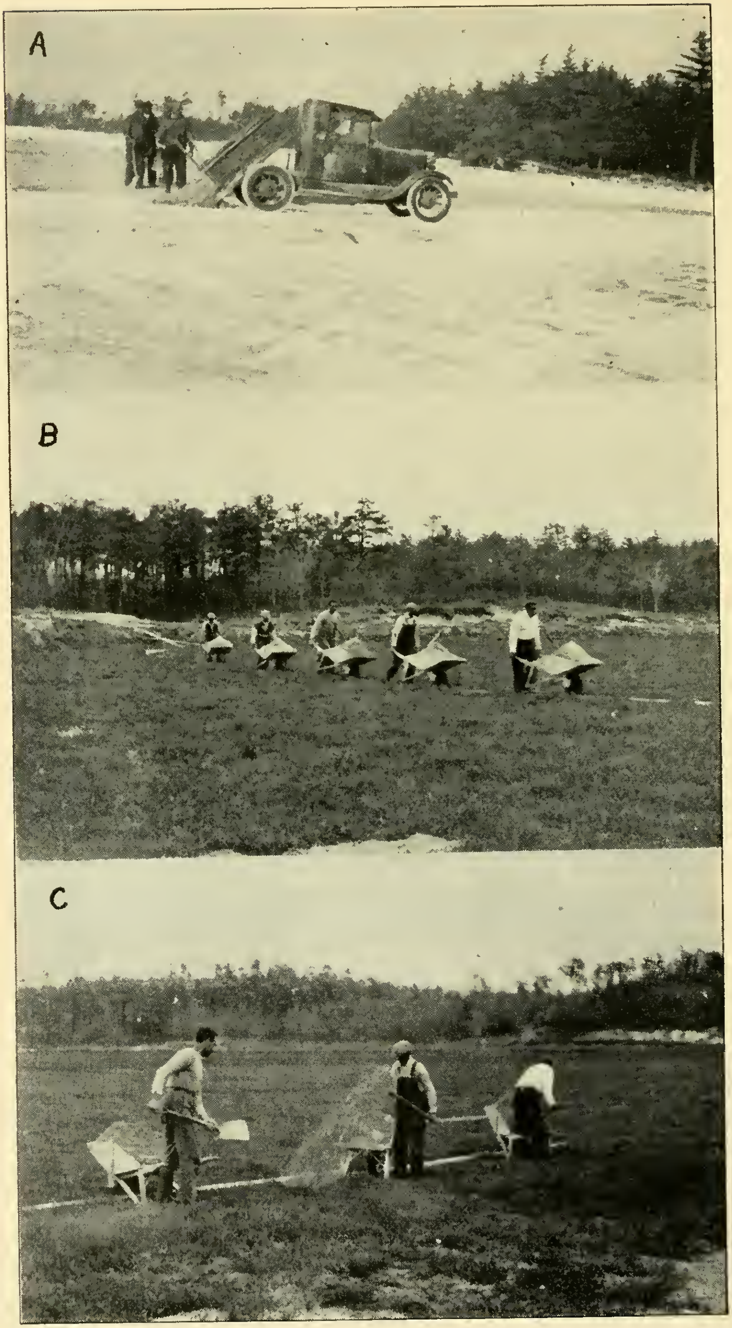

Fig. 19.
A. Resanding with Trucks on the Ice of the Winter Flood.
B and C. Resanding with Wheelbarrows.

irrigation. Occasional light flooding for a few hours at night followed by complete withdrawal of the water is sometimes done, but it is usually better to hold the ditches partly full throughout the dry spells. Watering with a sprinkling system, though costly, is effective for both irrigation and frost protection and will be done more on cranberry bogs.

The Use of Sand

As the cranberry roots form a dense growth in the sand over the peat, they become soil bound, and resanding gives them more soil to grow in. Largely on this account, resanded vines are generally thriftier and more productive than those not resanded. Moss and fallen cranberry leaves are poor conductors of heat, and bogs not resanded regularly are commonly well covered with such material and so very liable to frost injury.

The oftener resanding is done the more it protects against frost, the girdler, the green spanworm, and the tipworm; but bog conditions should determine its frequency. Bogs with little water for reflooding should be resanded every other year or every year lightly; those with plenty of water for frost and insect flooding and with a moderate vine growth should be resanded every third or fourth year; and those with ample water supplies and heavy vines never should be resanded. From a quarter of an inch to an inch of sand, according to circumstances, is put on at a time, being spread with square-pointed shovels. Experienced men are needed for this job.

Sanding may be done most cheaply in the winter (Fig. 19A) with favorable weather, but there is not enough ice for this on the Cape in more than one year in three. Considerable injury is done to the vines by resanding in the early spring and it increases rapidly as the season advances; resanding should not continue after May 5. Help is generally more plentiful in the fall and better attention can be given this work then. Whenever it is done, it usually reduces the following crop noticeably. The tops of the vines must be raked up out of the sand wherever they get covered too much with it. Ice resanding is done mostly with trucks; spring and fall resanding, with wheelbarrows (Fig. 19 B and C) or cars (Fig. 13). The cost of properly applying a third of an inch of sand varies from $30 to $70 an acre.

All stones must be screened from the sand before it is used, or collected from the bog afterward, else they will bruise the knees of pickers and be gathered with the berries in scooping. Bog gang screens, 6 feet by 3 feet or larger, and individual wheelbarrow screens are used for this, a three-quarter inch or inch mesh being best.

Pruning

Vines often grow too thick and tall, especially on new bogs with a rich bottom and a thin sand covering. The runners that float over the tops of the vines after harvesting must be cut off carefully with a knife rake or pruner (Fig. 20 A and B). Experienced men should do this work, for it is often very harmful when done carelessly. No other cranberry pruning is advisable. The vines should be mowed with a machine if they are so heavy that fruit production is much reduced. They will be even and usually less rank when they grow again. Some burn off heavily vined bogs; but the burning may harm the roots, the vines are slow to come to bearing again, and the bog is more exposed to weed growth.

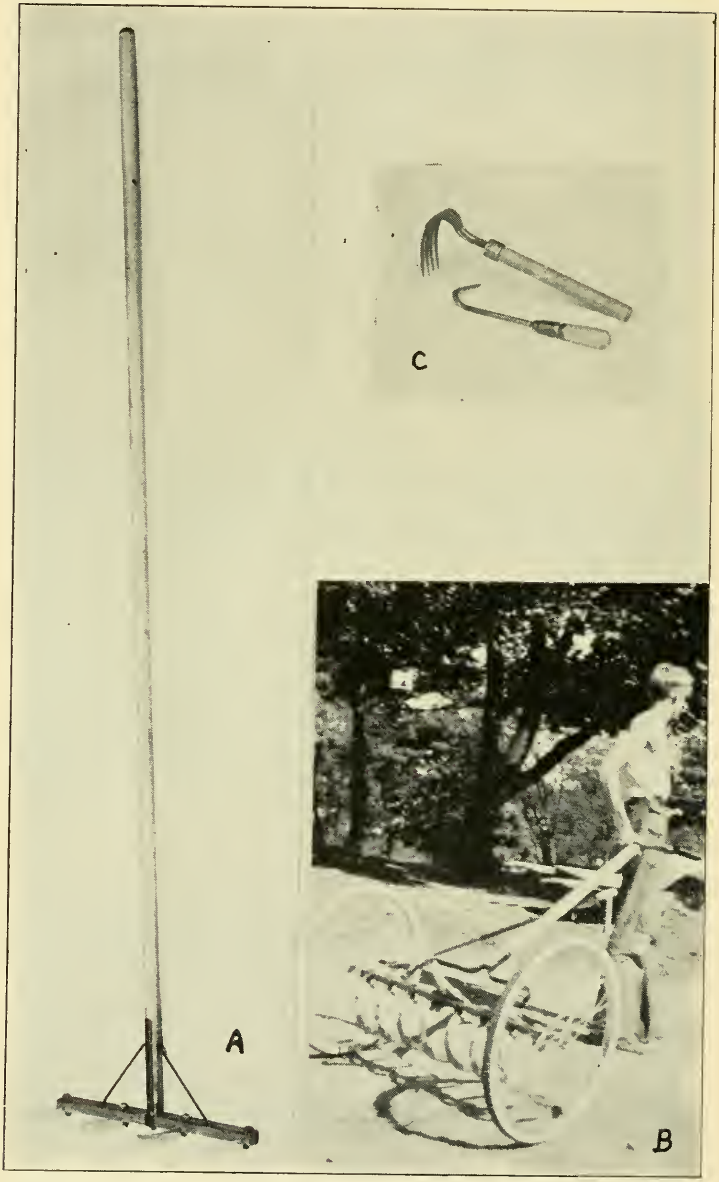

Fig. 20. Cranberry Tools.

A. Cranberry Knife Rake. The blades may be detached for sharpening.
B. Machine for Pruning Vines. It is drawn by hand along and then across the bog and is very useful if the blades are kept sharp.
C. Bog Weeders.

Fertilizers

No certain advantage is gained by fertilizing peat-bottom bogs. Nitrate of soda and acid phosphate often greatly increase the yield on "hard bottom" areas (sand or clay underneath instead of peat), and 150 pounds of the former and 300 pounds of the latter to an acre is a reasonable application. Potash has little value on any bog. Very late July may be the best time to apply fertilizer.

Nitrate is likely to promote too much vine growth on peat bottom, especially if the bog is new. It is generally better to get more vines, where they are desired, by holding the winter flood late than to fertilize for them. Continued use of nitrate impairs the keeping quality of the fruit and encourages weeds.

Fertilizer helps greatly to repair old bogs out of condition from grub injury. Reground nitrate of soda scattered broadcast early in April, 250 pounds to an acre, reduces haircap moss well and helps the vines compete with it.

Diseases[11]

Many fungous diseases attack cranberries. Some seriously affect the vitality of the vines or cause the leaves to drop, and some reduce the crop by blasting the blossoms and young berries or by rotting the berries on the vines and in storage. Late holding of the winter flood (to May 23) tends to curtail such troubles. Bordeaux mixture reduces rot of the berries on the vines and improves their keeping quality; it has been very helpful in some cases, but whether its use generally pays in this State is doubtful. Lead arsenate also has this effect, but its frequent use weakens the vines on sanded areas. Care in handling the fruit in harvesting, separating, sorting, and packing does much to reduce decay in shipment.

The rot diseases of cranberries caused by different fungi vary greatly in their prevalence in the different cranberry-growing regions of the country. Early rot, which blasts the flowers and young berries and rots the fruit on the vines and in storage, is the most serious of these troubles in New Jersey. As this disease is more completely controlled by spraying with Bordeaux mixture than the others, this treatment is especially valuable in New Jersey. Bitter rot, which rots some berries on the vines and more in storage, and end rot are the leading cranberry rots in Massachusetts. End rot, a late storage rot, is the only serious cranberry rot in Wisconsin and on the Pacific Coast. The relative scarcity of the earlier rots accounts largely for the success of the Searls variety[12] and of water scooping in Wisconsin and for the greater popularity of the McFarlin variety in the West than in the East.

New bogs should never be planted with vines having either false blossom or rose bloom. These are the important non-putrefactive cranberry diseases. Both often greatly lower the vitality of the vines and reduce fruit production. Vines affected by false bloossm come to have a witches'-broom development (Fig. 21 left), and their flowers open facing upward (Fig. 21 right) instead of turning down as healthy cranberry blossoms do. It is a virus disease, spread by a leafhopper (Fig. 22), and can be controlled by checking the leafhopper with 5 percent DDT dust, clear high-grade pyrethrum dust, or dusts containing rotenone, 50 pounds to an acre (Fig. 23). Rose bloom is a fungous disease which causes new shoots to be greatly enlarged and rose-colored, the vines sometimes appearing as though they were in full bloom. It affects late varieties most, especially

[11] Technical Bulletin 258 of the United States Department of Agriculture is the best general account of cranberry fungous diseases.

[12] This variety has not succeeded in the East because of the rotting of its fruit here.

Matthews and Howes. It may be treated by flooding for thirty hours or by spraying with Bordeaux mixture, 10 pounds of copper sulfate and 4 pounds of lime to 100 gallons of water, 250 gallons to an acre, about May 25. (H. F. Bergman.)

Fig. 21.
LEFT: Witches' Broom Growth Caused by the False Blossom Disease.
RIGHT: Flower Development of Vines with False Blossom.

Fig. 22. Blunt-nosed Leafhoppers
This insect carries the false blossom disease.

Insect Pests[13]

The chief cranberry pests in order of their importance are: the root grub, the fruitworm, the blunt-nosed leafhopper (carrier of false blossom), the black-headed fireworm, the gypsy moth, and the girdler.

[13] The best discussions of cranberry insects are Farmers' Bulletin No. 860 of the United States Department of Agriculture and Bulletin No. 445 of the Massachusetts Agricultural Experiment Station, the latter giving more up-to-date treatments. The extension services of Barnstable and Plymouth counties (with offices at Barnstable and at the court house in Brockton, respectively) issue a cranberry insect and disease control chart and a weed control chart every spring.

Fig. 23. Dusting with a Helicopter to Control Insect Pests.

Fig. 24. Cranberry Fruit Worm.
Berries cut open to show worms at work.

The fruitworm (Fig. 24) has taken an estimated third of the whole Cape crop in some years. It may be checked by holding the winter flowage till late May or by spraying or dusting in the middle of the blossoming period and again ten days later with derris or cryolite.

The black-headed fireworm (Fig. 25A) seldom harms strictly dry bogs much. It may be treated by flooding for ten hours at the end of May and again a week later. Dusting with DDT or pyrethrum or dusts containing rotenone is very effective.

Small patches infested with root grubs (Fig. 26) are treated with a solution of 7 ounces of sodium cyanide in 100 gallons of water, a gallon to a square foot (Fig. 27). This is fairly effective, but must be repeated in five years. A better treatment for large infested areas is to let the winter flowage off early in April, reflood about May 12, and hold the water till July 12. This usually cleans out grubs of all kinds well, but at the cost of the crop. This pest has taken 150,000 barrels a year from the Massachusetts cranberry crop for some time.

The gypsy moth (Fig. 25 B) may be controlled by holding the winter flowage till May 25, by reflooding about May 25 for twenty-four hours, or by spraying with 3 pounds of dry lead arsenate in 50 gallons of water about May 20. Flooding

Fig. 25.
A. Webbed Cranberry Branches, work of the Black-headed Fireworm.
B. Gypsy Moth Caterpillar Defoliating a Cranberry Branch.

Fig. 26. Cranberry Bog Infested with Root Grubs. The bare patches are a result of their work.

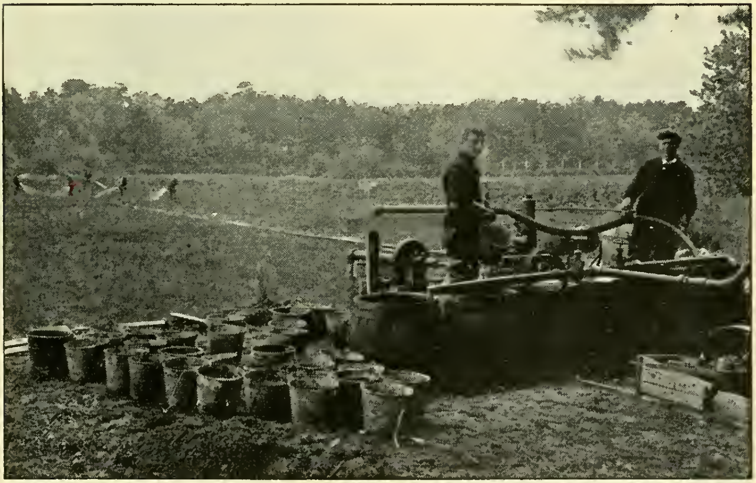

Fig. 27. Treating Root Grubs with Sodium Cyanide Solution.

for twelve hours kills the worms after they are a third grown. Dusting infested bogs and their surrounding uplands with 5 percent DDT dust whenever the worms are at work is highly effective.

The cranberry girdler seldom infests areas kept well sanded; it works chiefly in the trash of unsanded bogs among thick vines. Complete flowage after picking, beginning by September 25 and continuing for a week, is a good control Complete flooding for about twenty hours, the last of August or early in September, to check a severe attack is sometimes advisable, especially with the Howes variety. A serious infestation can be largely controlled by dusting with 10 percent DDT dust or with high-grade pyrethrum, 50 pounds to an acre, two or three times at four-day intervals in early to mid June, to kill the moths.

Both the brown spanworm (hatches late in June) and the false armyworm (hatches May 8 to 12) can be checked by spraying when the worms are hatching with 3 pounds of cryolite or dry lead arsenate in 50 gallons of water (Fig. 28). The latter is also controlled by flooding for eight hours about May 18.

The yellow-headed fireworm attacks only bogs without flowage. It is checked easily by spraying with 3 pounds of dry lead arsenate in 50 gallons of water, 250 gallons an acre, about May 22 or about July 13.

The last brood of the tipworm sometimes does much harm where the vines are not thrifty by reducing the bud formation for the crop of the following year. Resanding every other year controls this insect well on most bogs, but a bog should not be sanded so often for this alone.

Fig. 28. Spraying to Control Cranberry Insect Pests.
Note the long line of hose handled by the men. The power sprayer is always on the upland near the bog margin.

Growers should sweep their bogs with a net every few days till midsummer to find and gauge insect infestations (Fig. 29). It often does not pay to treat a light infestation with ground equipment, especially if the crop promises well, because of the mechanical injury involved. Counts of less than nine gypsy moth caterpillars or cutworms or less than thirty-six spanworms to fifty sweeps of the net may be disregarded, but closer control than this, with dusts and helicopters available, is desirable. Over three blunt-nosed leafhoppers to fifty sweeps should be treated.

Weeds[14]

All weeds should be removed from a bearing bog by the time the vines bloom and if sedges, rushes, cotton grass, or cut-grass appear later, they should be cleared out again, regardless of the injury done in weeding. Late fall and early spring, when the vines are dormant, is the best time to dig out such woody weeds

[14] The National Cranberry Association has published a handbook on cranberry bog weeds, well illustrated with photographs.

as hardhack, chokeberry, sheep laurel, leatherleaf, and poison ivy, and any weeds that may be green then (Fig. 20C).

Fig. 29. Examining a Bog with an Insect Net.

Water-white kerosene, 300 to 600 gallons an acre, applied as a spray or with a watering pot the second week in May, is a good control for grasses, sedges, rushes, loosestrife, horsetail, bayberry, alders, and brambles. Ferrous sulfate, used dry in July or August, controls sensitive and feather ferns, asters, and tear-thumb. A small handful of ferric sulfate, applied at the base of each plant early in the growing season, is very effective on horsetail, small ferns, royal fern, hardhack, wool grass, and spike rush or needle grass. A spray of 20 pounds of copper sulfate in 100 gallons of water, applied 400 gallons an acre early in August, is the best treatment for nut grass. This spray, applied 600 gallons an acre early in the spring or late in the fall, kills haircap moss well. Sodium arsenate, 1½ pounds in 100 gallons of water, 150 gallons to the acre, applied in August, helps greatly to control wild bean. Ditch weeds and undesirable growths on the uplands are killed with a spray of 15 pounds of sodium arsenite in 100 gallons of water. Paradichlorobenzene under a sand cover eliminates poison ivy, wild bean, and chokeberry. Special cutters for clipping weeds, several feet wide and operated with small air-cooled engines, are sometimes useful. They cut the weed tops into small pieces that fall down among the vines and do not have to be removed from the bog.

Fig. 30. Early Black Cranberries Ready to be Picked.

HARVESTING

Cranberry harvesting generally begins about Labor Day and continues till about October 20 (Fig. 30). The harvest period is so short that many growers, especially if the season is late, have to begin when the fruit is only partly colored. Early Black berries keep best if they are picked before they are fully red. They usually should be gathered the second week in September. The later Howes are picked, the better they keep; it is often best to gather them late in September, but they should be left on the vines till the second week in October where bog conditions allow it. Other Massachusetts varieties are harvested as follows: Black Veil, the first week in September; McFarlin, Bugle, Centerville, and Centennial, the second or third week in October. The berries grow sweeter and larger as they ripen, so the later they are picked, the better the sauce they make and the greater the yield.

Cranberries should be gathered only when the vines are dry. A frosty night compels the flooding of unpicked areas, and usually little harvesting can be done the next day. Berries picked late in the afternoon keep better than those gathered in the heat of the day.

Cranberries were picked by hand at first, and it took an army to gather the crop. Some hand picking is still done on the Cape (Fig. 31 A), but it is an expensive and probably unwise practice except on thin or poorly anchored vines where scoops do too much harm. Small but effective devices known as "snaps" (Fig. 31B) are often used to gather the fruit on new or sparse vines. Power machines (Fig. 31C) have been used considerably but are not widely favored.

The Cape Cod and Wisconsin crops are now picked mostly with scoops (Figs. 32 and 33B). Hand picking is more common in New Jersey.

To have the pickers work steadily, without haste and with as little waste as possible, is a good rule. If help is scarce and water supplies are low, however, it sometimes is best to pick the crop hastily to save it from frost, great though the waste. The speed with which scooping should be done also depends on the crop and on prices; $5 a barrel justifies rapid scooping unless the crop is heavy; but $10 or more with an average crop calls for careful work. Fully a fifth of the whole Cape Crop is left on the bogs by the pickers.

Fig. 31.
A. Picking Cranberries by Hand. B. Picking with a Snap Machine.
C. Harvesting Cranberries with Power Machines. One machine picks two acres a day.

It ordinarily is best to pay the scoopers by the hour. They may be hastened with bonuses. Picking by the box is done widely, and wisely, for it attracts the more experienced and efficient scoopers. Fifty cents a bushel box was a common 1947 wage.

It never pays to gather by hand the berries that fall to the ground. They always are in poor condition, having been tramped over more or less, and will decay quickly. Such berries are often taken from the water as flotage on the after-picking flood (Fig. 34A). Those so gathered are cleaned of trash quickly and completely while wet, with screens made for the purpose. Most of them are sold to canners.

Fig. 32. Scooping Cranberries.
One man sometimes scoops fifteen barrels in a day.

The berries as they are picked are dumped into bushel boxes on the bog, the boxes having slits in the sides and bottom for ventilation and slats at the ends for handling and for spacing in stacking (Figs 34 B snd 35 A). Many vines gathered by the scoops go into the boxes with the berries. It is widely supposed that the berries store better if the vines and chaff remain in the boxes with them, it being thought that they aid ventilation; but the vines have no such effect and unattached leaves promote decay. Sand picked up in the scooping is very harmful among the stored berries. Stones gathered with the berries bruise them as they are picked and when they go through the separator, impairing their keeping quality.

A foreman, thirteen scoopers, and three helpers are needed to pick a 15-acre bog. Two of these men carry empty boxes to the pickers and take the full boxes from the bog and stack them on the upland for trucking. Special wheelbarrows with pneumatic tires (Figs. 33 A and 34 B) are best for removing the berries from a bog.

After the crop is harvested, the vines are raked lightly with hand hay rakes. This clears the bog of loose material torn up by the scoops and trains the vines for the next year. There is a market for the rakings as a mulch in nurseries and for ornamentals. Dry bogs should be picked with snaps and be raked early the following spring, for the less the vines are disturbed in the fall, the less liable they are to winterkill.

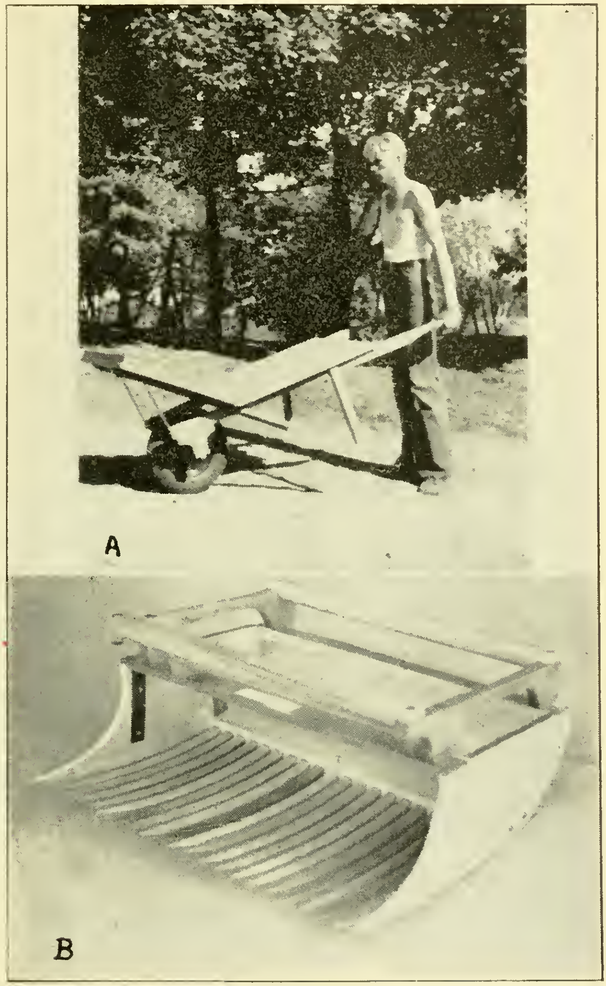

Fig. 33.
A. Special Wheelbarrow for Taking Boxes of Berries from a Bog. It is better than it looks.
B. A Cranberry Scoop. A picker can work steadily with one of these till it is nearly full. It holds about half a bushel.

STORAGE

The berries are stored in the packing house (screen house) in the picking boxes as they come from the bog (Fig. 35A). The building, if tightly constructed, should be kept close shut on damp and on warm days and be well aired on cold nights, with fans if necessary. It should have capacity to hold two-thirds of the maximum crop expected from the bog and a proper supply of shipping boxes and shooks, as well as room to sort and pack the fruit. A building of one floor, 40 by 70 feet, is large enough for a 12-acre bog. Open sheds are cheap and make good storage. Cellars are less satisfactory except in protection from freezing. The most modern cranberry storages (Fig. 35B) are lined with insulating materials to maintain a moderate temperature. Cold storage for this fruit is practicable. The berries keep best at a temperature of 35° F. but they color best at from 45° to 50°. They keep and ship better after cold storage than after common storage. They nearly always keep well in the years when the general crop ripens late or is made up of small berries.

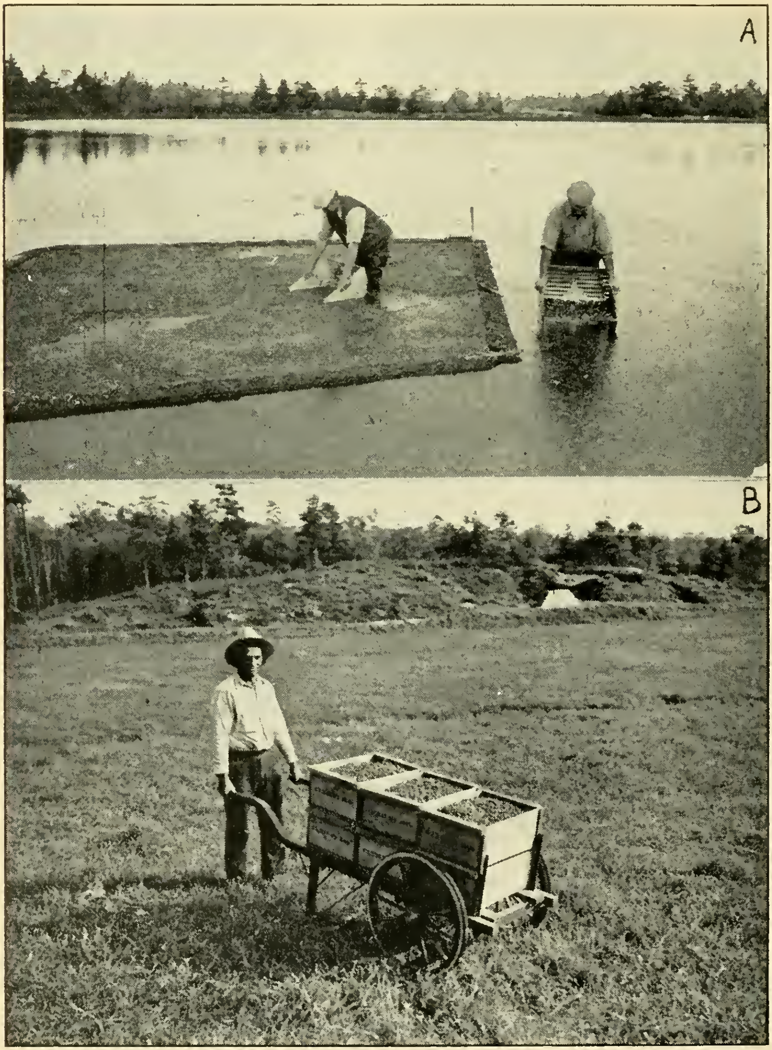

Fig. 34.
A. Gathering Floaters from a Bog Flowage. They are first assembled with planks.
B. Wheelbarrow Loaded with Full Picking Boxes. These boxes are usually about 19 ¼x14x8 1-3 inches, inside measure. Note the slat handles at the top of each.

Fig. 35.
A. Picking Boxes Full of Cranberries Stacked in a Screen House.
B. An Up-to-date Screen House, with part of a bog in the foreground.

PREPARATION OF THE BERRIES FOR MARKET

The first shipments usually go out within a week after picking begins, in early September, and that part of the crop that is handled as fresh fruit is nearly all sold by Christmas. Many prefer to take the lower prices which the earlier shipments usually bring and get rid of their berries promptly. Their fruit does not suffer the shrinkage that late-shipped berries do, and the cost of sorting is much less. Some, however, prefer to take these losses and gamble for higher prices. This has been increasingly risky in recent years.

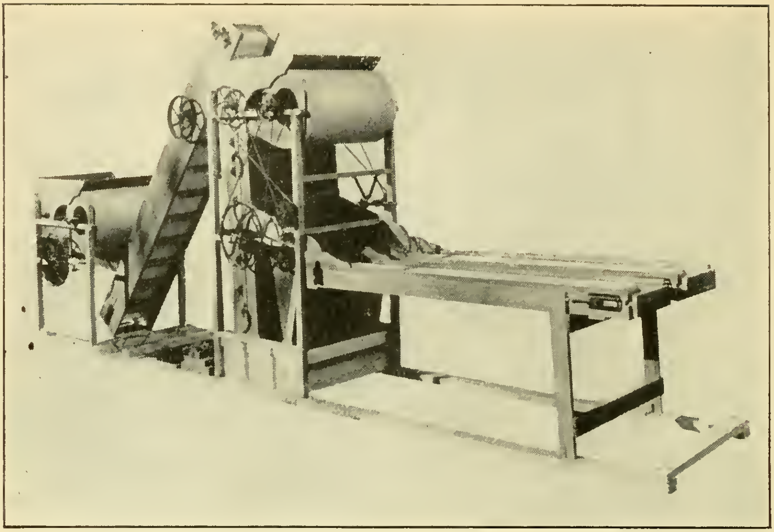

Fig. 36. A Cranberry Separator, with Extra Blower and Elevator at the left and Sorting Belts at the Right.
The extra blower makes the flow of berries through the separator more even; a two-inch mesh wire screen in the hopper takes out vines.

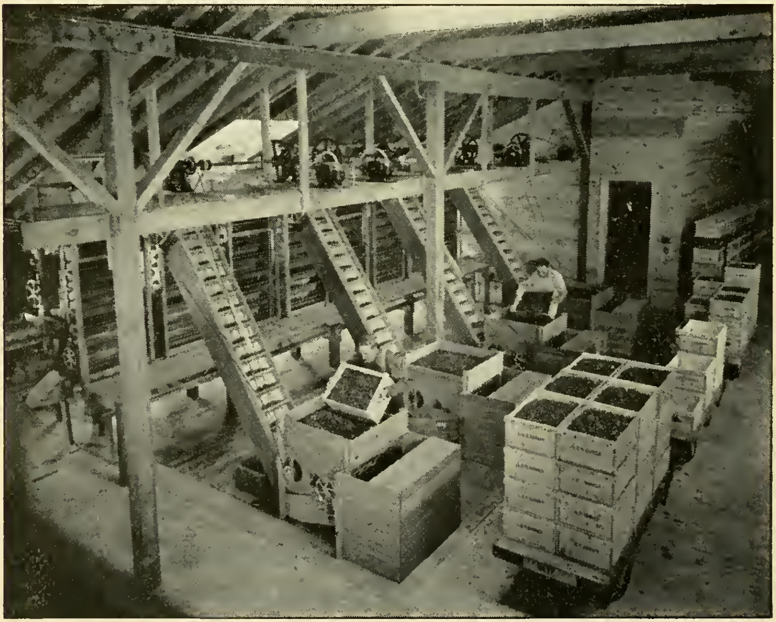

Fig. 37. Screen-House Scene.
A floor truck loaded with picking boxes full of berries at the right in the foreground. Four extra blowers and elevators, in the center, feeding a battery of eight separators at the left. Rows of shipping boxes at the right in the rear.

Fig. 38. Hand-Sorting Cranberries on Moving Belts.
Green or whitish berries and berries showing frost injury or decay are picked out.

Fig. 39. Packing Cranberries in Shipping Boxes. Inspector at right.

In preparation for market, the berries first go through a separator. There are several makes of these machines. Those used on Cape Cod and largely elsewhere (Figs. 36 and 37) have a hopper at the top to receive the berries, a blower to clean them of chaff, several bounding boards to separate the decayed from the sound fruit, and a grading device.

Much of the fruit of the early shipments is often so sound that it may be packed for shipping as it comes from the separator. Most of the berries, however, must be hand-sorted. Women do this work, mostly on moving belts (Fig. 38), in a well-lighted and comfortably warm room which is walled off from the cooler storage and packing rooms. The berries pass through this sorting room too quickly to warm up much. The fruit must be shipped as soon as it is packed for it deteriorates faster after it is sorted than before.

It is best not to sort or pack the berries on wet days, for they collect moisture in damp weather and are more likely to rot in transit if they are packed moist. The fruit was formerly shipped almost entirely in barrels, but now the quarter-barrel box and small cellophane bags are the principal packages. The cranberry barrel contains about 90 dry quarts, its dimensions being fixed by law. The box containers must be shaken well and the berries heaped slightly and pressed down in packing (Fig. 39) so that they may not come to market "slack-packed." Slack-packed berries are shunned by the trade because they lack in quantity and their keeping quality is impaired by thrashing. The weight of the berries in a quarter-barrel box ranges from 23 to 26 pounds, varying with the variety and condition of the fruit.

MARKETING

Much of the Cape crop is sold through a co-operative, the New England Cranberry Sales Company[15]. Other companies, in Wisconsin, New Jersey, and on the Pacific Coast, affiliated with the New England company in the American Cranberry Exchange[16], handle berries from those areas. This organization is well managed and helps the trade greatly by extensive advertising and by watching the cranberry markets throughout the United States and Canada and distributing the berries as they are needed, so preventing gluts. It has central packing houses and experienced inspectors, and the berries it handles are tested for keeping quality in incubators and packed uniformly under different brands according to their varieties and qualities. It establishes opening prices, basing them on careful studies of conditions, and pools most of its fruit. It has fostered research which showed that cranberries have important healthful properties, and distributes selected cranberry recipes gratis.

There are also a few independent distributing agencies, some of them very efficient. Considerable fruit is consigned. Buyers for cash are around every year.

PRESERVING

Owing mainly to the enterprise and energy of the cranberry growers directing the National Cranberry Association[17], the preserving of this fruit has become a great industry (Fig. 40). Nearly its whole development has taken place since 1925. Now over half of the crop of the country goes into cans as sauce or into bottles for beverages. Some of the fruit is dried, but this excellent product has found only particular and limited markets. Most cranberries of doubtful keeping quality now go to preservers, leaving only reliable stock for the fresh fruit trade.

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[15] Office at Middleboro, Mass.

[16] Office at 90 West Broadway, New York City.

[17] Office at South Hanson, Mass.

The National Cranberry Association does very extensive advertising, sponsors a buying pool for the growers, and maintains effective research to find new uses for cranberries. This concern and the New England Cranberry Sales Company provide helicopter and other bog services and sponsor bog financing.

Minot Food Packers, Inc., Hill Brothers Company, Stokely Foods, Inc., and Pappas Brothers, Gillies and Company are other concerns that can a lot of cranberries.

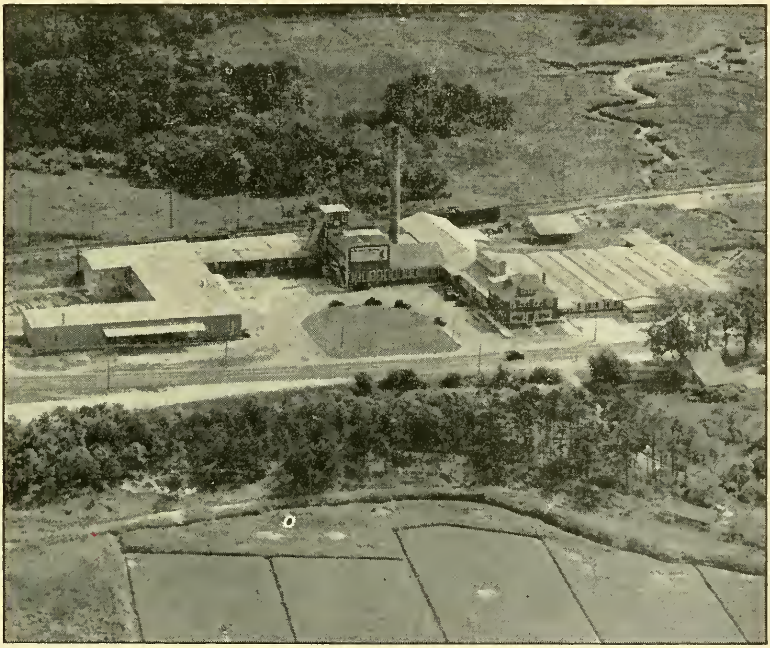

Fig. 40. Cannery at Onset, Mass., one of six operated by the National Cranberry Association.

MACHINERY AND TOOLS

A list of those who serve the cranberry industry and are located in the Cape Cod section is given for the convenience of growers. No specific recommendations for any listed firm or product is intended.

H—makes and repairs power picking machines
M—makes and repairs dusting machines and sorting machinery
N—provides insect nets
P—installs and repairs pumping plants
S—provides and repairs picking scoops only
T—provides wheelbarrows, picking scoops, and bog tools
X—makes and repairs packing equipment

H. R. Bailey Co., South Carver	P M T X
Beaton's Distributing Agency, Wareham	P, also bog supplies
F. L. Buckingham, Plymouth	T
Antone Burgo, Pleasant Lake	S
Arthur H. Chandler, Marshfield	S
Henry Guerin, South Middleboro	P
Hayden Separator Manufacturing Co., Wareham	P M T N
Mathewson Machine Works, 2 Hancock St., Quincy	H
Jay A. Ward, North Carver	P

Nearly all the spraying machines used by our cranberry growers are made by the following concerns:

John Bean Manufacturing Co., Lansing, Michigan
(Maxim Motor Co., 170 Wareham St., Middleboro, Mass., agent)
Fitzhenry-Guptill Co., 135 First St., Cambridge, Mass.
Frost Insecticide Co., Mill St., Arlington, Mass.
F. E. Myers Co., Ashland, Ohio
(Hayden Separator Manufacturing Co. agent)

AGRICULTURAL EXPERIMENT STATION
MASSACHUSETTS

BULLETIN No. 448 APRIL 1948

The Valuation of Dairy Farm Property for Local Tax Purposes in Massachusetts

By Alfred A. Brown

Valuations indicate the community's estimate of the property owner's obligation to it; yet they are frequently overlooked in the constant concern over taxes. This report attempts to give to valuations the importance they deserve and to suggest ways of increasing the objectivity of the valuation process.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

THE VALUATION OF DAIRY FARM PROPERTY FOR LOCAL TAX PURPOSES IN MASSACHUSETTS

By Alfred A. Brown
Professor of Agricultural Economics

INTRODUCTION

Taxes today as never before in our time need to be closely scrutinized. The taxing system and process needs to be understood. The tax official needs sympathy as well as criticism. The tax payer needs knowledge as well as relief. Despite changes in officeholders, one party for another, or "Outs" for "Ins," and their praiseworthy intentions to reduce taxes, the odds are against its being done.

Current tax levels and taxing practices are the surface product of at least 170[1] years of living together in this country and there are aspects of financing our community affairs that reach far deeper into the past. Defense against "our" enemies whether they were the tribe over the hill; the band across the inland sea; the legions of Caesar; the foot-weary soldiers of Napoleon before Moscow; the Empire troops of Wilhelm II; or the arrogant wearers of black shirts of a more recent day—defense against their depredations has been ever with us and at an increasingly staggering cost. The final accounting for the last war will not be done for several years; and then only by common consent. But we need not wait until then to realize that the amounts involved are so gigantic that from the day we decide to face them, lower taxes are impossible.

During the centuries, as each group in turn has defended itself against an aggressor on an increasing scale, there have been intervals when attention was diverted to the level of living: food, clothes, shelter, health, protection from fire and flood, care of the abnormal, and recreation for all. Just as defense has advanced from a family affair 50,000 years ago to a world affair in 1947, so has our attention to levels and ways of living; at a slower pace perhaps, yet still in that direction. In our own lifetime we have seen the community—the community of individuals, i.e., the town; the community of towns, i.e., the state or province; the community of states, i.e., the federal government; the community of federal governments or nations that is the League or the United Nations Organization—given more opportunities and responsibilities in raising the general level of living for all men. As the responsibility for the higher level of living has been given to the community, the cost in most instances has been transferred to the community and the payment made to the community—the tax.

Transferring a responsibility to the community alters its relationship to any specific person in the community and the person's relationship to it. Whereas freedom of acceptance or rejection, participation or non-participation, was the individual's privilege prior to the establishment of the community interest, once that interest is legalized each person is concerned whether he wants to be or not. Not only is each person concerned, but the community has been given the responsibility of determining the degree of his concern. Strange as it may seem,

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Mrs. Elaine P. (Miller) Roberson, formerly Research Assistant, collected much of the data on which this report is based. Miss Judith E. Rosenthal, formerly Laboratory Assistant, helped with the tabulations and analysis.

Without exception, during 1945, when the data were being gathered in the various towns, local officials were most cordial and helpful.

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[1] (1776-1946)

in view of the fairly widespread reluctance of qualified people to become interested in government, people fought a war so that they might determine this "degree of concern"; the famous "Taxation without representation is tyranny" exponents. The demand of that day was that in matters of taxation, they at least be heard. That right still exists; the public servant should know it; the citizen should not forget it. The effectiveness of the hearing, however, depends on the knowledge and understanding brought to it. The results of this study are intended to be an aid in that direction.

Although we have data only on Property Taxes, we can safely indicate that for most farm owners these have been their largest tax. Income taxes, federal or state; excise taxes; and sales taxes are part of the total tax bill against the farm. Compared with the amount of tax paid by property, they have been in general small.

Property taxes are worth studying not only for their size but because of the way in which they are determined. It is possible for a tax system to be burdensome, confiscatory, and capriciously unjust. The laws of the land provide safeguards to protect the taxpayer and rules for the guidance of the tax officials. Despite the regulations, the basic element in the tax bill—the valuation of the property—continues to be a matter of judgment. To be sure the law in Massachusetts reads—"The assessors of each city and town shall at the time appointed therefor make a fair cash valuation of all the estate, real and personal, subject to taxation therein . . . "[2] But after having the law someone had to interpret it; especially the meaning of "fair cash valuation." Inevitably, in this land known throughout the world for its sharp traders, greater precision was needed in the wording of the law. Justice Holmes brought his wisdom to bear on the point in 1892 by ruling that—"The cash value of an article is the amount of cash for which it will exchange in fact."[3] This at least narrowed down the interpretation so far as non-real property was concerned.

In 1919 the court declared: "Fair cash value of land for purposes of taxation is ascertained by a consideration of all those elements which make it attractive for valuable use to one under no compulsion to purchase but willing to buy for a fair price, attributing to each element of value the amount which it adds to the price likely to be offered by such a buyer."[4]

The court decisions are of little help in the annual task of the assessor. The routine task of annually checking farm property does not rest on precise definitions. The law has provided a foundation on which the assessor builds his valuations. The amounts do not vary much from year to year. Judgment is the assessor's best tool and judgment is a subjective quality.

Even after allowing for a high level of common sense among the assesors, the present system has permitted a great deal of variation in the valuation of real and personal property throughout Massachusetts. This despite the law which enables the Commissioner of Corporations and Taxation to ". . . visit any town, inspect the work of its assessors and give them such information and require of them such action as will tend to produce uniformity throughout the commonwealth in valuation and assessment."[5]

The assessors themselves, at the time we were doing the field work, appeared to be much interested in the valuations in the various towns and a common question of theirs was "What do they value cows or tractors at in that town?"

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[2] Commissioner of Corporations and Taxation, (Chap. 59, Sec. 38, p. 108) Commonwealth of Massachusetts. General laws relating to local taxation (Tercentenary Edition Revised to include 1943 Legislation) Boston 1943.

[3] National Bank of Commerce vs New Bedford, 155 Massachusetts 313.

[4] Massachusetts General Hospital vs Belmont, 233 Massachusetts 190.

[5] Commissioner of Corporations and Taxation, op. cit. Chap. 58, Sec. 1, p. 3.

The records on which this study is based were taken in 1945 and economic conditions were then such, perhaps, as to encourage a greater than usual interest in the values levied by others, but there was an undertone of wanting to be fair, to keep things in line. When we stop to recall that there are 300 towns in the state, 900 assessors in these towns, and roughly 18,000 farms of very diverse kinds, the challenge of uniformity presents a complex situation.

VALUATION IN PRACTICE

Poultrymen, fruit growers, and farmers in other fields may rightly wonder why dairying was singled out for special attention, and a few may even assume that the dairy industry gets preferred consideration. This despite the fact that dairying is no longer without a rival as the major type of farming in Massachusetts. The answer to the question is easy to find; the availability of basic data. The subsidy programs; the marketing studies; the general geographic distribution of the dairy farms all contribute towards the development of data.

Concentration of effort on the dairy farms neither precludes nor forbids expressing in general terms conclusions pertaining to buildings, land, or personal property. Sufficient data were secured on farms other than dairy to suggest that variation in valuation is not the result of type of farming. Vegetable growers, apple growers, or tobacco growers face the same general situation; the differences if any are ones of degree.

The passing attention given to taxes per se may also invite wonder. Taxes are what property owners pay. Taxes are the "burden." It was the tax situation that brought about this study. But taxes have meaning only in relation to something else: the services received; the ability to pay; the taxes of others; the errors of the past; the hopes for the future; and the specific tax components—tax rate and valuation. And of the two the tax rate is apt to be a function of the valuation.

In its simplest aspects, the amount appropriated at town meeting is divided by the valuation of the taxable property to get the mill rate, and multiplied by 1000 to get the rate per $1000 of valuation. Occasionally towns make a point of maintaining a given tax rate. In this event variation in appropriations (barring windfalls of unexpended balances) has to be reflected in valuation. Or what is more likely to happen is that the amount appropriated remains stable. The valuation of all taxable property in a town is a slowly changing aggregate. Annual changes in expenditures may be more promptly reflected in the tax rate.

Valuations, of course, like taxes or tax rates lose some of their meaning when extracted from the body of pertinent elements. They differ, however, in this major respect—they are not mathematically determined. They are a mathematical expression of an opinion on value arrived at via the means at hand. Valuation further represents the personal financial relationship of the property owner to the town. The tax rate is a community affair.

VALUATION OF REAL PROPERTY

Real property consists of buildings and land; the house, the barn, the sheds, the mowing, the pasture, and the woodland. If the acreage is greater than three or if the produce therefrom exceeds $250 annually the land with its structures is a farm according to census definition. Valuation lists do not specifically classify farms and the assessors' concept is apt to be less limited than that of the census.

The classification that appears in "Valuation Lists" is associated with ownership as well as with the kind of real property. Each piece of property for which a separate title exists is listed. Farmers and others who hold title to more than one piece of real property are well aware of this.

The notion of ownership has pertinent connotations in this regard. There is the notion which applies to the farm as an operating unit; there is the notion that applies to the farm as an aggregate of legal rights; there is the notion that applies to the farm as a unit for taxing purposes. The notions are seldom uniform although they may be compatible.

In arriving at values, the common practice seems to be to first consider each parcel[6] or lot[6] with its buildings as a salable unit at an over-all figure; a farm, with 50 acres and buildings, at \$3000 for assessing purposes. The law provides, however, that land and buildings must be separately valued so that the next step is to break down the over-all into unit values that add up to \$3000; e.g., house \$800, dairy barn \$800, shed \$100, land 50 acres at (\$3000 − (\$800 + \$800 + \$100) = \$1300. Reason suggests that the land, however, ought to be worth \$1500. Either the total has to be increased to \$3200 which appears a trifle high for the place, or buildings have to be reduced; and house and barn at \$700 each seems a little low. The choices are evident. Which shall it be? As one assessor cutely phrased it, "The whole is not equal to the sum of the parts."

The average of assessors' valuations on dairy farm real estate in the study broke down as follows: House \$1767; Other Buildings \$2125; Land \$3189; or a total real estate valuation of \$7081. It is perhaps coincidence, but of the total real estate valuation, 55 percent was on buildings and of the buildings 55 percent was on the work units—the barn, silo, sheds, etc.

Around the state, using county data for purposes of comparison, some interesting similarities and differences were observed. One should bear in mind that the groups are estimates based on a small number of dairy farms in each county and that the true average might be this value or another somewhere near it. The high average real estate valuation in Essex County is due to the inclusion of several estates; the mansions were excluded from the buildings groups but there was no way of sub-dividing the land into that which was "farm" and that which was "estate." The range of \$3000 around the state average with the Valley counties of Franklin, Hampshire, and Hampden on the low side and those in southeastern Massachusetts on the high is about what one would expect. Berkshire County valuations, however, tend to be more in line with those in southeastern Massachusetts, whereas those for Worcester County fall with the western Valley group.

The valuation on a county basis of the land owned by dairy farmers, Essex County excepted, falls pretty close to the state's average; \$500 on either side. The picture around the state differs on this item; the western counties plus Worcester being at or above the average; three of the eastern counties, Middlesex, Norfolk, and Barnstable, below; and two, Plymouth and Bristol, above.

Valuations on houses and on other buildings showed the most and widest variations. Worcester and the Valley counties were at or below the state average. Berkshire and the eastern counties were at or above for houses. There was a slight shifting of counties so far as other buildings are concerned; Hampden going into the above and Barnstable into the below group.

The meaning of these relationships is the object of interest; the why as well as the what. Aggregate values and bare values do not lend themselves too readily to disclosing causes of variability. They do, however, suggest possibilities. The

[6] Land units for which separate title exists.

higher than average land valuations in the western counties suggest larger than average acreages; in Plymouth and Bristol Counties, higher than average values per acre; i.e., more tillable acres or less pastures and woodlots. The lower than average valuations in Middlesex and Norfolk are due perhaps to smaller average acreages.

Table 1.—Average Real Estate Valuations per Farm By Counties in Massachusetts—1944.

County	Number of Farms in Sample	All Real Estate	Land	Buildings All	Buildings House	Buildings Other	Buildings Exceed Land in Value	Other Buildings Exceed House in Value
Berkshire.......	47	$7,132	$2,997	$4,135	$1,981	$2,154	x	x
Franklin.......	42	5,449	3,033	2,416	1,014	1,402		x
Hampshire.....	39	6,501	3,248	3,253	1,547	1,706	x	x
Hampden......	31	6,801	2,717	4,084	1,711	2,373	x	x
Worcester......	65	5,933	2,732	3,201	1,489	1,712	x	x
Middlesex......	44	6,729	2,482	4,247	1,995	2,252	x	x
Essex..........	35	10,567	6,266	4,301	2,052	2,249		x
Norfolk........	17	7,418	2,237	5,181	3,096	2,085	x	
Plymouth......	29	8,893	3,200	5,693	2,015	3,678	x	x
Bristol.........	34	7,294	3,052	4,242	1,695	2,547	x	x
Barnstable.....	8	5,994	2,268	3,726	2,094	1,632	x	
Total......	391							
State Average		7,081	3,189	3,892	1,767	2,125		

The differences in average house valuations may reflect not only true differences in the buildings themselves but also the influence of location—the competition from urban residential dwellings. Norfolk, Plymouth, Hampden, and Essex County valuations lend weight to the theory. Above average valuations in Berkshire and Barnstable may reflect the influence of the price and demand for summer property.

With "other buildings," the size and type of business might be the ruling factor.

The county average valuations conceal the individual differences with which property owners are concerned. They do, however, indicate the general structure of farm real estate valuation for Massachusetts dairy farms.

The geographical structure of relationships suggests that valuations have not kept pace with the changing nature of the Massachusetts dairy industry. During the past two decades dairying in Massachusetts has undergone a transformation. The development of the motor truck and the extension of the highway system made the entire production area accessible to all buyers. Milkshed lines were broken down and the cities of the state now constitute for the most part one huge market and the production area one vast milkshed. Market prices in turn are reflected at the farm and farm values influenced accordingly. One might expect that 50-cow farms would be valued for taxing purposes on about the same basis wherever they are located in the state.

House Valuations

Dairy farmers lived in houses that, on single-house farms, assessors valued at prices ranging from $200 to $5000. There were five houses, 1+ percent, assessed for more than $5000 but these were on places having additional dwellings. Almost one-fourth of the dwellings were assessed for less than $1000; and nearly one-half (43.4%) from $1000 to $2000; with the rest distributed at various amounts up to $5000.

TABLE 2.—HOUSE VALUATIONS ON DAIRY FARMS.
(Single-House Farms)

Valuation	Number of Farms	Percent	Valuation	Number of Farms	Percent
$200 – $999	91	23.3	$3,500 – $3,999	9	2.3
1,000 – 1,499	102	26.1	4,000 – 4,499	8	2.0
1,500 – 1,999	72	18.4	4,500 – 4,999	4	1.0
2,000 – 2,499	45	11.5	5,000 and over	5	1.3
2,500 – 2,999	30	7.7			
3,000 – 3,499	25	6.4	Total	391	100.0

The low-valued houses were not in general on the small farms, although the value per acre of the farms showing low-valued houses would indicate a larger proportion of acreage in low-value land; woodlot, pasture, swamps, inaccessible, rocky, hilly, etc. House value was not correlated with farm size. It was associated with value per acre.

TABLE 3.—FREQUENCY DISTRIBUTION OF HOUSE VALUATIONS BY FARMS. CORRESPONDING NUMBER OF ACRES, VALUE OF LAND, AND TOTAL REAL ESTATE VALUE.

House Valuation	Number of Farms	Number of Acres		Value of Land		Value of All Real Estate	
		Total	Per Farm	Total	Per Acre	Total	Average Per Farm
$999 or less	91	11,650	128	$ 192,620	$17	$ 455,235	$5,003
1,000 – $1,499	102	12,658	124	247,045	20	531,170	5,208
1,500 – 1,999	72	7,673	107	210,590	27	449,215	6,239
2,000 – 2,499	45	4,830	107	162,290	34	372,060	8,268
2,500 – 2,999	30	4,572	152	122,635	27	303,055	10,102
3,000 – 3,499	25	2,553	102	95,375	37	260,480	10,419
3,500 – 3,999	9	1,142	127	43,951	38	136,851	15,206
4,000 – 4,499	8	497	62	21,690	44	76,555	9,569
4,500 – 4,999	4	649	162	19,705	30	71,210	17,803
5,000 and over	5	973	195	26,890	28	112,890	22,578
Total	391*	47,197		$1,142,791		$2,768,721	
Average			120.7		$24		7,081

* Nine records omitted because of no enumeration of building value.

It seems scarcely possible that anyone could look at the table of house valuations and not ask at least two questions.

(1) From the valuation point of view are there as many differences in the houses on dairy farms as the records reveal? The extent of differences as indicated by specific pricing is not peculiar to houses. It runs through the entire local valuation process and reaches its extremes in land. The question warrants consideration.

(2) The second question pertains to precision in pricing. Examination of the data reveals a clustering of valuations around certain prices. This grouping of values can mean either that dairy farmers tend to have several common types of housing or that assessors have a tendency to use certain valuations.

The table of valuations seems to reflect a good deal of compromise in judgment. Below the $1000 level, the intervals at $50 suggest uncertainty as to whether the even hundred above or below would be correct. Above $1000, the interval of compromise apparently widens to $100, $250, and even $500 as the house value increases. It is not too presumptuous to assume that even the assessor would

TABLE 4.—VALUATIONS MOST COMMONLY USED IN ASSESSING HOUSES.

Valuation	Number of Houses	Valuation	Number of Houses	Valuation	Number of Houses
$200	2	$800	21	$1,800	17
300	3	900	16	2,000	26
400	4	1,000	29	2,500	20
500	4	1,200	33	3,000	16
600	12	1,400	8	3,500	5
700	12	1,500	25		
				Total*	253

* 17 values.

scarcely claim capacity for valuations at anything nearer than 10 percent of the figure that should be used.

The data, being on a state basis, do not lend themselves to consideration from the town point of view, the assessing area. It seems rather likely that other houses in a town enter into the process of valuing a particular house; houses on adjacent farms being used as a standard of comparison, or similar houses in different parts of the town. The structure of valuations is highly interwoven.

Seventy-two different values were used in assessing the houses in the $200 to $5000 range. Seventeen or 23.6 percent of the values accounted for 253 or 64.7 percent of the houses.

Land Valuations

Land was assessed at values which ranged from $1 to $1625 per acre. On 1197 parcels there were 153 different values per acre and the values were in continuous series from $1 to $62 beyond which eight gaps of a dollar each occurred to $100 and thereafter more frequently, irregularly, and in varying amounts.

The most common value was $10 per acre; the modal class of values was $10 to $19 per acre; and over half the values were below $30 per acre.

TABLE 5.—SCHEDULE OF MOST COMMONLY USED VALUATIONS PER ACRE.

Valuation per Acre	Number of Parcels	Valuation per Acre	Number of Parcels	Valuation per Acre	Number of Parcels
$5	41	$30	36	$100	23
10	95	40	24	200	8
15	46	50	57	300	8
20	58	60	12	400	6
25	36	75	11		
				Total	461

The regularity with which some values per acre recurred suggests that intentionally or not assessors applied a value per acre to a given acreage to get the parcel value for assessment purposes. On the basis of derived values, the valuation schedule shown in Table 6 was developed. The rates listed accounted for 38.5 percent of all parcels valued.

The picture of land values which one can draw from the schedule may not be too far from reality although it has some blotches which need to be studied further in order to explain them. Some of the apparent irregularity may be accounted for by sampling vagaries; some of them are undoubtedly man-made, such for example as the bulking at $20, $50, and $100 after the "curve" had turned downward at $10.

TABLE 6.—FREQUENCY DISTRIBUTION OF VALUATION PER ACRE OF 1197 PARCELS OF LAND LISTED TO 397 FARMS.

Valuation per Acre	Number of Parcels	Valuation per Acre	Number of Parcels	Valuation per Acre	Number of Parcels
$0 – $9	173	$75 – $99	46	$700 – $799	3
10 – 19	318	100 – 199	64	800 – 899	4
20 – 29	213	200 – 299	24	900 – 999	1
30 – 39	112	300 – 399	13	1,000	3
40 – 49	76	400 – 499	7	1,001 and over	3
50 – 59	81	500 – 599	3		
60 – 74	51	600 – 699	2	Tota	1,197

The schedule reflects the basic difficulty in property valuation; the conflict which inevitably develops between trying to follow the letter of the law and trying to be reasonable about it. The emergence of so many common values suggests either a measure of realism among assessors or an attitude of resignation.

The valuation of farm land for tax purposes is not a simple matter. With dairy farms especially, the land even on the home place is seldom uniform. Land is a very general, all-inclusive designation in the first place for the various soil types that exist on a farm and then for the uses to which those soils are put. Add to these the modifying effects of location and management and the process becomes increasingly difficult.

Some measure of rationalization is inevitable. Although the available data do not permit town comparisons, it is likely that within towns this is taking place, otherwise Table 5 would not show nearly 40 percent of the farm parcels valued at rounded amounts. The proposition then becomes one of encouraging uniformity among towns in the valuation of farm lands and devising methods which will facilitate its attainment.

Barn Valuations

Usable records were available for 385 barns. Valuations ranged from $100 to $12,000. On the basis of cows and two-year-olds sheltered, the barn valuation per animal unit ranged from $12.79 to $90.09 with an average of $50.57.

Probably the most significant relationship disclosed by the data is the association of barn value per animal unit with number of cows per farm. As the listed barn valuation increased, the number of cows per barn also increased. But the two did not move together at the same pace. Barn valuation increased at a more rapid rate up to the $2500-$2999 class. Beyond that class there were insufficient data from which to draw conclusions. The tendency, however, seemed to be one of an increasing number of cows with barn value per animal unit leveling off.

TABLE 7.—FREQUENCY DISTRIBUTION OF DAIRY BARN VALUATIONS.

Valuation	Number of Barns	Cows per Barn	Barn Value per Cow		Valuation	Number of Barns	Cows per Barn	Barn Value per Cow
$100 – $499	70	14.2	$21.79		$3,500 – $3,999	1	73.	$47.95
500 – 999	141	17.3	38.44		4,000 – 4,499	4	43.3	98.84
1,000 – 1,499	81	25.6	44.40		4,500 – 4,600	2	50.5	90.09
1,500 – 1,999	32	26.2	63.69		5,000 – 12,000	9	90.0	84.24
2,000 – 2,499	31	32.8	64.36					
2,500 – 2,999	4	58.	46.55	Total		385		
3,000 – 3,499	10	47.4	65.93	Average	$1210.81		23.9	$50.57

One might ask why barn valuation on a per cow basis should show any relationship to herd size. As herd size increases, larger barns are necessary (barring changes in herd management) and total valuation might be expected to increase. But are larger herds housed in better barns? Are they twice as good; three times as good; from a market value viewpoint? Or does the dairy barn set the standard of value for the entire property?

VALUATION OF PERSONAL PROPERTY

The separation of a man's property into categories for purposes of taxation is an intriguing aspect of our community life. The procedure undoubtedly had its origin in the legal framework of society, and its injection into the tax system may scarcely have been noticed. Fairness must have been in the minds of the first elected public officials who faced the task of raising funds for public purposes. The State Constitution, Part the First, Article X reads, "Each individual has a right to be protected . . . . He is obliged to contribute his share to the expense . . . ."[7] and Part the Second, Article IV, ". . . . that such assessment may be made with equality . . . ."

The Massachusetts laws are reasonably specific in defining Real Property and Personal Property. According to Section 3, of Chapter 59, "Real estate for the purpose of taxation shall include all land within the Commonwealth and all buildings and other things erected thereon or affixed thereto."[8] In addition to the house, barn, sheds, etc., such items as silos and gasoline pumps are separately valued by some assessors. Thus far, fences seem to be immune.

Personal property is less easily disposed of. Section 4 of Chapter 59, reads "Except as provided . . . personal estate shall include:

"First, goods, chattels, money and effects wherever they are; ships and vessels at home or abroad, except as provided in Section 8 of this chapter and in Section 67 of Chapter 63."[9]

The list of exceptions is long and diffuse. It reflects many of the difficulties involved in developing a tax system.

The system should be fair; so in the first instance the goods of all are subject to taxation. But,

1. There are some members of society who are less able to bear a tax than others so their personal property is exempt. (Sect. 17, p. 89)

2. There are some members of the community to whom the general public is indebted beyond the ordinary means of payment. At loss as to a satisfactory method of paying its debts, legislators and the public fall back on giving them freedom from certain taxes. (Sect. 22, p. 90)

3. There is general agreement that production should not be discouraged by burdensome taxation of the means of production. But even more specifically that no undue burden should be placed on the person who earns his living with his hands; originally most of society—farmers, artisans, and fishermen. (Sect. 20, p. 90)

4. There used to be and still is among some people a belief that double or multiple taxation is unjust. Accordingly, some attempt is made to except certain intangibles, the income of which is taxable under other laws. (Sect. 27, p. 93)

All told, there are thirty-five numbered paragraphs of exemptions. The ones of obvious interest to farmers are paragraphs 20 and 21; paragraph 20 which

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[7] General Laws, Tercentenary Revised to include 1943 1943 p. 1.

[8] General Laws, 1943, Chapter 59, Section 3, p. 81.

[9] General Laws, 1943. Chapter 59, Section 4, p. 83.

exempts farming utensils, and 21 which exempts horses and cattle less than one year old, swine and sheep under six months, and domestic fowls not exceeding fifteen dollars in value.

Three classes of personal property appeared on the Valuation Lists.

1. Livestock; 2. Machinery and Equipment; 3. Stocks on Hand.

Except for livestock, where provision is made to list by kind, personal property was seldom identifiable. Occasionally, under the machinery listing there would be a notation of "tractor" or "farm truck." Stocks on hand in a few instances were found to be apples in storage. Assessors apparently exercise a good deal of latitude in the valuation of some kinds of personal property.

The valuation lists do not tell us much about machinery. Occasionally, a tractor is identified as such, but for the most part there is no further classification. Twenty-five percent of the farms had a machinery valuation; the lowest was $20, the highest $5000; and the average $388.80. Of the farms showing machinery valuation 77 percent had less than $500, 12 percent had between $500 and $1000, and 11 percent had $1000 or over.

Table 8.—Machinery Valuation per Farm.

Valuation	Number of Farms	Valuation	Number of Farms	Valuation	Number of Farms
None	300	$300 – $399	[illegible]	$700 – $999	2
$20 – $99	22	400	5	1,000	6
100 – 199	24	500 – 500	6	1,100 – 5,000	5
00 – 299	17	600 – 699	4		
				Total	400

It is interesting to compare this with the investment in "Machinery and Equipment" reported in a 1942[10] study of the Returns From Dairy Farming in Massachusetts. The average for all farms in the study was $2051; with $2915 for the high income group, $1361 for the medium income group, and $1762 for the low income group.

Too hasty conclusions should not be made. No special provision is made for assessing equipment, and on dairy farms this item is a valuable one. Cooling tanks, milking machines, cans, etc., can absorb sizable sums.

Assessment experience with livestock is well illustrated by the valuation of cows. There was a great deal of variation in value per head, and some in method. For the most part, however, the differences were between, rather than within, towns. In a group of eighty-four towns, there were fifty-five that had the same method of uniform valuation applicable to herds (grade or mixed) in that town; twenty-nine towns had more than one value in each town with two of the twenty-nine having four values.

Values on cows in Grade or Mixed herds ranged from $40 to $200; with cows in 62 percent of the herds valued between $50 and $80 per head. The distribution on a herd basis is given in table 9. Cows in the few purebred herds in the sample were valued at or near $100 per head. The maximum premium in any town over grades was $50 and the minimum, $11.

[10] Returns from Dairy Farming in Massachusetts in 1942, C. R. Creek, F.M. 15, October 1943.

TABLE 9.—ASSESSORS' VALUATIONS ON DAIRY COWS ON MASSACHUSETTS FARMS. GRADES — 1944.

Valuation per Cow		Farms Number	Farms Percent		Cows Number	Cows Percent
$40		20	5.13		446	5.24
40+ but less than $50		13	3.33		206	2.42
50 but less than 60	62.05%	87	22.31	57.91%	1,639	19.27
60 but less than 70		82	21.02		1,708	20.08
70 but less than 80		73	18.72		1,578	18.56
80 but less than 90		35	8.97		916	10 77
90 but less than 100		13	3.33		514	6.04
100 but less than 110		56	14.36		1,312	15.43
110 but less than 120		3	.77		49	.58
120 but less than 130		6	1.54		102	1.20
140		1	.26		32	.38
200		1	.26		2	.024
Total		390			8,504	
Average valuation $71.48						

On the dairy farms, cattle in addition to cows were listed as follows:

Yearlings	Youngstock
Heifers	Beef
2-year olds	Meat
3-year olds	Steers
Other cattle	Bulls

There were several instances, 10 percent of the towns, in which cows were valued on a herd basis. It appears from the records that in all except three instances this was the result of "rounding-off" to the nearest even unit. In the three exceptions, the method apparently was one of looking the herd over; getting its size and setting a value on the herd as a unit.

The valuation of cows like land tries the objective capacity of the assessors. And for taxation purposes, perhaps "Cows is Cows" just as for literary purposes "Pigs is Pigs." However, when we consider the task and circumstances, it is surprising that there is not more rather than less variation. Cows may be Grades or Purebreds; on a given farm there may be both Grades and Purebreds—a not unusual sitation when a farmer is building up his herd; the market value of cows depends on two things—the local price of milk and the loca lprice of beef; and so far as milk prices are concerned, it is not the current price, but the expected price that is (or should be) effective. Under these conditions an approach to uniformity is quite an achievement.

Cattle appeared on the lists in all conceivable combinations; reflecting the variation in farms over the state. The principal classes, however, were yearlings, heifers, 2-year-olds, and bulls. In an area in which the dairy industry disposes of its output almost exclusively as fluid milk, it is not surprising that slightly over one-fourth of the farms (in the sample) had no young stock or other cattle of an assessable age. The proportion of farms on a herd maintenance basis was also slightly over one-fourth. And the proportion of farms that was either developing[11] a herd replacement program or going off[12] it accounted for about one-third.

The average valuation for yearlings in grade or mixed herds was $29.37 per head with a low of $10, a high of $100. Most of the valuations were clustered about $20, $25, and $30, although there were sizable numbers at $15, $35, $40

[11] Yearlings but no 2-year-olds.

[12] 2-year-olds but no yearlings.

TABLE 10.—VALUATIONS ON YEARLINGS, TWO-YEAR-OLDS, AND HEIFERS. GRADE OR MIXED HERDS — 1944.

Valuation per Head	Yearlings		Two-Year-Olds		Heifers	
	Number of Herds	Number of Heads	Number of Herds	Number of Heads	Number of Herds	Number of Heads
$10.00	7	16			3	11
13.33	1	3				
13.67	1	6				
14.29	1	7				
15.00	20	75	2	7	3	18
16.67	3	12			1	3
17.14					1	7
20.00	25	154	6	22	5	24
25.00	40	216	9	53	10	46
25.48					1	21
30.00	43	175	16	87	5	29
31.25	1	16				
33.33	1	3				
35.00	10	81	12	79	4	28
37.50	I	4				
40.00	16	130	29	103	7	41
45.00	2	9	6	20		
45.28			1	18		
46.67			1	3		
50.00	10	48	30	130	5	10
56.43	1	7				
60.00			4	25		
62.50	1	4				
64.28	1	7				
65.00			1	2		
70.00	1	1				
75.00	1	3			2	7
90.00			5	36		
100.00	2	4				
Total	189	981	122	585	47	245
Average Valuation:						
Per Head		$29.37		$42.03	$29.51	
Per Head (on a herd basis)		28.90		41.41	30.94	

and $50. The same pattern of assessing procedure is apparent; rounding off at 5-dollar intervals on valuation per head, with a few instances of lump sum valuation.

For two-year-olds, the average valuation per head was $42.03. Actual valuations varied from a low of $15 to a high of $90 with most of them at $30, $35, $40 or $50. More two-year-olds were valued at $50 than at any other amount, whereas for yearlings the most commonly used value was $25. Fewer valuations were used on two-year-olds than on yearlings, 13 compared with 22. But as with yearlings there were several valuations frequently used in addition to the modal group.

Valuation levels on heifers were not as numerous as on yearlings and two-year-olds. Nor was it as easy to identify a common figure that assessors used. Twenty-five dollars per head was more generally used than any other value. From $20 to $50 ($25 excepted) at five dollar intervals, the several values were used with about the same frequency.

The data suggest that the heifer category not only can but does cover the yearling and two-year span and even in the valuation of heifers this difference is observed. Some assessors will also be interested in noting that average valuation per head for animals classed as yearlings and as heifers is nearly identical, $29 plus.

Bull valuations showed many similarities to the valuation of other classes of livestock. Yet, there were differences. The top valuation on bulls was $500, whereas no cows in mixed or grade herds were valued at over $200. There were

Table 11.—Valuations on Bulls.

Valuation per Bull	Number of Farms	Number of Bulls	Valuation per Bull	Number of Farms	Number of Bulls
$0 – $49.99	53	77	$76 – $99.99	6	7
50	73	86	100	45	56
51 – 69.99	27	36	101	10	16
70	12	14			
75	30	32	Total	256	324

29 different valuations used for assessing bulls, but of these only five were generally applied (Table 11) and they accounted for valuations on 75 percent of all farms with listed bulls. Fifty dollars was the most common valuation; applied as it was to 73 or 28.8 percent of the animals.

Among the 388 herds with mixed or grade stock, 133 or 33 percent had no bulls listed and 48 or 12.4 percent had more than one. Except in three instances uniform valuations were set on all bulls on a given farm.

The valuation of a bull relative to that of the cows in a herd may be of more interest to livestock men than to assessors; especially to those who have been trying to foster better sire programs. Only 27 percent of the bulls were in herds in which the bulls were valued at more than the average valuation of cows in the herd. Thirty percent of the bulls carried the same valuation as the average of that for the cows; 43 percent had valuations below that of the cows in the herd. It is interesting to observe that in most of the instances where bull valuations were lower than the average for cows, the bulls were valued at $50 or below. Uniform valuation was most common in the $51-$75 bull valuation bracket. Above the $75 level, bull valuations equaled or exceeded that of cows except in three instances.

CONCLUSIONS

The tax system in one detail or another is seldom free from attention. Periodically individuals or groups make suggestions for its "improvement." Revision comes slowly, however, and it may be well that it does so long as inertia, stubbornness, or indifference are not mistaken for deliberateness.

The valuation record on the dairy farms in the current study indicates that there is still room for improvement. Within the limitations noted this is as it should be, particularly in a dynamic community. The tax system is an inherited device originally designed, but since altered and alterable, by men and should bear some relationship to the times and existent state of knowledge. No one should expect that the fit will be perfect. Characteristically a tax system will always be behind the times. It is a stable mechanism, moving seldom more than twice a year—at the time of annual appropriations, and when valuations are set—serving the business needs of the community. And these needs are no less subject to general economic conditions than are those of any other business.

Currently the objectives in valuation are not being approached. The difficulties and shortcomings of determining, let alone using market prices in a once-a-year appraisal are very real. Three hundred communities individually valuing property present a challenge to the rule of uniformity. The test of fairness, itself a matter of relativity and subject to personal bias, is difficult to apply.

Failure in attainment is to some extent the fault of the system. Well-qualified boards of assessors can overcome some of their handicaps but their effectiveness is restricted to their own towns. Supervisors from the Office of the Commissioner of Corporations and Taxation can bring only such aid as is possible within the structure of the system.

Currently the need is for greater objectivity; for standards that assessors generally can use in the valuation procedure. A new point of view may be a necessary prerequisite to this end. Evidence is abundant that for real property market value or sale value is inadequate. At some, perhaps, but at very little risk, it can be noted that *no* studies of Assessment have been made that show agreement between assessed value and market value. It might be clarifying to acknowledge that for assessment purposes real propetry has a particular value; a value which may be associated with market value but which is nonetheless distinct for taxing purposes.

Consideration of this viewpoint would ease the acceptance of a classification system for farm property; a device which would be an aid to objective assessment. Such a system could provide for standard valuations for all farm property of a given classification at least within towns. Some of the inequity between farms would be eliminated by this practice. As experience with the system increased, inequitable differences among similar classes of farms in different towns would tend to be corrected. It is inconceivable that we could standardize our concept of a farm without having it influence relative value.

The mechanics of a classification system for farm property are less easily stated than the general criterion which is "capability." As used here, capability refers to farm productivity and is an extension of the term as used by the Soil Conservation Service which applies it only to the land. For land, the classes as used by the Soil Conservation Service would be satisfactory; additional classes for buildings would have to be established; and a factor or factors developed for location differences within towns. The amount of detail involved is a variable but would depend to a large extent on the objectives set for classification.

The classification of land and buildings for economic purposes is not new. The New York State College of Agriculture at Cornell some years ago devised a set of economic classes[13] by which the relative value of farms in New York State could be generally identified. Other states and communities have had varying experiences.

A system of classification depends on an intimate knowledge of the potentialities of the farm and a willingness to establish and accept general standards. Until recently the unavailability and costs of technical skill have been a deterrent to large-scale classification. With the organization of the Soil Conservation Service, however, this handicap can be gradually removed. Fulfillment of its program depends on the accurate mapping and description of the soils on each farm. The Soil Conservation Service maps or maps of similar type might form an excellent beginning for a classification schedule.

Personal property presents some additional problems. Machinery and livestock may not seem to have as much in common as land and buildings, but these physical differences need not be too much of a handicap. The assessment of machinery and equipment might be improved by clarification as to the items to be covered. To this, if items like tractors and attachments are to be assessed, a rate schedule similar to that used for autos might be added.

Market value as a basis for assessment appears more adaptable to livestock and stocks on hand than to any other personalty. Even in this category the differences in valuation on cattle and poultry require attention. Cows in milk, growing yearlings, laying pullets have different values than dry cows or old hens. Purebreds presumably have different values than grades, and heavy producers

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[13] A. B. Lewis, N. Y. (Cornell) Agr. Expt. Sta. Memoir 160, 1934.

than light. The common denominator to which livestock other than horses and mules can be reduced is value on the butcher's block. This denominator might be utilized to advantage for the assessment of "meat" animals. The Commissioner of Corporations and Taxation might in November of each year announce the values to be used for meat animals during the succeeding assessing period. Such values could be determined from market reports prepared by the United States Department of Agriculture.

Inequalities in assessment are but part of the inequality in the tax system. They are, however, within the grasp of local taxpayers and officials. Steps towards understanding their extent and reducing their size could be taken if a will towards that end existed.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 449 SEPTEMBER 1948

Annual Report

For the Fiscal Year Ending June 30, 1948

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

UNIVERSITY OF MASSACHUSETTS

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1947-48

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

The Effect of Public Regulation of Milk Marketing Upon the Organization of the Milksheds of Massachusetts Markets. (A. A. Brown.) Eastern fluid-milk markets and Boston in particular again had to reach into the North Central States for supplies during the fall and winter of 1947–48. The emergency short season turned out to be the longest on record.

Transportation rates and services are a major element in establishing the cost of this milk to dealers. To the rail information on these items, an attempt was made to add similar data for trucks. Movement by truck has not been undertaken regularly between the areas studied. Some shipments have been made and rates quoted but the preferred method of transportation is via rail tank car.

Shipments made by truck to other areas have been handled on a contract carrier basis at a minimum charge per load for which a maximum volume was set; viz., Juneau, Wisconsin, to Atlanta, Georgia, $431.50 for a load not to exceed 35,000 pounds. The comparable rail structure was $1.18 per 10-gallon can with a minimum of 2500 gallons. Expressed in terms similar to the rail tariff, the cost by truck in this instance was $1.06 per 10-gallon unit.

The transportation phase of this study has been completed. It has become increasingly apparent with the sustained shortages of fluid milk in the fall months that public regulation involves more than State Milk Control Boards and their Federal counterparts. Public health agencies and emergency commissions, such as the war-induced WFA and OPA, need, where possible, to integrate their objectives with those of the group regularly responsible for public milk supplies.

A Study of Farm Real Estate Taxation, Methods of Taxation Reform, and the Effect of Such Measures on Farm Income. (A. A. Brown and Avery A. Arnold.) Unreasonable variations in the valuation of farm property are due primarily to the basis on which valuations are made. Market value for tax purposes is difficult to determine at any time, and in periods of rising or falling prices practically impossible. A revision in point of view appears necessary if the inequities due to subjective valuation are to be minimized.

Real property for taxing purposes has a specific value; a value which may but probably will not be identical with market value. If this premise is tenable, the development and utilization of a classified property tax system would be a big step towards less unexplained variation in valuations.

Personal property for taxing purposes may have valuations determined even more realistically. But again agreement on the validity of the basic premise is a prerequisite. Market values as now used are nominal. They assume the exchange of the personalty, generally livestock, for its continued use unchanged except for ownership. The shortcomings of such assumptions appear in the variations in valuations. A common denominator for livestock of various kinds is its salvage value. The butcher's block is the great leveler. Since valuations are established but once a year and since actual market values are published regularly, average meat values at primary markets—Boston, for example—during the month of November or December would be a more equitable value to apply.

For other personal property, especially machinery, a schedule of values could be devised similar in structure to that used for determining excise taxes on motor vehicles. Much machinery appears to be overlooked altogether, and one reason for this may be the difficulty of determining a reasonable value.

Marketing of Hatching Eggs. (A. A. Brown, B. E. Brown, and J. A. Ward.) Although not all the field schedules have been taken, some preliminary observations can be made.

The hatching-egg industry is made up of several components: broiler-hatching, flock replacement, foundation stock – R.O.P.

Under some conditions eggs from any mated pens go into broiler-hatching. Generally, however, buyers locally or in the principal outlet area—the Del-Mar-Va peninsula—determine the matings. The constant effort maintained by the broiler industry towards improving the product it sells adds to the hazard of specifying preferred matings. If producers of broiler-hatching eggs can anticipate these demands, their marketing problems become fewer. On a slow market, matings rather than price regulate the sale of broiler-hatching stock. Currently, stock of Barred Rock males mated with New Hampshire Red females is preferred by broiler-raisers. Since there is now some market for broiler-hatching eggs the year round, poultrymen with this stock are in a favorable position marketwise.

Seasonally the broiler-raising industry offers some opportunities to other Massachusetts flock owners who choose to take the risks involved. During late winter and in the spring when hatchings are being made here for replacement stock, the broiler territory is often an outlet for cockerels. During the summer and early fall the demands for hatching eggs are such that heavy fowl matings other than the Rock-Hampshire cross more readily. Both of these operations involve a large element of uncertainty. Since both operations are supplementary to the production of replacement stock, the possibility of large gains has outweighed the possibility of smaller losses in recent years.

Marketing of Massachusetts Potatoes. (R. A. Fitzpatrick, A. A. Brown, A. A. Arnold and A. C. Chatel.) Preliminary work incidental to providing adequate data on supply has been completed. The make-up of the industry, the acreage grown, and the varieties planted, underwent pronounced shifts during the war years.

Many small growers came into the industry or under the support price program became identifiable. The number of potato growers increased from 10,545 to 15,313 between 1939 and 1944. The number of small growers in 1945 was 14,000. Most of the increase in number appeared in this group.

Plantings increased 7,000 acres, nearly 50 percent, between these census years. Between 1942 and 1943 commercial acreage as measured by P & MA data increased about 3,000. In subsequent years some further addition was made so that by 1944 commercial acreage had increased by 4,000 out of a total shift of 7,000.

The noticeable increase in Katahdin acreage between 1939 and 1946 was at the expense of both Cobbler and Green Mountains, although Green Mountain acreage leveled off after 1944. Acreage of Chippewa, another newcomer during the thirties, was also greater than that of Cobblers by 1945 and has held there.

Storage information is not yet complete; however, it appears that few Massachusetts growers have permanent facilities for late holding.

Fluid Milk Prices in Major Northeastern Markets. (A. A. Brown, B. E. Brown and A. C. Chatel.) Work under this project has followed two lines, both of which should lead to a better approach to pricing in markets drawing milk from a common shed. Sales, supply, and producers' price data for the Worcester and Springfield markets have been brought up to date. In fulfillment of cooperative arrangements with the New England Research Council, milk-sales data were developed on a daily basis for the flush and short seasons in 1944 in the Northeastern States. Information on the rail movement of milk and cream from various common points in the shed into the New York and Boston markets was also made available. This material supplemented that provided by the Rhode Island and Connecticut stations.

Partial analysis of the data has been made along with tentative allocation of milk and cream sheds among the various markets.

Philadelphia's low price with the substantial differences at major markets to the North and South of it is one of the potentially more significant findings. The assumption had been that New York City was or would be the base market.

Of additional interest will be the closeness with which the theoretically determined short-season milk and cream supply areas approximate the historical relationship for Boston and New York.

DEPARTMENT OF AGRICULTURAL ENGINEERING

H. N. Stapleton in Charge

Forage Handling Investigations. (H. N. Stapleton.)

Barn Hay Drying. The application of high-volume fans supplying unheated air for mow drying has been made for the purpose of improving the efficiency of the barn drier. Since farm electric lines usually limit the size of electric motors to 5 or 7½ HP a fan selection which increases air volume per horsepower permits greater drying capacity with this limited power.

By pretesting large-diameter 2-blade propeller fans in a blast-gate tunnel, a tentative selection of satisfactory sizes for 3 HP and 5 HP motors has been made. Wind tunnel work also showed that, without the standard 1-diameter length of discharge tube permitted by the manufacturer's test code for determining fan ratings, a standard fan will not deliver the air volume of which it is capable when the tube is applied. The use of additional mounting rings from larger diameter fans to bell-flare the inlet was significant in improving the performance of the fan except near free delivery and near blockoff. The bell-flare also decreased significantly the noise level of these fans. No significant advantage could be found from the use of a ¼-diameter torpedo hub mounted in the discharge tube.

The application of 5 HP on a 2-blade 54″ propeller fan with 60″ ring and 1-diameter length discharge tube added proved satisfactory in one of the barn mows on the University Farm. Serving a 34′ x 72′ mow through a centrally located main duct, slatted its entire length, a maximum static pressure of 7/16″ water column was developed. The calculated delivery of the fan was 35,000 cfm or more throughout the drying period. The calculated water load placed at one time and to be removed by the forced air was 15,300 pounds. Satisfactory drying conditions were obtained.

The use of 3 HP on a 2-blade 40″ propeller fan with 44″ and 48″ rings added, but without a discharge tube, on an air scoop for drying baled hay permitted the drying of bales on a mow floor without the use of a previously constructed air distribution system. Bale width tunnels, two bales in height, leading from the air scoop through the length of the pile of bales permitted air escape both between and through the bales with heights up to eight tiers. Satisfactory drying was obtained with calculated water loadings up to 8000 pounds. Static pressure developed within the air scoop at no time exceeded 3/8″ and the calculated delivery of the fan was never less than 22,000 cfm.

Satisfactory drying is considered to be obtained when there is no mold development and when during and after the drying operation the hay emits an aroma rather than an odor. It is considered that the practical limit of water loading for these fans has been reached, as the time required to reduce the moisture content of the hay to 25 percent with these loadings has been 4 days.

Warm Room Brooding. (H. N. Stapleton.) The use of a hover-convector shield with a wall-mounted pipe panel has indicated that with restricted ventilation the temperature gradient across the floor of a narrow room can be made quite uniform. With this equipment, crowding to 0.3 square foot per chick, with two different ages in the room, was possible under warm room conditions. The warm room, together with the crowding, was considered to give a slower rate of both growth and feathering than was obtained with the same stock under other brooding conditions.

DEPARTMENT OF AGRONOMY

Dale H. Sieling in Charge

The Fixation of Phosphate by Iron and Aluminum and Its Replacement by Organic and Inorganic Ions. (Dale H. Sieling, Richard M. Swenson, and C. Vernon Cole.) It has been observed that hydrous oxides of iron and aluminum and solutions of iron and aluminum salts will fix phosphate by chemically combining with the phosphate at low pH values. The compounds formed were shown to be the hydrated basic phosphates of iron and aluminum represented by the formulas: $Fe(H_2O)_3\ (OH)_2\ H_2PO_4$ and $Al(H_2O)_3\ (OH)_2H_2\ PO_4$. The conclusion that the compounds were basic phosphates rather than normal phosphates was based on the observation that for each iron or aluminum ion one phosphate and two hydroxyls were required for complete precipitation. If the normal phosphate were formed, one phosphate and no hydroxyl would be required to completely precipitate each iron or aluminum ion.

The amount of phosphate which would combine chemically with one iron or aluminum ion increased as the phosphate increased up to a value where one phosphate was combined with one iron or one aluminum ion. In no instance was the ratio of phosphate to iron or aluminum in the precipitated compound greater than unity even when the amount of phosphate present was nine times that of the iron or aluminum.

Arsenate reacted with aluminum in the same manner as phosphate but was found to be about one-fifth as effective in replacing chemically combined phosphate as was phosphate in replacing chemically combined arsenate. Fluoride reacted with aluminum in the same manner as phosphate and arsenate and, when in large excess, the fluoride caused the formation of the soluble hexa-fluo-aluminate ion. Fluoride was effective in replacing chemically combined phosphate and arsenate. The effectiveness increased progressively as the concentration increased until it was complete when the ratio of fluoride to aluminum reached six.

Organic anions were effective in replacing phosphate which had been chemically combined with iron or aluminum. Citrates, gallates, iso-ascorbates, tartrates, and mucates were particularly effective; while gluconates, hydroxybenzoates, and salicylates were less effective, and amino acids were not effective at all. Only those anions possessing the property of forming stable complexes with the iron or aluminum were effective in replacing the phosphate with which these metal ions were chemically combined.

Purified lignin and humus replaced chemically combined phosphate from basic iron phosphate. An increase in hydroxyl concentration also was effective in replacing chemically combined phosphate; however, its effectiveness was less than that of some of the organic anions.

Practical applications of the findings are suggested as follows:

1. An increase in the actively decomposing organic matter and in the pH value of an acid soil would result in the release of fixed phosphate and aid in preventing further phosphate fixation.

2. Soluble fluorides might be employed to release fixed phosphates. This would be practical in those areas where fluorides are known to be deficient in soils and water supplies. This fluoride deficiency has been shown to be related to a nutritional deficiency in both man and animals which results in the development of poor tooth and bone structure. The use of fluoride would then have the two-fold effect of releasing chemically combined phosphate and increasing the fluoride content of the crops and the water supplies.

3. Many soils are made unusable for shallow-rooted crops because of the use of excessive quantities of arsenates to control insect pests. In these cases arsenates are fixed in the topsoil in large quantities. To remove the arsenate from the topsoil and to cause its transfer into the subsoil, one could treat the topsoil with phosphates, fluorides, lime, or organic matter, or combinations of these materials. Shallow-rooted crops could then be grown on the reclaimed soils after appropriate fertilization.

The Absorption of Chemical Elements by Food Plants. (Walter S. Eisenmenger and Karol J. Kucinski in cooperation with C. Tyson Smith, Feed and Fertilizer Control Laboratory.) The object of this project is to determine the factors which influence the intake of elements in plants. The relative intake by plants of calcium, magnesium, potassium, and sodium was studied when applied singly and in pairs. Sulfates, phosphates, chlorides, bromides, and iodides were also determined in tissues of plants grown on soils treated with these anions.

Analysis of seedlings grown in the greenhouse showed that the addition of copper lowered the movement of magnesium from the nutrient medium and the seed to the aerial portion of the plant. When copper was applied to soil in field plots, the magnesium intake by plants was not lowered. However, when copper and calcium were applied together in the field plots, the amount of calcium absorbed by the plants was appreciably higher than where the same amount of copper and calcium was applied singly.

In another phase of this study, where sodium fluoride was applied to the soil, the fluorine content of the plants increased proportionately with the increasing rate of sodium fluoride applications to the soil.

The Relationship of Plant Development to the Capacity to Utilize Potassium of Orthoclase Feldspar. (Walter S. Eisenmenger and Cornelius C. Lewis.) Twenty-two seed plants of varying degrees of development were grown in soil in three series. To one series no potassium was added; to another, potassium chloride; to the third, feldspar in quantity equivalent in potassium content to the second series. At maturity the potassium content of the plants was determined by chemical analysis, and percentage gains in all series were computed.

The percentage gain of potassium from both soluble and insoluble sources tended to decrease as the plants ascend from the lower to the higher order of development.

In the control medium, plants of the lower orders showed deficiency symptoms earlier than those of the higher orders.

The lower developed plants, such as larkspur, rape, poppy, lespedeza, velvet leaf, and geranium, absorbed a larger quantity of potassium from the orthoclase feldspar than did the more highly developed plants such as lettuce, sunflowers, sage, and spinach. With few exceptions, the lower the plant in its development, the more easily it secured potassium from relatively insoluble sources.

Magnesium Requirements of Certain Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) The need of plants for magnesium to maintain normal physiological processes is not easily determined because the amounts of the element required by different species are not the same. The magnesium requirement is higher for garden crops than for such crops as wheat, rye, or oats. Some of the hybrid varieties of corn are seemingly unable to secure sufficient magnesium from magnesium-deficient soils where open-pollinated corn may grow normally. With the exception of a few botanical families, the more highly developed plants do not show magnesium deficiency symptoms to the same degree as do the lower orders of plants. This may mean either that the lower orders of seed plants need more magnesium or that they are more sensitive to abnormal conditions.

The pH of a soil influences the degree of magnesium deficiency. On a soil which was magnesium-deficient and which had a pH of 6.8, there was less chlorosis and growth was less retarded than on a magnesium-deficient soil where the pH was 4.5. This is probably due to the more rapid washing out of the magnesium ions from the weathering rock particles under lower pH conditions. Magnesium-deficiency symptoms are not usually present where the soil has a high pH value or high organic matter content. It has been observed that magnesium deficiency in plants is associated with soils having a low base exchange capacity.

When magnesium salts are applied to a soil where annuals are grown, an increase in the magnesium content of the plant tissue is found. This is not true for all perennials. Certain species of perennials, as they grow older, seem to lose their capacity to increase their magnesium content.

Magnesium Deficiency Investigations. (W. S. Eisenmenger and Dale A. Hinkle.) Analyses of leaves from 18 different species of plants which were grown on magnesium-deficient and magnesium-treated plots showed that a deficiency of magnesium in the soil greatly reduced not only the chlorophyll content of leaves but also the xanthophyll and carotene content. Coefficients of correlation between the losses of any two of the three pigments were high and positive. When the chlorophyll content was used as a criterion of magnesium deficiency, it appeared that, for the most part, those plants low in the scale of evolutionary development suffered more from magnesium deficiency than plants higher up in the scale.

A greenhouse study was made to determine the effects of the cations in the alkali group of the periodic table upon the absorption of magnesium by tomatoes. Lithium at the rate of 30 parts per million proved toxic when applied to Merrimac sandy loam. The addition of 300 parts per million of potassium, 125 parts per million of rubidium, or an equal amount of cesium had no effect on the amount of magnesium absorbed, or on the degree of chlorosis of the lower leaves as compared with a check treatment in which nothing was added. However, all these treatments, as well as the check treatment, resulted in significantly less magnesium absorption and less pigment production than a treatment in which magnesium was added. Sodium at the rate of 300 parts per million overcame magnesium deficiency to some degree as was shown by the absence of chlorosis of the leaves and a slightly higher uptake of magnesium.

Magnesium sulfate applied around apple trees at the rate of 5, 15, and 25 pounds per tree failed to increase the magnesium content of the leaves.

Yields were recorded for nine vegetable and berry crops grown on plots which were known to be deficient in magnesium. One plot was treated with magnesium alone; a second with magnesium and lime; a third with lime alone; and a fourth received neither magnesium nor lime. All plots received 1 ton per acre of 5-8-7 fertilizer especially prepared to contain no magnesium. Blueberries yielded highest where neither lime nor magnesium was added; tomatoes and eggplant, where magnesium alone was added; beets and cabbage, where magnesium and lime were added; and raspberries, peppers, string beans, and carrots, where lime alone was added.

The results of the studies on vegetables indicate the importance of magnesium in vegetable fertilizers, since a high carotene content is desirable from a nutritional standpoint.

Tobacco Quantity and Quality Following Early Fall Application of Nitrogen Fertilizer. (Walter S. Eisenmenger and Karol J. Kucinski.) When tobacco is grown following such crops as corn, clovers, and grasses, which are high in lignin, symptoms of brown rootrot are more likely to occur. Micro-organisms instrumental in decomposing tissues containing much lignin need an abundance of nitrogen and consequently rob the tobacco plant temporarily of this element. Nitrate of soda at the rate of 0, 50, 100, 200, 300, and 500 pounds of nitrogen per acre was applied to some hay plots in the early fall and to others in the spring before the plots were plowed. In nearly all cases, these treatments resulted in increased yields and improved quality of the tobacco grown on these plots; however, the higher rates of 300 and 500 pounds of nitrogen did not greatly increase the yield over the lower rate of 200 pounds. Those plots plowed in the early fall showed a greater response to nitrogen than those similarly treated but plowed in the spring. The micro-organisms apparently need the warmth of the early fall to act more fully on the plant tissues plowed under.

In a similar experiment where corn was plowed under, the yield and quality of the succeeding crop of tobacco was best where the corn was plowed under in the early fall.

Chloropicrin for Tobacco Seedbed Sterilization. (C. V. Kightlinger.) Chloropicrin has been used extensively by Massachusetts tobacco growers during the last few years to sterilize tobacco seedbeds and, in general, it has been satisfactory. However, in 1947, some seedbeds which had been sterilized with chloropicrin in the fall of 1946 were almost total failures. Some growers attributed these failures to the presence of residual chloropicrin which had not evaporated because of the low soil temperature which followed its application. Many growers are now afraid to use chloropicrin for soil sterilization and, owing to the general unavailability of steam sterilization, they have no satisfactory substitute.

The object of this experiment was to determine whether late fall sterilization of tobacco seedbed soil with chloropicrin would cause poor germination and growth of tobacco seeded the following spring. Other factors affecting the production of tobacco seedlings were also studied.

Four seedbed plots, 30 feet long and 6 feet wide, each received 25 pounds of a 8-4-8 tobacco fertilizer: two in late October, 1947, and two shortly before seeding time in the spring of 1948. One of each pair of plots was sterilized with chloropicrin in late October, 1947; the other two were not sterilized. The soil temperature of the plots was about 50° F. at the time of treatment with chloropicrin and remained low for the rest of the fall. The observed results were as follows:

Plot I. *Fall Fertilized and Sterilized.* The germination of seed was very good; the seedlings grew well and weed control was good. The productivity as well as the weed control in this plot was equal to that obtained in another seedbed which had been sterilized with chloropicrin and fertilized early in September. At that time the temperature of the soil was well above 60° F. and remained so for a considerable time.

Plot II. *Fall Fertilized but Not Sterilized.* The stand and growth of seedlings were good but not so good as on Plot I. The weed infestation was heavy.

Plot III. *Fall Sterilized and Spring Fertilized.* The stand of seedlings was very poor with no plants at all occurring in large areas. The seedlings grew poorly throughout the season. The weed control was good but less effective than on Plot I. Possibly the poor stand of tobacco seedlings offered less competition to those weeds which survived the sterilization, and thus the weeds grew more vigorously.

Plot IV. *Spring Fertilized but Not Sterilized.* The stand of tobacco seedlings and their subsequent growth was poor throughout the season. Weed infestation was heavy but somewhat less than on Plot II.

The general conclusions and practical applications of these observations are: Chloropicrin, although applied late in the season, was apparently not the cause of the seedbed failure in this trial. The failure of the seedbed was attributed to effects of the spring application of the fertilizer. It is believed that tobacco seedbeds should be fertilized in the fall or at least a considerable time before the seeding if the fertilizer is applied in the spring.

Fertilizer Placement for Potatoes. (C. V. Kightlinger and H. M. Yegian.) It is the purpose of this project to determine how different ways of applying fertilizer affect the growth and yield of potatoes.

Fertilizer of 5-10-10 formula was used at the rate of 2200 pounds per acre and was applied in three ways: all banded; half banded and half broadcast; and all broadcast. The broadcast fertilizer was harrowed into the soil thoroughly before the potatoes were planted. The banded fertilizer was applied in the usual manner by the potato planter.

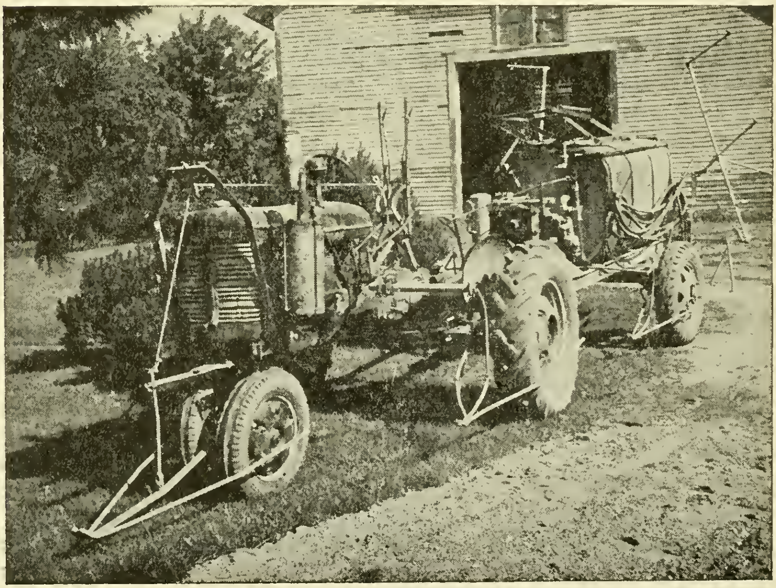
The plots were one-twelfth acre in size and were replicated four times. Green Mountain potatoes were planted about the middle of May and were sprayed with Bordeaux mixture at weekly intervals from the middle of June until frost killed the vines in late September, with DDT and nicotine used as needed to control insects.

Plots where the fertilizer was all banded produced much better growth of vines and much larger yields of potatoes: 23 percent more marketable potatoes than the plots on which the fertilizer was half banded and half broadcast, and 51 percent more than the plots on which the fertilizer was all broadcast. Also, considerably fewer B grade and cull potatoes were obtained from the plots on which the fertilizer was applied all banded than from the other plots.

Potato Vine Lifters. (Karol J. Kucinski.) When potato vines become large enough to cover the space between the rows, the moving of spraying equipment through the field crushes the vines, thus causing a decrease in yield. An improved vine lifter has been developed which will pick up the vines from the space between the rows and push them back into the rows. This allows the passage of the wheels of both the tractor and the sprayer without injury to the plants.

The lifters were patterned after those developed by John W. Slosser, Engineer, Research Division of the Soil Conservation Service, in cooperation with the Maine Agricultural Experiment Station. Certain modifications of the basic design were made to improve the operation and utility of the lifters.

Each lifter is attached to its control by means of a clevis and pin coupler to make its removal from the tractor easy. The vine lifters for the tractor rear wheels are suspended from the arms which usually carry the cultivators and can be operated hydraulically. The vine lifter for the front tricycle wheel is suspended by a small rope attached to the hanger rod of the lifter and through a pulley to the hand-lever used in connection with the cultivator. The two lifters for the wheels of the sprayer are suspended from an arm attached to the sprayer frame and the hand-lever is used to adjust the lifters and can be operated from the driver's seat. The lifters are made of ¾″ steel rod and the hanger arms from 5/8″ steel rod. The lifters for the tractor would be designed as required for each make and model. The accompanying illustration shows the vine lifters attached to the sprayer and the tractor.



Simple-to-Make Potato Vine Lifter Attached to Tractor and Spray Rig.

Tests of Spray Materials for the Control of Late Blight of Potatoes. (C. V. Kightlinger and H. M. Yegian.) It is the object of this investigation to compare the effectiveness of some of the newer fungicides with the standard Bordeaux mixture for controlling late blight of potatoes, and to determine the effect of these materials on vine growth and production.

In 1947 the investigation was confined to the use of Bordeaux mixture, neutral copper (COCS), Dithane 14, and Dithane 278. Test plots of one-thirtieth acre were established for each kind of fungicide and for one check treatment where no fungicide was used. The plots were all replicated four times and were randomized. Green Mountain potatoes were used as the test crop and were sprayed with recommended rates of fungicide at weekly intervals from mid-June until frost killed the vines in late September. Insects were controlled as needed with sprays containing DDT and nicotine.

Late blight occurred too lightly in 1947 to make the results conclusive; however, the more evident observations can be summarized as follows:

1. Bordeaux mixture was the most effective of the fungicides tested for controlling late blight, but it caused a noticeable depression in the growth of the plants.
2. Neutral copper, Dithane 14, and Dithane 278 were about equally effective in controlling late blight, but were less efficient than the Bordeaux mixture. These materials did not depress the growth of the vines significantly.
3. With all of these fungicides, spraying at weekly intervals was not sufficient to completely control the blight during the time the plants were growing the fastest.

Potato Variety Trials. (Karol J. Kucinski and Ralph W. Donaldson.) Eight potato varieties commonly grown in this region have been tested annually with respect to their yielding qualities. Based on 10 to 14 year averages, the varieties rank themselves in the following order: Green Mountain, 436 bushels; Chippewa, 368; Russet Rural, 364; Houma, 342; Warba, 336; Irish Cobbler, 308; and Sebago, 305 bushels.

Soil Conservation Research Projects. In cooperation with the Research Division of the Soil Conservation Service, United States Department of Agriculture. (Karol J. Kucinski, Project Supervisor.)

A Survey of Erosion Problems Arising from Changes in Soil Use. The commercial growing of potatoes in the western foothills and plateaus of Massachusetts has become well established during the past few years. Old sod and pasture lands which have not been plowed for as many as thirty years are now being cleared and put into potato production. Since the potato fields are rather large areas located on sloping hillsides, where the season does not permit the use of winter cover crops, considerable soil erosion has taken place. Periodic analysis of the soil taken from selected areas shows that in nearly all cases the organic matter content has decreased more than 50 percent from what it was five or six years ago. The farmers realize that their soils are deteriorating rapidly, and are calling on the Soil Conservation Service "Operations" for technical aid in solving their problems of erosion and soil depletion. Contour planting, terracing, and rotation with green manure crops are the control measures recommended.

Studies to Determine the Effects of Loss of Top Soil on Crop Yields. In order to illustrate the value of top soil and organic matter, a field experiment was initiated, in which the top soil (to plow depth) was totally removed from a plot while an adjacent plot was left undisturbed as a check plot. Spring wheat, white sweet clover, winter rye, and buckwheat were grown on fertilized and unfertilized portions of these two areas. The decrease in yield due to top-soil removal ranged from 63 to 81 percent for the fertilized areas and from 91 percent to complete crop failure for the unfertilized areas.

The Investigation of Beach Grass. The native or American beach grass (*Ammophila breviligulata*) found commonly on Cape Cod has been used successfully in the stabilization of beach areas and coastal sand dunes. A heavy type of transplanting machine which has been developed recently is capable of planting about six acres a day. The use of this machine has made it economically feasible to transplant beach grass and has created a demand for large quantities of transplanting stock. There are some indications that fertilization of natural beach grass will tend to increase the stands and thus provide more and better propagating stock per given area.

Studies are in progress to determine what response beach grass will make to fertilization and liming, in the natural state and after it has been transplanted.

Investigations with Various Winter Cover Crops for Onion and Potato Fields in the Connecticut River Valley. The date and rate of seeding and kind of cover crop used depend somewhat on the preceding and succeeding crop. For several years such crops as winter rye, barley, oats, buckwheat, domestic rye grass, and Italian rye grass have been seeded at weekly intervals from the beginning of September through the last week in November. Winter rye, oats, and barley produced excellent cover when they were sown in September and early October; fair to medium cover when seeded from middle to late October; and poor cover when seeded during November, especially during the last week of November, when growth was considered unsatisfactory. Not very much stooling resulted when these crops were seeded after the middle of October. Italian or domestic rye grass and buckwheat do well when seeded in early September. Rye grass, when planted early, produced a thick mass of fine roots, which may be superior to the coarse roots of the cereal plants for the prevention of water erosion. Some rye grass may survive mild winters, and this should be taken into consideration if seedings are made in fields to be used for certain crops like onions where it is not the custom to plow in the spring. Barley and oats, which winterkill yet produce a desirable protective mat cover, may be used in onions and other small-vegetable fields. The mat thus produced can be easily disked and will not interfere with the preparation of the field in the early spring. Buckwheat can be used as a green manure crop, catch crop, or cover crop, but is not satisfactory as a winter cover crop. It is killed by the first light frost, and the mat produced on the soil surface is not a sufficient protection against erosion.

The rate of seeding for oats, winter rye, and barley is 1½ to 2 bushels per acre, and the larger rate should be used if seeding is made during October. For Italian or domestic rye grass, when used as cover crops, 25 pounds per acre has been found to be a desirable rate of seeding, and for buckwheat about 35 to 40 pounds.

Use of Snow Fencing in Controlling Wind Erosion. Farmers in the Connecticut Valley have the problem of protecting their soils and crops from wind damage. The winds which occur during early spring result in losses of soil, seed, fertilizer, and young crops. This damage usually occurs at particular areas on a farm, called "blowouts." To control these local "blowout" spots temporarily until the crop has established itself, some form of windbreak may be used. Trials have shown that snow fencing is satisfactory for this purpose. The cumbersome guy-wires generally used in connection with the fencing for protection against snow drifting are not necessary when the fencing is used for wind erosion control. Old iron pipes or wooden stakes 4½ to 5 feet long, driven 18 inches into the ground and spaced a rod apart, will hold the 4-foot-high lath fencing throughout the entire season. If the fencing is placed on the windward edge of the "blowout" at right angles to the prevailing winds and the crop rows are placed parallel to the fencing, very little loss of tillable area or inconvenience in operation of farm machinery will be experienced. One fence row is usually sufficient to control "blowouts" of the size commonly found in this section.

Breeding Work with Orchard Grass. (W. G. Colby.) This project was described in the Annual Report for 1945 (Mass. Agr. Expt. Sta. Bul. 428, p. 13). The orchard grass strain, Finnish Late Hay, has continued to give good results when grown with alfalfa or Ladino clover. The strain has received some criticism for lack of vigor. However, for growing with Ladino clover, less vigorous strains are desirable because they do not crowd out the clover two or three years after seeding; for use with alfalfa the competitive factor is not so important.

Breeding work has been progressing in an effort to select vigorous late-maturing plants, and several such plants have been isolated during the past year. Whereas commercial orchard grass reached the bloom stage by June 12, several of these late-maturing selections did not reach bloom stage until June 28. Most of the late-maturing orchard grass strains are susceptible to winter injury, especially in the seedling stage. Finnish Late Hay is as hardy as most commercial strains. Attempts to test the winter hardiness of these late-maturing selections failed last year because of the heavy ground cover of snow throughout most of the winter.

Red Clover Variety Trials. (W. G. Colby.) Seed for the varieties included in these trials was supplied by the U. S. D. A. Bureau of Plant Industry. Following are the varieties tested in 1947: Midland, Dollard, Ottawa, Wisconsin Mildew Resistant, Cumberland, Southern Selection, Kentucky Selection, and New Hampshire Perennial. The three southern anthracnose-resistant strains, Cumberland, Southern Selection, and Kentucky Selection, have proved to be winter hardy and have given just as good if not better performance than the best northern strains. Kentucky Selection and Southern Selection in particular were outstanding. Plots seeded in the spring of 1946 still had a 20 percent stand by the spring of 1948. Comparable plots of Midland clover, a recommended northern strain, had less than a 5 percent stand. Results thus far indicate that seed companies supplying seed of some of the anthracnose-resistant strains to southern clover-growing sections could, when seed supplies are adequate, use seed of these same varieties for northern red clover-growing sections.

Trials with New Oat Varieties. (W. G. Colby.) Heavy summer thunder showers caused serious lodging with all varieties included in the oat variety test carried on in cooperation with the U. S. D. A. Division of Cereal Crops. Three varieties, Ajax, Clinton, and Mohawk, although seriously lodged, nevertheless gave good yields of fair quality grain. Ajax and Clinton have been grown for several years and both varieties have been outstanding for their resistance to lodging and have also ranked high in grain yields. Mohawk was grown for the first time in 1946. Although not among the highest-yielding varieties in 1946, its stiff straw was an outstanding characteristic.

Trials with Alfalfa Strains and Selections. (W. G. Colby.) In the spring of 1946 an alfalfa nursery was planted which included some 60 selections and varieties of alfalfa. Standard varieties such as Kansas Common, Oklahoma Common, and Baltic, and newer varieties such as Buffalo, Ranger, and Atlantic were all grown with some 50 clonal selections from Nebraska and Kansas. Few differences have been noted in the performance of these strains. Several of the newer strains are resistant to the bacterial wilt disease but since there has been no evidence of this disease up to the present, the resistant varieties have been no better than any of the other varieties and selections. It is questionable whether a farmer in Massachusetts is justified in paying premium prices for seed of wilt-resistant varieties of alfalfa like Ranger or Buffalo unless he knows that this disease is a serious problem on his farm.

Onion Breeding. (Hrant M. Yegian.) The tendency to produce doubles is found in all varieties of set type onions, *Allium cepa* L. The size of the set and the environmental factors are considered to play an important part in the appearance of this undesirable character. Sets over three-quarters or one inch in diameter are more likely to produce double bulbs during favorable growing seasons than the sets under three-quarters of an inch. Some variations, however, occur in the double bulb frequencies in sets of different varieties but of the same size. This would suggest that inherent differences in susceptibility to produce doubles exist in the several varieties.

In an endeavor to obtain a further understanding of the causes of doubles in set onions, various local Ebenezer varieties were selfed and selected. In one instance a double set attached together at the base was produced from the selfed seed of one of the selections. Cases of double sets from a single seed are rare. This newly found case strongly suggests that the character of doubles in onions is probably of a genetic nature.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald.) The element nickel has been studied during the past year. Procedure has been the same as that outlined for other elements in earlier reports. Eight cows were used for the study (two each of the Ayrshire, Holstein, Guernsey, and milking Shorthorn breeds); the supplement, nickel(ous) chloride, was fed at the rate of 500 milligrams (approximately 125 milligrams of elemental nickel) per cow daily. Much of the time spent on the project was devoted to perfecting a method which would detect minute traces of the element (of the order of five parts per billion or less).

The analytical work on the season's milk samples has been completed; although the trend was toward an increased amount of nickel in the milk when the cows received the supplement, the results were not uniform and not statistically significant. This is believed to be due to imperfections of method; it is therefore planned to make further study of methods and technique and to repeat the trials next year.

A Study of Quality in Roughage: Composition, Palatability, and Nutritive Value of Hays as Affected by Curing, Harvesting, and Storing Procedures. (J. G. Archibald, M. L. Blaisdell, and H. N. Stapleton.) Twelve lots of hay have been studied, involving the analysis of 50 samples. Nine of these lots were from the College Farm; three from cooperating farmers. In addition to regular fodder analysis, sugar and carotene were determined in all samples. The chemical changes which take place in the hay from cutting time to feeding time (often 3 to 6 months) were followed closely for all lots of hay from the College Farm and for one lot from a farmer cooperator. Factors studied were exposure to prolonged sunlight; exposure to rain; field curing and storing as loose hay; field curing and storing as baled hay; barn drying of loose hay; and barn drying of baled hay. One feeding trial with two milking cows was conducted over a four-month period.

Action of either bright sunlight or rain for two days reduced carotene content of field-cured hay at loading time to about a third of its initial value. Sunlight, although it caused some lowering of the sugar content, had a much less adverse effect on sugar than on carotene.

Barn drying of either loose or baled hay may have possessed some initial advantage over field curing in conservation of carotene; but by the time the hay had been in storage several weeks, this advantage had largely disappeared, owing apparently to adverse storage conditions (high mow temperatures). This was also true to a lesser extent for sugar. Sugar content of some lots of hay was markedly reduced in storage, regardless of method of curing; this is thought to be due to the fact that the hay was stored too wet and/or to trouble with blower installations.

The advantages of baling and barn drying may be entirely offset by attempting to barn-dry either baled or loose hay at too high moisture levels. Tentatively 40 to 45 percent of moisture is suggested as the upper limit for safe storage over a barn dryer.

From the standpoint of carotene and sugar conservation, present methods of curing and storing hay need further study. There is some evidence to show that where a blower is operated efficiently, sugar is quite well conserved; but if farmers are interested in saving as much carotene as possible, good silage seems to be the answer in the present state of our knowledge.

The feeding trial was conducted with hay in which the sugar content had been greatly reduced (from around 6 percent to about 2 percent) by adverse curing conditions. When this hay was supplemented with sufficient crude glucose syrup to bring the total sugar intake back to normal, the cows produced 1.1 pounds more milk (4%—F.C.M.) daily than when the supplemental sugar was withheld. Shrinkage in milk flow from month to month was 1.6 percent when the syrup was fed and 7.8 percent when it was withheld. Whether this favorable result was a specific effect of the added sugar, or whether it simply represented a response to increased intake of total digestible nutrients is not known. Further light on the question will be sought this coming season by using a larger number of cows in a comparison of two kinds of hay, similar in character, except that one will have normal sugar content, while the other will be designedly low in sugar.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Survival of Escherichia coli from Sewage in Soil of a Septic Tank Disposal Field. (James E. Fuller.) This study was prompted by the failure to recover *Escherichia coli* from the soil of the disposal fields of an experimental septic tank installation (Mass. Expt. Sta. Bul. 441, p. 17, 1947). In the present project pure cultures of *E. coli* are being inoculated into soils, both sterilized and nonsterilized, and their survival in the soils is determined by accepted cultural procedures. The work is still in a preliminary stage, but results indicate that the organism survives for only a few weeks under optimum conditions of moisture and temperature. The results of the study reported in Bul. 441, and of an earlier one (Study of septic tank efficiency, Mass. Expt. Sta. Bul. 436, p. 17, 1946), have been published as a Station bulletin (Mass. Expt. Sta. Bul. 446).

Bacteriological Study of Sewage Sludge. (James E. Fuller.) Previous experience in this laboratory had shown that *Escherichia coli* from sewage disappears in a comparatively short time when sludge from a sewage disposal plant is put onto a sand filter bed. The present study was undertaken to determine the reasons for this disappearance and thus to provide some basic information concerning the physiology of *E. coli* and its relation to its environment. The results will be correlated with those obtained from the study of the soils of septic tank disposal fields.

To date two possible causes have been considered that might be responsible for the disappearance of *E. coli* from sludge. The first was the presence of some antagonistic biological factor such as bacteriophage or antibiotic substances produced by associated microorganisms in sludge. Results failed to indicate any such factor. The other possibility was that other microorganisms might offer competition, especially for nutriment, with which *E. coli* cannot compete successfully in sludge. *E. coli* is a normal inhabitant of the human intestine where it has optimum temperature and easily utilizable simple organic sources of carbon and nitrogen. When sludge was placed on a sand filter in the laboratory and held at room temperature, *E. coli* disappeared after 14 days, while *Aerobacter aerogenes* and other soil types of *coliform bacteria* persisted. At body temperature (37° C.), *E. coli* survived up to 56 days, and *A. aerogenes* survived much longer This suggested a temperature influence, since *E. coli* is accustomed to the temperature of the human body. When organic food substances (dextrose and peptone) were added to sludge, *E. coli* survived for 21 days, whereas it had disappeared in 14 days without the added nutriment. Sludge, from which *E. coli* had disappeared, was sterilized in an autoclave to destroy competing microorganisms. *E. coli* was inoculated into the sterile sludge and has survived for 42 days. These results all favor the competition theory as an explanation of the disappearance of *E. coli* from sludge.

Effect of Volatile Disinfectants on Survival of Microflora in Soil. (Charles Hurwitz and Frank H. Dalton.) These studies were undertaken to provide a method for sterilizing soil for laboratory studies which would permit subsequent removal of the sterilizing agent and would cause a minimum of change in the soil itself. A sealed jar containing the soil sample was evacuated and the atmosphere saturated with one of the following volatile disinfectants: chloroform, hydrogen cyanide, chloropicrin, formaldehyde, and ethylene oxide. The rate of survival of the soil microflora was determined by plate counts and by broth-culture inoculation techniques. Ethylene oxide sterilized the soil after 11 hours exposure, formaldehyde after 3 days, and chloropicrin after 8 days. Hydrogen cyanide and chloroform decreased the numbers of viable microorganisms but did not sterilize the soil after 8 days exposure.

The extractability of copper and manganese from the soil with ammonuim acetate was used as an indication of changes brought about in the soil as a result of exposure to the disinfectants. Contact of the soil with formaldehyde caused a 187 percent increase in extractable copper. With ethylene oxide the increase was 309 percent; and with chloropicrin, 444 percent. Extractable manganese increased from 0.14 p.p.m. in the untreated soil to 2.5 p.p.m. in the soil treated with ethylene oxide, 7.7 p.p.m. in the soil treated with formaldehyde, and 21.7 p.p.m. in the soil treated with chloropicrin.

It is interesting to note that the use of formaldehyde and chloropicrin resulted in possibly toxic concentrations of manganese. These two fumigants are widely used in seedbed preparation.

Two papers entitled "Effect of volatile disinfectants on survival of microflora in soil" and "The effect of sterilization of soil upon the solubility of soil copper and manganese" have been submitted to Soil Science and Florists' Exchange, respectively, for publication.

Microbiological Fixation of Copper in Soil. (Charles Hurwitz.) This is a continuation of work previously reported (Mass. Expt. Sta. Bul. 441, p. 15, 1947). In attempting to determine the form of copper whose solubility was affected by unknown components of oat straw and alfalfa meal, it was found that the solubility of copper sulfide and copper phosphate, two prevalent forms of insoluble copper salts, was not increased by the soluble components of the crop residues. It is therefore inferred that the metallo-organic salts of copper, and not the inorganic salts, are the forms affected. Two papers have been published: "Extraction of copper from soil as affected by soluble components of oat straw and alfalfa meal," Soil Science Vol. 65, No. 3, March, 1948; and "Effect of decomposition of added oat straw and alfalfa meal on solubility of soil copper in ammonium acetate," Proceedings of the Soil Science Society of America, 1947.

Effect of Decomposition of Plant Residues on the Solubility of Soil Manganese. (Charles Hurwitz.) The results, entitled ' Effect of temperature of incubation of amended soil on exchangeable manganese", have been submitted to Soil Science for publication. The effect of the temperature of decomposition of oat straw and alfalfa meal on the solubility of soil manganese in Merrimac sandy loam was studied at 4° C., 14° C., 31° C., 37° C., and 47° C. Neither water-soluble nor easily reducible soil manganese was affected, but ammonium acetate-soluble manganese showed marked variations. Little change was observed at 4° C. and 14° C., but above 30° C. the ammonium acetate-soluble manganese increased as a logarithmic function of the temperature of incubation. After further incubation, the exchangeable manganese decreased to initial levels. There was a tendency for the increase to be maintained over a longer period at the higher incubation temperatures. Glucose and peptone, when added to soil instead of oat straw and alfalfa meal, also increased the ammonium acetate-soluble manganese, both the increase and subsequent decrease being more rapid. When no organic matter was added to the soil, no increase in soluble manganese was observed from 4° C. through 37° C. At 47° C. a slight but significant increase was observed.

These findings may prove important in the management of greenhouse and seed-bed soils where steam sterilization is used. Toxic concentrations of manganese may result from the sterilization temperatures. Oxidation of these toxic concentrations to insoluble forms may be delayed or may not occur because of the destruction of the manganese-oxidizing bacteria by heat.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie, A. Vincent Osmun and D. H. Marsden.)

The Dutch Elm Disease Problem. The first discovery of the Dutch elm disease in Massachusetts was in 1941, when a tree in Alford, Berkshire County, was found to be infected by the causal fungus, *Ceratostomella ulmi* (Schwarz) Buisman. As of July 6, 1948, the disease fungus has been isolated from 1422 elm trees of 94 municipalities in 11 counties on the mainland of Massachusetts; Barnstable, Dukes, and Nantucket being reported as disease-free at present. Those towns with a relatively large population of weed elm trees are confronted with a difficult disease control problem; but where the number of elms is more restricted and the trees have received the care given valued trees, practical disease control should be possible. Three distinct zones of build-up in disease are apparent in the State. From the original outbreak, the disease has spread rather widely in Berkshire County. In the Connecticut Valley region, the increase in the number of diseased trees has been conspicuous in the last three years; and more recently in eastern Massachusetts, elms in the vicinity of Boston have been seriously affected. The spread of the disease from year to year is shown by the following table:

Year	Cumulative Totals		
	Trees	Towns	Counties
1941	1	1	1
1942	7	5	2
1943	11	6	2
1944	43	15	2
1945	85	24	3
1946	381	47	8
1947	1052	68	11
1948 (July 6)	1422	94	11

In studies to determine the spread, build-up, and possible benefits of combative measures, laboratory diagnosis of specimens is required for accurate determination of the causal fungus. The specimens are collected by scouts trained in the detection of characteristic symptoms on trees suspected of the disease. Diseased trees are reported to the Massachusetts Department of Agriculture and that Department carries out a cooperative disease control program with municipal governments or agencies responsible for affected trees. In a prepared schedule sanitation and other measures designed to restrict the spread of the disease are outlined for varying local conditions. These measures are presently under further study, including experiments in cooperation with the Department of Entomology on the use of spray materials for the control of bark beetles which serve as vectors of the disease fungus.

In general, the rate of increase in the number of diseased trees reported is most conspicuous in those areas where suppressive measures are lacking, poorly timed, or misapplied. Delay in the application of disease restrictive measures is costly, and expected benefits may be tragically nullified if essential work awaits a convenient assignment.

Thirteen progress reports (mimeographed) and six press releases were sent out during the year.

Cytospora Disease of Spruces. A common malady of ornamental spruces is a canker disease which attacks twigs and branches. In previous reports the cause of the disease was identified tentatively as the fungus *Cytospora Kunzei* Sacc. Lacking the identification of the causal fungus in its perfect stage on spruce, the disease was called, commonly, the "Cytospora disease" or "Cytospora canker."

In April 1947, a fungus identified as *Valsa Kunzei* Fr. was found associated with cankers on twigs and branches of Norway spruce and Colorado blue spruce. This fungus, believed to be the perfect stage of the aforementioned Cytospora, was described in detail, and a study was made of the growth and appearance on artificial culture media and on sterilized host tissue. Inoculations on young Norway spruce trees with *Valsa Kunzei* resulted in cankers and the death of some of the inoculated branches.

The Valsa stage may be involved in the natural spread of the disease by means of wind-blown ascospores, and further investigations into that possibility are needed. Also, a more intimate knowledge of factors predisposing spruces to the disease and avenues of host infection by the fungus are to be desired as prerequisites to an attempt to achieve effective control.

Other Tree Problems. Forty-eight diseases of twenty-three species of trees, including seven diseases of elm, were identified from more than 1500 specimens and inquiries received during the year. The Cephalosporium wilt of elm was reported from one additional municipality in the State. *Verticillium* sp. was isolated from several species of woody plants.

Winter injury to trees and to evergreens in particular was extensive this year. Later, during the extended period of wet weather at the time tender foliage was developing, conditions were ideal for infection of leaves by fungi. Elms, maples, sycamores, oaks, and ashes were among trees on which foliage was seriously affected and partially lost in early summer because of leaf diseases. Also, heavy infection of leaves by the black spot fungus indicates that additional loss of elm leaves may be expected by midsummer.

Two other tree disease problems have occasioned increasing numbers of inquiries in recent years. The death of individual branches and limbs in maples, leaving characteristic reddened or bronzed flags presents a problem which calls for study; and the dying of oaks lacks specific explanation. In limited studies, a combination of circumstances, including the preliminary weakening of the oaks by the defoliating gypsy moth, appears to be a logical explanation of the heavy mortality among these trees.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Work was continued on the effects of fungicides applied as powder-dips to cuttings immediately after treatment with a root-inducing substance, usually indolebutyric acid, applied by the solution-immersion method.

The following fungicides thus used were harmless to the cuttings of these species: Spergon (tetrachloro-parabenzoquinone) with Canada hemlock, *Genista pilosa*, and *Juniperus squamata Meyeri*; Phygon (2, 3-dichloro-1, 4 naphthoquinone) with Canada hemlock and *Genista pilosa*; morpholine thiuram disulfide with Carolina hemlock; zinc ethylene bisdithiocarbamate with red cedar; and a zinc dimethyl dithiocarbamate-cyclohexamine with Chinese juniper.

The use of the following fungicides similarly applied was followed by poorer rooting or apparent injury in the case of cuttings of these species: Arasan (tetramethyl thiuram disulfide) with Canada hemlock, heather, and *Genista pilosa*; Semesan Jr. (1.0% ethyl mercury phosphate) with Canada hemlock, Carolina hemlock and *Pachistima Canbyi*; Puraturf (6.0% phenyl mercury triethanol ammonium lactate) with Canada hemlock and creeping juniper; 2 percent Ceresan (2.0% ethyl mercury chloride) with Carolina hemlock and *Pachistima Canbyi*; zinc trichlorophenate with red cedar and *Pachistima Canbyi*; Fermate (ferric dimethyl dithiocarbamate) with heather.

It should be noted that here and throughout the report on this project better rooting means rooting in larger percentages or in a shorter time or with a larger root system.

In cooperation with Dr. Malcolm A. McKenzie of this Department, work was begun on the vegetative propagation of an elm, the Christine Buisman variety of *Ulmus carpinifolia*, which has been found to be resistant to the Dutch elm disease. Not more than 54 percent of the root-cuttings taken in early December lived more than 24 weeks after their insertion in sand, with proximal ends exposed, in a greenhouse bench; and the average length of the top growth made meanwhile was 4.5 inches. Root-cuttings taken in early March and similarly handled made root and top growth much more rapidly, with 95 percent of them living and rooted at the end of 59 days; and the average length of the top growth made meanwhile was 9.0 inches. Early March root-cuttings which were wholly covered, both distal and proximal ends under the sand, gave very inferior results.

Talc was compared with activated charcoal as a carrier of indolebutyric acid or naphthaleneacetic acid applied to cuttings by the powder-dip method. Talc so used gave better results than the charcoal with cuttings of English ivy, Hinoki cypress, bearberry, *Pyracantha coccinea*, *Ilex crenata*, *Picea glauca* and *Berberis Sargentiana*.

Taken in October, cuttings of American holly rooted equally well in sand and in flue-ash, but there was a better survival of cuttings of hemlock in sand than in flue-ash.

December cuttings of Canada hemlock rooted in larger percentages if made of wood in its first or second year rather than of wood in its third year. The rooting of cuttings of Carolina hemlock was much improved by indolebutyric acid 200 mg./l., 23 hours.

Cuttings of sugar maple rooted fairly well if taken in June and treated with indolebutyric acid but there was a high mortality among the rooted cuttings during the following winter in the greenhouse. Rooting of November cuttings of *Berberis Sargentiana* was hastened by indolebutyric acid 6 or 12 mg./gm. talc. Cuttings of *Rhododendron calendulaceum* taken in June rooted poorly without treatment, very well after instanteous-dip treatment with indolebutyric acid 5 mg./cc.

Two papers were written and published.[1]

Diseases of Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Fungicides were applied to soils in a carrier of commercial fertilizer (usually a 5-8-7 formula at the rate of 15.6 grams per square foot of soil surface) immediately before seeding. Their effects on the damping-off of several vegetables, on smut of onion (caused by

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[1]Doran, W. L. and Beaumont, A. B. Vegetative propagation of kudzu. Jour. Amer. Soc. Agron, 39:9:834-835. 1947 (Mass. Agr. Expt. Sta. Contrib. No. 625).

Doran, W. L. Get out your knife and see how you can multiply. Horticulture 25:16:447, 461. 1947.

Urocystis cepulae Frost), on clubroot of cabbage (caused by *Plasmodiophora brassicae* Wor.), and on growth of plants are here summarized. Rates of application of the fungicides are in all cases expressed as grams per square foot, 1.0 gram per square foot being about 96 pounds per acre. None of the materials were injurious to plants unless it is so stated, and their use was often followed by an increase in average green weights of seedlings.

The result of the control of pre- and post-emergence damping-off is expressed as the percentage increase in number of living seedlings, the basis of comparison being the numbers of plants which lived in untreated soil. Numbers of living cabbage seedlings were increased 633 percent by Phygon (2, 3-dichloro-l, 4 naphthoquinone) 0.65 gm.; less by Arasan similarly used; and 377 percent in one case, 889 percent in another, by Tuads (tetramethyl thiuram disulfide) 0.65 gm. Increase in weight of cabbage seedlings was 86 percent with Phygon, 50 percent with Tuads. Numbers of tomato seedlings which lived were increased 281 percent by Tuads 0.65 gm., 246 by Phygon 0.65 gm. Increases in average green weights of the seedlings were 183 and 233 percent, respectively. The use of Tuads 0.65 gm. was followed by an increase of 35 percent in the number of living beet seedlings and 82 percent in the number of living lettuce seedlings.

With more than 50 percent of the onion seedlings infected with smut in untreated soil, Tuads 0.65 gm., Phygon 0.65 gm., or Fermate (ferric dimethyl dithio-carbamate) prevented all smut. Since Tuads and Phygon gave better control of damping-off than Fermate, larger numbers of plants survived, the increase over numbers surviving in untreated soil being more than 1000 percent with both materials. However, Phygon sometimes retarded the growth of onion seedlings slightly, so Tuads or Arasan (another tetramethyl thiuram disulfide product) is probably to be preferred. When 50 percent of the onion seedlings in untreated soil were infected with smut, there was no smut with Arasan 0.6 gm. and, as a result of good control of damping-off, numbers of living plants were greater by more than 2000 percent.

The organic fungicides used gave some degree of protection against clubroot of cabbage when it was not too severe in untreated soil, and the abstract of a paper on this phase of the subject has been published.[1] But with 100 percent severe infection in untreated and heavily watered soil, there was poor or little control of clubroot by Arasan 0.7 gm., Phygon 0.7 gm., Tuads 0.65 gm., or a zinc dimethyl dithiocarbamate-cyclohexylamine complex 2.0 gm.

With clubroot of cabbage severe, 100 percent infection in untreated soil, there was also 100 percent infection in soil to which hydrated lime 20 gm. had been applied and in soil to which mercurous chloride 0.2 gm., but no lime, had been applied. But when hydrated lime 20 gm. and mercurous chloride 0.2 gm. were applied together to this soil, there was only 13 percent clubroot, the degree of infection was slight, and the average green weight of the plants was 128 percent greater than in untreated soil. Mercurous chloride 0.2 gm. or mercuric chloride 0.1 gm. retarded the early growth of cabbage if applied to *unlimed* soil immediately before seeding, but not if applied to soil limed as described above. (This was true also of their effect on onion seedlings.) Neither of these mercury salts was injurious to cabbage plants if applied to soil 22 days before seeding.

The effect of soil-moisture content on the control of clubroot is now under investigation, with soil watered daily to 50, 65, and 80 percent of its water-holding capacity. Thirty-six days after seeding, there was 100 percent clubroot in the wettest soil, 56 percent in the soil 65 percent saturated, 10 percent in the dryest

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[1]Doran, W. L. Fungicides applied in fertilizers for the control of cabbage clubroot and damping-off. (Abst.) Phytopathology 37:11:848. 1947.

soil, and no clubroot at any soil-moisture content in soil treated with both hydrated lime 20 gm. and mercurous chloride 0.2 gm.

Tobacco Frenching. (L. H. Jones.) Research this past year has been concerned with the effect of partial sterilization of the soil on the elimination of the frenching factor; with the control of frenching by adding iron to the soil and its relation to iron content of the foliage; and with the symptoms of frenching induced by nitrogen deficiency and soil temperature, separately or combined.

A compost soil was divided into four fractions for treatment by autoclaving, air-drying, or formaldehyde, with one portion left untreated as a check. Both soil temperatures, high 95° F. and low 70° F., were used. Nitrogen was frequently added to the soil and the diphenylamine test on the foliage always showed nitrates present in the plants. No frenching occurred at the low soil temperature of 70° F. or on the plants in the autoclaved soil at 95°F. Air-drying of the soil did not prevent frenching in this experiment although it had been effective in previous experiments. Formaldehyde was not a preventive, although the soil had been treated with four times the amount usually recommended.

That the organism, or frenching factor, does not enter the soil through fresh cow manure is indicated by the results of an experiment in which manure was mixed with autoclaved soil and the plants grown at 95° F. No frenching occurred. Frenching did occur when the manure was mixed with non-autoclaved soil and in the check soil receiving no manure. The nitrogen content of the plants was high in all tests.

Freezing the soil does not eliminate the frenching agent. Immediately after thawing, soil from a pile subjected to freezing all winter produced frenched plants in 7 days, whereas soil protected against freezing required 10 to 13 days.

Chemical analysis for iron in the above-ground portion of Havana Seed tobacco plants indicated a relationship between iron content of the plants and frenching. The iron content was much lower in plants grown at a soil temperature of 95° F., which frenched, than in plants grown at a soil temperature of 70°, which did not french. However, when the soil was autoclaved before the plants were set, no frenching occurred at 95°, and the iron content of the plants was even higher than that of plants in autoclaved soil at 70°.

The addition of a ferrous sulfate–peat mixture prevented frenching and gave the plants a very high iron content. However, when the iron was supplied from the less available iron of ferric phosphate mixed with peat, frenching was not prevented by three lessening amounts and the iron content of the plants was no greater than that of plants grown in soil to which no iron was added. The heaviest application, however, did prevent frenching and the plants were higher in iron content, containing an amount similar to that found in plants growing in autoclaved soil where frenching did not take place.

It has been reported frequently that frenching is due to nitrogen deficiency. During the year it has been established that the early symptoms of frenching, pinhead mottling, induced either by high soil-temperature or by nitrogen deficiency are so nearly alike that the one cannot be distinguished from the other by general observation. Study of the various steps in the onset of the diseaase has shown that the pinhead mottling induced by high soil-temperature appears at the tip of a young leaf, earlier leaves being a dark healthy green; while pinhead mottling due to nitrogen deficiency appears first on the side near the margin of a yellow-green leaf, stunted by lack of nitrogen, the earlier leaves being quite yellow and even fired. Succeeding leaves in both instances are so nearly alike that, unless on the plant, the cause would be sheer guesswork. Sometimes it is possible to use the diphenylamine test to distinguish the cause.

Both causes produce chlorotic, narrowing leaves, even to filiform. Rosetting also occurs. Frenching from high soil-temperature is usually obtainable within 20 days and has been obtained in as little as 5 days. In these experiments, the shortest time in which pinhead mottling was obtained from a nitrogen-deficient soil was 38 days.

Plants with frenching due to nitrogen deficiency have always resumed normal growth after the application of nitrogenous material to the soil, but affected leaves did not completely recover. Frenched plants resulting from a high soil-temperature do not respond to applications of nitrogen, but resume normal growth if the soil moisture is reduced so that the plants wilt, or if the soil temperature is reduced to about 70° F. Frenched plants with chlorotic leaves due to nitrogen deficiency remain chlorotic till nitrogen is supplied. On the other hand, the chlorosis resulting from a high soil-temperature frequently disappears and newly developing frenched leaves, even the filiform type, may develop with a normal green color.

The theory that a lack of available iron is the cause of the type of frenching induced by a high soil-temperature is further substantiated by an experience with chlorotic rose plants in a greenhouse. The temperature in the greenhouse was high (August). A manure mulch supplied ample nitrogen, which was verified by the diphenylamine test on foliage tissue. An application of a mixture of iron sulfate (copperas) and peat followed by a heavy watering brought recovery to the plants. Discs made from the chlorotic leaves and floated on a solution of ferrous sulfate (Fe 6 p.p.m.) recovered a normal green color, while the checks remained chlorotic.

Tomato Leaf Mold Caused by the Fungus Cladosporium fulvum Cke. (E. F. Guba, Waltham.) All the effort since the last report has been concerned with the further improvement of Improved Bay State tomato with respect to quality and yield of fruit and resistance to leaf mold. This tomato is essentially similar to the Bay State tomato described in Massachusetts Agricultural Experiment Station Bulletin 393, 1942, with the factor for resistance to all forms of the fungus *Cladosporium fulvum* Cke. added. The variant of the pathogene to which Bay State, Globelle, Vetomold-121, and Vetomold are highly susceptible does not trouble Improved Bay State, which is resistant to all forms of the pathogene and has been reported to be highly resistant wherever in the world it has been grown. This tomato is grown extensively under glass in Ontario, New York, Nova Scotia, and the New England States, and the financial benefit to growers has been great.

Similar resistance to *Cladosporium* has been bred into several English forcing tomatoes such as Carter's Sunrise, Kondine Red, Hundredfold, Best-of-All, and Market King. The study of these hybrids is in progress in the desire to develop a range of commercially acceptable resistant types.

Search for Inherent Resistance to Tomato Late Blight Fungus. (E. F. Guba, Waltham.) Approximately 200 types of tomatoes have been tested for their behavior to the late blight fungus, *Phytophthora infestans* (Mont.) de Bary. The tomatoes were grown to maturity in the field in the summer of 1947, but because of unfavorable weather conditions for the fungus it was not possible to promote the disease.

Growth and fruiting habits of the plants were recorded. Epidemic conditions for the fungus were established among stands of seedlings of these tomatoes in the greenhouse in the early season of 1948. Included in these tests were *Lycopersicum esculentum*, *pimpinellifolium*, *hirsutum*, *peruvianum*, and numerous plum, cherry, and currant fruiting types in red, orange, and yellow colors and plant growth varying from extremely prostrate to erect. Most of these tomatoes are primitive and were obtained either directly from South America or through the Office of Foreign Plant Introduction, U. S. Department of Agriculture. From duplicated tests in the greenhouse, some promising types immune to the late blight fungus have been found. These represent survivals in the presence of complete devastation of the rest of the planting from the disease. These plants are being grown for seed and further study before undertaking a contemplated breeding program.

Causes and Control of Decay of Squash in Storage. (E. F. Guba, Waltham.) The objective was to learn the value of fungicidal protectant treatments in the field in relation to squash keeping. A field of squash was maintained and sprayed during the summer months. In addition, the squash were immersed in fungicides after harvest and checked periodically for infection during the winter storage season. Careful records of yields and disease were maintained.

Black Rot, caused by the fungus *Mycosphaerella citrullina* (C.O.Sm.) Gross, was unusually destructive on Butternut and Hubbard squash. Unusually warm weather up to December was an important factor contributing to the losses in storage. In the field the disease was best controlled with Fermate which yielded 3.2 percent infected squash; Parzate, 2.8 percent; and Zerlate, 1.7 percent. Unsprayed plots averaged 31 percent infected squash.

The successful control of Black Rot of Butternut squash in storage requires protectant spraying with fungicides in the field. Dipping the squash at harvest in Parzate, Phygon, or Zerlate suspensions controlled Black Rot well only when the squash had been sprayed in the field. When the stem end was removed, stem end infection was as prevalent as side infection. When the stems were retained, there was less disease at the stem end than on the sides. Painting the stem end with Phygon or Zerlate greatly reduced stem end infection, especially among squash from plots sprayed with fungicides in the field. The results show the possibilities of reducing Black Rot in storage by protectant field spraying and disinfestation of the squash with fungicides prior to storage.

Resistance to Fursarium dianthi Prill et Del., the Cause of a Serious Carnation Wilt Disease. (E. F. Guba, Waltham.) Considerable hybridizing has been done, and seedlings have been grown from successful crosses. Some 75 promising seedlings have been propagated from cuttings during the winter of 1947-48. These have been placed with two growers, recommended by the New England Carnation Growers Association, for further judging, and any that are acceptable will be subjected to tests to determine their reaction to disease, and notably to Fusarium Branch Rot.

Investigations of Fungicides which Promise Value in Apple Disease Control. (E. F. Guba, Waltham.) The objective implied by the original title of this project, i.e. "Interrelation of Wettable Sulfur, Lead Arsenate and Lime in Apple Spraying", has been attained. Project now is designed to acquaint growers with the advantages and limitations of new materials as protectants and eradicants for scab.

Lime or clay appeared to depreciate the fungicidal value of Puratized Agricultural Spray. Fermate or high grade wettable sulfur added to Puratized Agricultural Spray can be beneficial. Both Phygon and Flotation Sulfur Paste gave excellent scab control. Phygon causes a serious chlorosis of the foliage which appears to be corrected satisfactorily by the addition of twice as much Epsom salt. Epsom salt added to the spray produced darker green foliage.

The eradication of scab with Puratized Agricultural Spray was again incomplete in 1947 and 1948. Used as a protectant spray, it has given very good scab control on McIntosh trees. The fungicidal action of this spray residue deposited on glass slides is lost after 24 to 48 hours, indicating decomposition and the volatile nature of the active principle.

Scab eradication in 1948 was outstanding and striking with phenyl-mercuri acetate (Fungicide No. H L 331, California Spray Chemical Corp.); phenyl mercuri monoethanol ammonium acetate (Puratized B); and phenyl mercuri formamide (Puratized 806) (Gallowhur Chemical Corp.). The striking fungicidal action of these mercury sprays upon visible and incubating scab infection suggests that satisfactory control of this disease is possible with a belated and curtailed schedule of applications.

Miscellaneous Studies. (E. F. Guba, Waltham.)

Control of Seed Decay and Damping-off of Vegetable Seedlings by Seed-borne Chemicals. The tests of this year have concluded the effort to determine the best chemicals for the various kinds of vegetable seeds. Cuprous oxide, Semesan, Arasan, Spergon, and Phygon have general use; and Semesan, Jr., Fermate, and Zinc Oxide, special and limited application. Information is offered to the vegetable industry in the Vegetable Seed Treatment Chart published by the Extension Service of the University.

Contact Dermatitis Among Celery Farmers. Coincident with the introduction of green Summer Pascal celery, many farmers have complained about dermatitis on the hands and forearms from contact with this celery. Sensitive workers develop dermatitis especially while harvesting and stripping celery in the field, and contact with rotted and ripe celery is especially hazardous. Spoilage of celery in the field is due to the bacterial soft rot organism *Erwinia carotovorus*. On an average, one-third of the white workers are infected. Colored workers from the Bahama Islands and Jamaica are not sensitive. Numerous celery growers were tested for sensitivity with healthy and rotted celery tissue, with dextro-limonene oil extract of healthy stalks and leaves taken up in 9 parts of persic acid, and with crude oil from stalks and leaves without dilution. Workers sensitive to celery dermatitis in experimental tests gave positive reactions as indicated by erythema, pruritis, ulceration, vesicles, induration, and maculopapular lesions. The injurious factor is ascribed to dextro-limonene, the oil in the celery.

This study was conducted in cooperation with Dr. John G. Wiswell, Dr. John W. Erwin, Dr. Francis W. Rackemann, and Miss Lena L. Neri of the Massachusetts General Hospital, Boston. Some phases of the study require further research for completeness.

A report of the study has been accepted for publication by the American Journal of Allergy.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Factors Affecting the Vitamin Content of Milk and Milk Products. (Arthur D. Holmes.) The two types of milk, cows' and mares', used in the four studies that were completed during the past year were produced on the University farm under normal conditions. With one exception, i.e., milk from a Palomino mare, all the mares' milk was obtained from young Percheron mares. The cows' milk was mixed herd milk produced by the five dairy breeds of cows included in the University herd.

Composition of Mares' Milk as Compared with that of Other Species. (Arthur D. Holmes, Albert F. Spelman, C. Tyson Smith, and John W. Kuzmeski.) The mares' milk used in this study was produced by a Palomino and four Percheron mares. All were mature, well-developed, normal animals, four to ten years old, and in their first or fifth lactations. The study was made in the spring and 26 samples of milk were assayed. The average values obtained for the milk of Percheron mares were: water 89.7 percent; protein 2.3 percent; reduced ascorbic acid 89 mg. per liter; phosphorus 63 mg., potassium 64 mg., magnesium 9.0 mg., and calcium 102 mg. per 100 g. These values indicate that mares' milk contains more water than cow, goat, ewe, buffalo, camel, or human milk; less protein than cow, goat, ewe, buffalo, or camel milk, but more than human milk; more ascorbic acid than cow, goat, or human milk; less phosphorus than cow or goat milk but more than human milk; only about one-third as much potassium as cow or goat milk; and less magnesium and calcium than cow or goat milk, but four times as much calcium as human milk. The ratio of calcium and phosphorus is considerably higher in mares' milk than in cows' or goats' milk but possibly lower than in human milk.

Apparently this paper was of service to people in widespread areas, for the numerous requests for reprints rapidly exhausted the available supply.

Stability of Reduced Ascorbic Acid in Mares' Milk. (Arthur D. Holmes and Carleton P. Jones.) The milk was produced by mature Percheron mares at the end of the lactation period. The samples were collected late in the fall and pastures provided nearly all of the forage for the mares, but since the season was warm and sunny, the rainfall ample, and the pasture had been closely grazed, the grass was young and green.

Fifteen samples of mares' milk with initial potencies of from 86 to 161 mg. of reduced ascorbic acid per liter were stored in the dark at 10°C. They were assayed at daily or longer intervals. Four samples observed for 10 days lost an average of 2.5 mg. per liter daily; four samples stored 20 days lost 1.8 mg. per day; two stored 28 days lost 1.3 mg. daily; and three stored for 33 days lost 1.1 mg. per liter per day. These data show that the rate of loss of reduced ascorbic acid from mares' milk is only a fraction of the rate of loss from cows' milk.

Some Characteristics of Mares' Colostrum and Milk. (Arthur D. Holmes and Harry G. Lindquist). Assays were made daily of the colostrum and early lactation milk produced by one Palomino and three Percheron mares. The experimental period was of fifteen days' duration for the Palomino and twenty-one days for the Percherons. The pH value of the colostrum was very stable for the first four days; on the fifth day it was decidedly higher; and from the fifth to the twenty-first days it was quite constant. The fat content of the colostrum averaged 2.5 percent for the first four days of lactation; from the fifth day it decreased slowly during the remainder of the experimental period. The quantity of total solids in the colostrum decreased very rapidly during the first two days and thereafter decreased slowly. The reduced ascorbic acid was relatively low in the colostrum but increased fairly steadily from the first to the sixteenth day of lactation and then decreased somewhat. At the first estrual period, which ordinarily occurs about nine days postpartum, both the fat and ascorbic acid content of the milk changed from the values obtained before or after the estrual period. All the mares were bred at the first estrus. The foals of the two mares that were bred late in the estrual period developed diarrhea, a condition which is not uncommon for the first postpartum estrus of mares.

Permanency of Synthetic Ascorbic Acid Added to Milk. (Arthur D. Holmes and Carleton P. Jones.) In a study of the stability of ascorbic acid in mares' milk, Holmes and Jones found the rate of disappearance of ascorbic acid from mares' milk was only about one-seventh that reported by Hand for cows' milk. Mares' milk contains several times as much ascorbic acid as is found in cows' milk. Accordingly a study was made of the rate of loss of reduced ascorbic acid from cows' milk to which a sufficient amount of synthetic ascorbic acid had been added so that the ascorbic acid content of the milk approximated that of mares' milk.

Two series of 20 samples each were prepared by adding 75 mg. or 150 mg. of ascorbic acid to a liter of raw cow's milk. The samples were stored in 500-cc. flasks in the dark at 10°C. As aliquots were removed day by day for analysis, the volume of milk decreased and the volume of air in the flasks increased correspondingly. For the series of samples of milk to which 75 mg. of ascorbic acid per l. was added, the loss was 11 percent per day for the first 3 days and 5 percent per day for the remaining 7 days, or 7 percent per day for the entire period. For the series of samples of milk to which 150 mg. of ascorbic acid per l. was added, the loss was 6 percent per day for the first 4 days and 1 percent per day for the remaining 6 days, or an average of 3 percent per day for the 10 days of storage.

A Study of the Changes in Vitamin Content Coincident with Different Stages and Rates of Maturity of Vegetables Used for Home Consumption. (Arthur D. Holmes.) The investigations conducted on this project during the past fiscal year were confined to two vegetables, tomatoes and squashes, that were grown on the University farm under controlled experimental conditions. Assays were made of typical specimens to determine the extent that cultural conditions or varieties affected the nutritive value of the vegetables under investigation.

Variation in Composition of Winter Squashes. (Arthur D. Holmes, C. Tyson Smith, and William H. Lachman.) Assays of the edible portion of five varieties of squash commonly used in this area as a winter vegetable showed considerable variation. Blue Hubbard was not as rich in carotene, phosphorus, and potassium as Butternut and Golden Cushaw, which are relatively new varieties that are gaining popularity. The Buttercup squash, which is frequently referred to as "a dry squash," contained less water and more reducing sugars than any of the other varieties. The Butternut was very rich in carotene, phosphorus, and potassium. Des Moines contained the smallest amount of carotene and ascorbic acid but the largest amount of calcium and magnesium of any of the varieties. Golden Cushaw was rich in carotene and contained the most protein, phosphorus, and potassium of any of the varieties included in this study. The results of the assays show considerable variation in the composition of the different varieties of winter squashes and of the different squashes within the varieties even though all were grown under uniform soil, fertilizer, and climatic conditions.

Effect of Different Mulches upon the Nutritive Value of Tomatoes. (Arthur D. Holmes, C. Tyson Smith, Charles Rogers and William H. Lachman.) An experiment of 6 years' duration was made to determine the possible effect of mulching upon the composition of tomatoes. A standardized Rutgers-Stokes strain of tomatoes was used. Plots with comparable soil were selected for three mulch treatments and a check, with two replicates of each. Four-inch layers of three types of mulch—horse manure with shavings, rye straw, and Servall (shredded sugar cane stalks)—were spread on the experimental plots as soon as the tomato plants were set out. During the past year, the sixth of the experiment, 12 samples of 12 mature tomatoes each were assayed. The water, total solids, total sugars, and ascorbic acid contents of the tomatoes were similar for the check and the mulched plots. The tomatoes from the mulched plots contained more soluble solids and carotene than those from the check plots. Larger amounts of calcium, magnesium, phosphorus, and potassium were found in mulch-plot tomatoes than in the control-plot tomatoes. Judged by the results noted above, mulching tomatoes increases the mineral, especially phosphorus and potassium, content of the tomatoes.

Studies on the Quantitative Estimation of Hemicelluloses. (Emmett Bennett.) The data reported in the Annual Report for 1946-47 under this heading are published in the Journal of Analytical Chemistry.

Quantitative chemical procedures based on the removal of hemicellulose from holocellulose have received further consideration. Approaches have included (1) a study of the effects of acid hydrolysis, using different concentrations of acids, (2) alkaline extractions at different pH levels, and (3) means to determine when the holocellulose residue is substantially uniform, although possibly still retaining a quantity of furfural-yielding components. Results from the first and third approaches were of most promise. Limited data indicate that a slight increase in the concentration of the acid is more effective in bringing about hydrolysis than an increase in length of time. When plotted, these data also indicate that extraction is continuous. These observations would indicate that the whole cellulosic structure is attacked to some extent during the entire period of hydrolysis.

The alkali lability test, when applied to a holocellulose from which the hemicelluloses have been removed, yields an alkali number ranging from 0 to 3; before the hemicelluloses are removed by alkali, the number is of the order of 14. It would therefore seem possible to use the alkali number as a guide in determining approximately the time at which the incrusting hemicelluloses have been removed. The cellulosic residue is apparently not attacked appreciably by reagents used in this test.

The Chemical Investigations of Hemicelluloses. (Emmett Bennett.) Investigations dealing with the chemistry of hemicelluloses have been continued, with special attention to the hemicelluloses of corn stalks. Four different fractions when hydrolyzed yielded approximately 55, 68, 75, and 77 percent of reducing sugar as xylose. Specific rotations were all negative and had the values 40°, 46°, 34°, and 30°. Xylose appeared to be present in all fractions.

Quantitative estimations of xylose as the dibenzylidene dimethyl acetal did not prove successful and further work has been discontinued for the time. A good quantitative procedure for xylose would be very desirable. Because of certain disadvantages in the use of as-diphenylhydrazine for the determination of arabinose, attempts were made to utilize benzyl phenylhydrazine. The procedure, while fairly accurate for certain mixtures, was found to be unsuitable for general use.

Two of the fractions noted above yielded positive tests for starch, while two were negative. In each case the starch-like substance could be removed by treatment with a polidase-S enzyme preparation. Whether the presence of starch has a bearing on the origin of the pentoses is still an open question.

Results obtained thus far seem to indicate that fractions may differ qualitatively as well as quantitatively. In general, however, the fraction most resistant to extraction is likely to be the purest and the most homogeneous in character.

A report on the hemicelluloses of maize cobs and rye straw may be found in the Journal of Agricultural Research 75: 43-47 (1947).

The Investigation of Agricultural Waste Products. I. The Chemical Investigation of Lignin. (Emmett Bennett.) Attempts to increase the nitrogen content of lignin have been continued. Lignin was again oxidized by pure oxygen in a medium of concentrated ammonium hydroxide. It is known that organic compounds of phenolic nature absorb oxygen when dissolved in an alkaline solution. Ammonification appeared to take place simultaneously with oxidation. A maximum of over 8 percent of total nitrogen was obtained by oxidation for a period of 144 hours. The amounts of nitrogen combined, however, were not entirely proportional to the length of time of oxidation. The amount of ammoniacal nitrogen was approximately 34 percent of the total in all cases. This amount of nitrogen, which appears to be about the maximum attainable under the conditions, supports an hypothesis regarding the chemical structure of lignin.

In order to determine the extent to which changes were made during oxidation, the alkali lability test was used. Oxidations in this case were brought about in 0.2N sodium hydroxide. While it is doubtful whether a significant increase in the alkali number was obtained by oxidation for different intervals of time in sodium hydroxide, the number was significantly higher than that for samples oxidized in ammonium hydroxide.

That the size of the alkali number is, to a considerable extent, a function of the phenolic groups may be seen from the fact that when lignin is methylated, the alkali number becomes nearly zero. Furthermore the fixation of nitrogen seems to be dependent upon the hydroxyl groups, since nitrogen does not appear to be fixed to any extent in methylated lignin by oxidation with pure oxygen in concentrated ammonium hydroxide.

These data would tend to indicate that the formation of humus from lignin in the soil could be brought about by changes occurring in the hydroxyl groups.

THE CRANBERRY STATION
East Wareham, Massachusetts

H. J. Franklin in Charge

Administration. As provided by the legislature, a cranberry extension specialist was added to the official staff at the Cranberry Station in October, 1947, Mr. J. Richard Beattie, County Agricultural Agent of the Plymouth County Extension Service, taking this position. He will have over-all charge of the cranberry extension work in all Massachusetts counties interested in the cultivation of this fruit.

General. Severe drouth with high temperatures and excessive sunshine in August did much to curtail the 1947 Massachusetts cranberry crop and depreciate its condition. This and record high temperatures in October were very harmful to a satisfactory marketing of the fresh fruit.

The general terminal fall and winter budding of cranberry vines in Massachusetts in preparation for the 1948 crop was conspicuously good, in very marked contrast to that of the previous year which was notably poor.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.) The second part of the work on cranberry insects—that dealing with pests not worm-like and attacking mainly the cranberry foliage and fruit—was finished and presented for publication. The insect and disease control chart was revised and brought up to date.

Chlorinated camphene, used both as a dust and as a spray, proved to be a fairly effective control for gypsy moth caterpillars.

Prevalence of Cranberry Insects in the Season of 1947:

1. Black-headed fireworm clearly more troublesome than usual in both broods.

2. Gypsy moth caterpillars practically absent on the bogs in the eastern part of Barnstable County, as in 1945 and 1946. As this area was very heavily infested with this pest every year for a good many years before 1945, it is believed by some that the egg masses of the insect were killed by the penetrating salty spray driven by the 1944 hurricane.

The 1947 gypsy moth infestation in Plymouth County and the western part of Barnstable County considerable, probably about average.

3. False armyworm, spotted fireworm (*Cacoecia*), and firebeetle (*Cryptocephalus*) infestations light or absent.

4. Cranberry sawfly caterpillars much more generally abundant than usual.

5. Fruitworm infestations spotty, but about normal on the average; much more troublesome than in 1945 and 1946.

6. Cranberry weevil and spittle insect much more abundant than usual on the Outer Cape, causing much concern there.

7. Red mites (*Paratetranychus*) more harmful on cranberry bogs than for many years.

8. Black cutworms on some bogs after removal of grub-control flood, but did less harm than usual.

9. Honeybees and especially bumblebees abundant on the bogs everywhere, though rather less so than in 1946.

Weather Studies. (H. J. Franklin and C. E. Cross.) Continuing interest in cranberry weather relations prompted further study, the results of which were prepared for publication as a supplement to Bulletin 433 of this Station. Important new information was obtained, that relating to the effects of the weather on the condition of the fruit having special value.

Frost Forecasts. (H. J. Franklin.) This special service was continued. Over 8000 acres of bog in the hands of 213 subscribers were covered by the telephone warnings, this being nearly four-fifths of the cranberry acreage with fair to full flowage protection. An accessory warning service by radio, in cooperation as heretofore with the United States Weather Bureau office at Logan Airport, was handled through Station WEEI at Boston.

Bibliography of Cranberry Literature. (H. J. Franklin.) From time to time, work has been done on a bibliography of cranberry literature. Cranberry literature has been carefully checked up to 1935, and about 1500 references have been made on 3 x 5 cards. The first reference found was in 1808. References were not numerous until about 1915, but since then there have been 25 or more a year. The literature from 1935 on is now being checked. When brought up to date, the bibliography will probably have over 2000 references, which it is planned to arrange by subjects. Any information on references to cranberries occurring in scientific journals where cranberry literature is not regularly published would be appreciated.

Control of Cranberry Bog Weeds. (C. E. Cross.) Since grasses, sedges, and rushes continue to be the chief weed problems of cranberry growers, efforts have been made to extend the season in which oils can be used selectively in the treatment of these weeds. The first two weeks of May continue to be the safest time for the treatment of weeds with both kerosene and Stoddard Solvent. Frost flooding of the bogs and rainy weather during these two weeks usually prevent the accomplishment of all the oil work projected on weedy bogs.

It is unsafe to spray Stoddard Solvent, even at the rate of 200 gallons per acre, after the terminal buds of cranberry vines have opened. Weather conditions at the time of spraying do not affect the results of spraying late in May—any new growth touched with this oil is seriously injured, though last year's leaves and stems may not be hurt. Any work in late May or early June with Stoddard Solvent must be done as an individual weed treatment, the oil being applied to the base of the weed only and kept from contact with any new growth on the cranberry vines.

Stoddard Solvent at 200 gallons per acre will kill asters, white violets, several species of Panicum, and numerous sedges and rushes. Experiments on a great variety of weeds are being continued.

Studies of the weather in relation to kerosene spraying have been made and lead to the following conclusions:

1. It is far more important that the bog be dry prior to oil treatment than that it remain dry afterward. Many grasses, sedges, and rushes die readily if dry when sprayed, even though rain falls immediately after treatment. The same types of weeds die after kerosene treatment even if the bog is flooded four hours afterward.

2. If cranberry vines have made some new growth, kerosene sprays can apparently still be used without vine injury if the shelter air temperature is 60°F. or lower. In some instances no injury occurred from kerosene spraying on vines with one inch of new growth when the temperature was 70°F. Too little is still known of the effect of humidity, sunshine, and wind velocity on the toxicity of oil sprays; but at present cool, cloudy, and windy days appear preferable to warm, bright, and calm days for late kerosene treatments.

Paradichlorobenzene was dissolved in kerosene and sprayed on cranberry vines and weeds. The addition of PDB does not add appreciably to the weed-killing properties of kerosene, the material dissolves only after excessive agitation, and the solution is very harmful to new growth on cranberry vines.

Further trials with paradichlorobenzene applied to cranberry bogs under one inch of sand indicate that the kill of small bramble (Rubus) and three-square grass (Scirpus) is inadequate to warrant the treatment. However, both spring and fall treatments using 7½ pounds of PDB per square rod under one inch of sand when wild bean is dormant appear to give nearly complete control of this weed.

When PDB is used under sand in new plantings, the cranberry vines develop so slowly that this treatment is not recommended.

Exhaustive tests of isopropyl phenyl carbamate failed to show any use for this material in cranberry weed control.

Winterkilling Studies. (C. E. Cross.) Experiments during the last two winters have shown that a single layer of 8-ounce burlap is sufficient to prevent the winterkilling of cranberry vines. The same is true of rough cotton cloth such as is used in the making of 100-pound sacks. Two thicknesses of tobacco netting did not give adequate protection to the cranberry vines. Substantially more cranberries were harvested from areas covered with cotton and burlap than from unprotected areas.

Frost Experiments. (C. E. Cross.) Burlap and cotton cloth were used on bogs to determine what degree of frost protection they would afford as covers over cranberry vines. Temperatures on frosty nights ranged from 4 to 8 degrees F. warmer under the coverings—the more severe the frost, the greater the protection. Paper was tried as a cheaper material. Though it apparently afforded good protection from low temperatures, it could not be anchored even in light winds, and is therefore considered impractical.

Soil Water Studies. (F. B. Chandler.) Studies of soil water made with wells and with tensiometers (instruments to measure the tension required to move water in the soil) show that one section of a bog is not uniform in water movement for drainage or irrigation. Some bog sections or parts of sections may be poorly irrigated although the ditches are filled with water. During the coming year, several growers are cooperating and more data will be available later.

Fertilizer Requirements of Cranberry Plants. (F. B. Chandler and William G. Colby.) The plots previously started have been continued and about 100 new plots added, for the purpose of studying the different sources of nitrogen (nitrate of soda, sulfate of ammonia, cyanamid, Urea-form and tankage), sources of phosphorus (rock phosphate, normal superphosphate, and triple superphosphate), amounts of nitrogen per acre (10, 20, 40, and 80 pounds of nitrogen per acre), and ratio of nitrogen to phosphorus (1-1 and 1-2.) Time of application and minor elements are also being studied. The results so far do not justify any recommendations.

DEPARTMENT OF DAIRY INDUSTRY

D. J. Hankinson in Charge

Sanitizing Agents for Dairy Use. (W. S. Mueller.) The newer sanitizing agents for dairy use have in common a quaternary ammonium salt of one form or another which is the active bactericidal material. A new development is a cleaner-sanitizer combination. These new products are now available in both liquid and powder form.

Some of the results of this study, "Testing Quaternary Ammonium Sanitizers and Their Use in the Dairy Industry" were published in *Soap and Sanitary Chemicals*, September, 1947 issue.

The following progress has been made:

1. *A Method for Evaluating the Sanitizing Efficiency of Quaternary Ammonium Compounds and Other Germicides Proposed for Sanitizing Food Utensils.* (W. S. Mueller and E. P. Larkin.) The method is described in the last annual report. During the past year more data have been obtained on several technical steps, for the purpose of improving the standardization of the suspension of test organisms as used in the test. A hand homogenizer was used for breaking up clumps of bacteria in suspension. A spectrophotometer was used for measuring the turbidity of the bacterial suspension and this value was correlated with the number of bacteria present as determined by the plate count. Three distinct types of bacteria were used in the study: a gram-negative organism, *E. coli*; a gram-positive organism, *S. aureus*; and a sporeformer, *B. cereus*. The different organisms were variously affected by homogenization. The plate count of *S. aureus* was increased 70 percent; that of *B. cereus* was slightly decreased. No significant effect was noted on *E. coli*.

Curves plotted for each of the three organisms show the relationship between the plate count and turbidity value as measured by the spectrophotometer. Results indicate that suspensions of non-sporeforming organisms can be standardized to a reasonably accurate number by the use of transmission curves. Results with *B. cereus* were doubtful; therefore standardization of spore suspensions by the use of the homogenizer and spectrophotometer cannot be recommended at the present time.

2. *New Developments in Sanitizing Teat Cups Between Cows Milked.* (W. S. Mueller and D. B. Seeley.) The method commonly used today for sanitizing teat cups between cows milked is ineffective because contact with the germicide is too short. This is a major cause for the spread of mastitis from an infected to a non-infected udder.

As a result of this study, a new method for sanitizing teat cups has been developed, in which the basic idea is the use of an extra milking-head assembly, thus making it possible to keep the teat cups in the germicidal solution for two minutes or more without increasing the milking time for the herd. This markedly reduced the total bacterial counts of the teat cup and under laboratory conditions killed almost all of the *S. agalactiae* organisms, which are chiefly responsible for mastitis due to infection.

From this study it is concluded that the new method of sanitizing teat cups between cows milked greatly reduces the chance of spreading mastitis through the herd, without increasing milking time or interfering with barn routine.

3. *Effect of Some Water Constituents on Quaternaries.* (W. S. Mueller and D. B. Seeley.) While "hard waters" have been reported to be incompatible with quaternaries, it seemed desirable to have more information on the effect of each of the many constituents normally found in potable waters. The germicidal potency of an alkyl-dimethyl-benzyl-ammonium chloride was tested against *E. coli*, and the tentative conclusions are as follows:

a. There was no direct correlation between water hardness as measured by the soap method and the germicidal potency of the quaternary solution.

b. The following ions had no adverse effect on the germicidal potency of the quaternary: cations—potassium, sodium, and lithium; anions—chloride, sulfates, and nitrates.

c. The following cations when present in sufficient quantities reduced the effectiveness of the quaternary: calcium, magnesium, and bivalent and trivalent ionized iron. Calcium and magnesium acted alike; trivalent ionized iron was far more detrimental than bivalent ionized iron.

d. A 200 p.p.m. solution of the quaternary studied had sufficient germicidal potency to do most sanitizing jobs even when the concentration of calcium plus magnesium was as much as 600 p.p.m.

e. A 200 p.p.m. solution of the quaternary was completely inactivated by 10 p.p.m. of trivalent ionized iron.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Transfer of Ownership and Its Effect on Agricultural Land Utilization. (David Rozman.) Work on this project has proceeded with the examination of records obtained in agricultural communities in several parts of the State. The Registry of Deeds and assessors' records have provided the basis for a complete list of land transfers in the selected areas, from the beginning of 1940. The towns studied during the past year were New Braintree in Worcester County, Amherst in Hampshire County, and West Newbury in Essex County. The study involves ascertaining present as well as former uses of each individual property. Further information is obtained from the records of the Agricultural Conservation Service so far as they are available. For the years already examined and analyzed, the following preliminary data indicate the changes occurring in agricultural land use and ownership.

There has been a continuous increase in the number of transactions affecting agricultural land throughout the period, reaching greatest intensity in the immediate postwar year. The number of transactions in the three towns under consideration increased from 32 in 1940 to 69 in 1946; and the number of acres involved, from 858 to 2700. In most cases the type of land use has shown a change under new ownership in both the prewar and the postwar periods. In 1940, out of a total of 32 transfers, only 13 farm units retained their former use; and in 1946, only 19 out of 69. Some of the farming units lost their identity after transfer and became part of a larger farming unit.

Changes from part-time farming into full-time farming or the reverse occurred in about equal numbers, both in the prewar period and in 1946. On the basis of incomplete preliminary figures, it appears that the movement of farm land into non-farming use is somewhat greater than the reverse movement of non-farm land into farms.

As a part of the study of the general trend in Massachusetts agriculture, an agricultural production program for 1948 was worked out and published in mimeographed form.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne, W. D. Whitcomb, W. J. Garland, and C. S. Hood.) In the cooperative experiment with the Dow Chemical Company, dormant application of experimental materials D-289 and D-542 on apple killed overwintered eggs of apple aphids. Unsprayed trees in the test block showed 2050 aphids per 50 buds, with some buds showing as many as 105 plant lice; while on sprayed trees only an occasional bud showed a single aphid. No retardation in seasonal development resulted from either material.

Dormant application of D-289 and D-542 on sweet cherries practically eliminated black cherry aphis for the season. For the first time since this block had been set out, the trees were practically free from the evidence of this pest. No further steps were taken to control aphids in this block during the entire season, in contrast to previous years when several sprays of nicotine sulfate had been applied each year in an unsuccessful effort to check this pest.

Dormant application of D-289 and D-542 in the variety pear block gave very good control of pear psylla, although protracted cold windy weather so prolonged the appearance of adult psyllas that the dormant application was not quite so effective as in 1946 when more normal weather prevailed.

Laboratory tests of D-289 on egg masses of eastern tent caterpillar showed promising reduction in numbers of emerging larvae. The light infestation in this area made it impossible to operate on any large scale. Results were sufficiently good to warrant further study in a season of greater attack.

B-542 in dormant application on cultivated blueberries gave striking control of a very troublesome species of Lecanium (*L. quercifex*). Results with this material were so nearly perfect that we hope to spray the entire blueberry plantings in college plots and eradicate this potentially serious pest. This is one of the first successful attempts to control this pest on blueberries.

At Waltham, experimental applications of new materials for the control of summer infestations of the European red mite were made on August 13 and 18, 1947, where the average infestation was 4 to 6 mites per leaf. Counts of 60 leaves per treatment 10 to 14 days later showed excellent control from all materials, as follows:

Code Number	Formula	Dosage (per 100 gallons)	Reduction of Mites per Leaf (percent)
C-740	Chlorophenyl ethane and DDT	2 quarts	98.8
C-714	Chlorophenyl ethane	1 pint	97.7
+C-726	Chlorophenyl methane	20 ounces	
D-111	Dinitro ortho cresol	16 ounces	96.8
Check	None		5.2

Abnormally high temperatures and prolonged drouth occurred in the period covered by this experiment, and C-740 caused moderate foliage injury under these conditions.

Insecticides for the Control of the European Corn Borer. (A. I. Bourne.) The first brood infestation in general was comparatively light, although some fields in well-protected areas in the lower Connecticut Valley showed considerable damage. The second brood was more serious, and many late plantings which were untreated suffered severe damage. Cold wet weather in May retarded pupation, which, for the most part, took place at irregular intervals following an occasional warm day. Moth emergence was correspondingly delayed and the first eggs were observed about June 10. First hatching was noted about mid-June.

Growth of corn was somewhat retarded by the same weather conditions. In some fields planted April 29, the plants were just breaking ground by mid-May and only reached a height of 3-4 inches during the warm period in the closing days of the month. Cool weather during most of June did not improve conditions greatly. Very hot weather in the last days of June and through July, however, stimulated rapid growth and the earliest planted fields were ready for harvest by about July 25.

Corn borer damage in the experimental plots was not severe even in untreated plots, where the average from all pickings was 85 percent clean corn compared with an average of 98 percent clean corn in treated plots. However, in the check plots only 75 percent of the yield was of marketable grade, and the total yield averaged 35 percent more marketable ears in the sprayed plots than in the check plots. The heaviest yield was on the Derris and Ryanex plots, which averaged 42.4 percent more ears of marketable grade than the unsprayed check plots, indicating that, even with a moderate infestation, feeding of the larvae lowered the vitality of the plants enough to cause not only a reduction in total yield but an even more serious reduction in ears of marketable quality.

Potato Spraying Experiments. (A. I. Bourne.) Potatoes were planted on May 12. May was slightly cooler than normal, with slightly more precipitation than usual, well distributed over the month as light rains except for two storms on the

3d and 25th. Cold weather somewhat retarded the first appearance of the plants, but once they broke ground they made steady and satisfactory growth. June also was slightly cooler and rainfall slightly less than usual. Growth was somewhat slow but was not seriously interrupted. The balance of the growing season was warm and very dry. The location of the experimental plots in rather a low area and on heavy soil prevented serious retardation, and the plants progressed very well and matured a good crop.

No spray injury was noted at any time during the season except a possible trace following calcium arsenate. The plants showed a tendency to ripen slightly earlier than usual but many were alive until the heavy killing frost in late September. This was very noticeable on the DDT plots, which remained green right up to frost.

Early flea beetle attack was comparatively negligible, but by late July the second brood appeared in some size and continued to mid-August. A moderate infestation of plant lice appeared in early August. Aphids were in moderate abundance through all plots except those given DDT emulsion, where only a few appeared.

Fifteen applications were made at weekly intervals from June 12 to September 17 to protect all new growth from attack. At least three extra applications were made to furnish protection in case of the recurrence of blight, which caused such havoc to tomatoes and potatoes in 1946. By mid-August the plants in the Bordeaux-sprayed plots began to show less vigor and considerable scarring from flea beetle attack. Where calcium arsenate was added, somewhat less flea beetle damage was noted, but there was a light amount of spray injury. The plots receiving DDT were of superior appearance, upright, vigorous, and remarkably free from any trace of insects.

The contrast between the DDT plots and the other plots grew more noticeable as the season advanced. Examination of growing tips from the different plots indicated the protection furnished by DDT. Samples from the Bordeaux plots showed 4560 perforations per 10 tips, while similar samples from the DDT (wettable powder) plot showed only 264 feeding punctures and from the DDT (emulsion) plot, 220; and superficial examination of the plants in the latter plots failed to indicate any damage.

Yields were high in both plots sprayed with DDT. The highest yield was slightly over 466 bushels per acre in the plot where the DDT emulsion was applied. The yield in the DDT (wettable powder) plot was 96 bushels per acre (or 30 percent) greater than in the adjoining Bordeaux plot; and where the DDT emulsion was applied, the increase in yield was 148 bushels per acre or 46.5 percent greater than where Bordeaux alone was used.

Control of Onion Thrips. (A. I. Bourne.) Onion sets were preferred to seed onions because the cold, wet spring season prevented early preparation of the plot and sets would furnish material for tests much earlier than would seed onions.

Thrips infestation developed slowly after a somewhat late appearance. A very few were found by the third week of June, and hot dry weather in July promoted rapid increase. Throughout the Valley, the prevailing weather conditions delayed thrips development so that many of the fields of set onions were pulled before thrips had reached very great numbers. Some of the plantings of seed onions, maturing later in the summer following the hot dry weather of July and August, showed moderately heavy attack.

The first application of insecticides was on July 15 when the plants averaged 15 to 16 inches in height and had an average of about 30 thrips per plant, a comparatively light infestation.

Following very thorough application to relatively small plants, all the sprays gave excellent initial kill: Black Leaf 40, Ryanex, and DDT, 99 percent control; Derris and DDD, 95 percent or over. After 7 days, the Derris, DDT, and DDD plots showed no increase in thrips population; Black Leaf 40 and Ryanex, however, did not give prolonged protection.

Of the dusts, DDT and BHC (benzene hexachloride) gave practically complete control following heavy application, and only slight increase in thrips population after a 7-day interval. Plants dusted with BHC retained a pronounced odor for weeks, but the onions when harvested did not have their flavor impaired. Ryanex dust gave approximately 94 percent control.

Control of Cabbage Maggot. (W. D. Whitcomb, W. J. Garland, and C. S. Hood, Waltham.) The natural infestation of the cabbage maggot in the experimental planting at Waltham caused 79 percent commercial injury in 1947. In the same planting, one and two applications at 10-day intervals of benzene hexachloride–talc dust at the rate of 25-30 pounds per acre gave perfect control. The most effective dusts contained 5 and 3 percent benzene hexachloride, but dust containing 1 percent benzene hexachloride was commercially satisfactory.

Benzene hexachloride harrowed into the soil at the rate of 2 pounds per acre before transplanting failed to give satisfactory protection.,

The treatments which gave excellent control produced 85 to 95 percent marketable heads, and there was no taste or odor contamination at harvest. Although no records were obtained, observations indicated that the cutworm injury was completely eliminated by these treatments.

Studies of Odor and Taste Contamination from Soil Treatment with Benzene Hexachloride. (W. D. Whitcomb, W. J. Garland, and C. S. Hood, Waltham.) Benzene hexachloride is an effective insecticide for the control of wireworms and cabbage maggot. However, it has a strong, persistent musty odor and taste which may be imparted to vegetables grown in treated soil.

In the experimental garden where areas were treated with benzene hexachloride at the rate of 2, 3, and 5 pounds per acre, carrots, onions, parsnips, and radishes were judged free from odor or taste contamination at the harvest by fifteen disinterested testers. Potatoes were contaminated at all dosages, and beets at the higher rates of application.

In general, the odor and taste of BHC were accentuated by boiling and baking. Potatoes still retained the odor to an undesirable degree seven months after harvest. Radishes and turnips were contaminated when the benzene hexachloride was applied as a dust to the plants after the shoulder was developed above ground.

Control of Squash Vine Borer. (W. D. Whitcomb, W. J. Garland, Waltham.) The natural infestation by the squash vine borer in the experimental plantings at Waltham in 1947 was 49.5 borers per vine. Applications of dust gave appreciable protection when applied at weekly intervals during July.

The most effective treatment was dusting with 3 percent DDD (Rhothane) which gave 81.6 percent protection. Other dusts which gave satisfactory protection were effective in the following order: 5 percent methoxy DDT; 0.5 percent DDT plus 0.06 percent pyrethrins; and 40 percent ryania powder.

The infestation in both the untreated and the dusted plants was about 30 percent greater in *Cucurbita maxima* plants than in *C. pepo.*

Biology and Control of Common Red Spider on Greenhouse Plants. (W. D. Whitcomb, W. J. Garland, and C. S. Hood, Waltham.) Parathion, a new organic phosphate insecticide, was found to be very effective for control of the greenhouse red spider on greenhouse roses when used as a 25 percent wettable powder. Infestation before spraying averaged 35.6 spiders per leaf on Better Times variety, and 14.8 spiders per leaf on Briarcliff. When Parathion was applied as a spray at the rate of ¼, ½, and 1 pound (equivalent to 1, 2, and 4 ounces of toxicant) per 100 gallons of water, all spiders were killed at each dilution. Furthermore, all spiders were killed on specimen plants protected by a hood of sheeting cloth, indicating very effective toxic action from the fumes. Mask and gloves were used during application.

No spiders have been found on these plants for three months after spraying, and no significant injury to the rose plants occurred.

Apple Maggot Emergence. (W. D. Whitcomb, Waltham.) Emergence of apple maggot flies at Waltham was the latest for any season since the cages have been operated, and applications of spray and dust for control of this pest, consequently, were delayed. The first fly was not found until July 6 which is 10 days after the average (8-year) date. Fifty percent emergence was reached on July 20, and flies continued to appear until August 18, which is about two weeks later than usual.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In the vicinity of Waltham, the plum curculio continued to be the most destructive insect pest of apples. On four unsprayed trees, 594 curculio beetles were collected by jarring between May 28 and June 18, 1947. Peak collections on June 2 and 16 indicated the periods of maximum activity when spraying was necessary for effective control.

In laboratory examinations the number of eggs in gravid female beetles was found to average 29.6, with a maximum of 43.

Insectary experiments using five pairs of beetles per cage, with apples as food, showed 41 punctures per beetle on the unsprayed apples in the 30 days of the experiment. DDT–lead arsenate killed all of the beetles in 6 days, with 2 punctures per beetle. BHC (benzene hexachloride), 3 pounds of 6 percent gamma isomer in 100 gallons of water, was about half as effective, and at 2 pounds per 100 gallons was unsatisfactory. The addition of HETP (hexaethyl tetraphosphate) 1-1600 prevented oviposition completely and gave excellent protection for about 7 days.

In orchard experiments involving the examination of about 18,000 apples, the combination of lead arsenate 2 pounds and 50 percent DDT wettable powder 2 pounds in 100 gallons gave the best control and was more effective by about 8 percent than lead arsenate alone at either 4 or 6 pounds in 100 gallons. BHC, 6 percent gamma isomer, at the rate of 3 pounds in 100 gallons permitted 42 percent of the fruit to be stung and was unsatisfactory. The addition of HETP 1-1600 to lead arsenate was less effective in the orchard than in the laboratory because its rapid breakdown failed to maintain protection between applications.

Study of Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and W. J. Garland, Waltham.) Experimental fumigations with aerosols containing a naphthalene base fumigant (Fulex) failed to satisfactorily control the common red spider on carnations in one 4 or 6 hour exposure (47-58 percent dead), but were effective in two successive exposures at 7-10 day intervals (86-100 percent dead). The aerosol was effective when discharged into the upper part of the room, but not from the floor.

Effective formulae were 25 percent Fulex concentrate with Freon and 20 percent Fulex-azobenzene with Freon. Addition of approximately 5 percent gamma isomer of benzene hexachloride to both Fulex concentrate and Fulex azobenzene aerosols gave 100 percent control of aphis on carnations and maintained the same effectiveness against the red spider mite.

Experimental fumigations in a commercial greenhouse with four applications of 17.5 percent azobenzene powder in a pressure fumigating can failed to give satisfactory control of the citrus mealybug on gardenia, although aphis and red spider mite were completely killed. The standard dosage of 2 pounds per 20,000 cubic feet was increased to 7½ pounds without controlling the mealybug. No injury to gardenia plants occurred, but the blooms and the paint on the greenhouse were noticeably stained.

Biology and Control of the Celery Plant Bug. (W. D. Whitcomb, W. J. Garland, and C. S. Hood, Waltham.) Although the first generation of the celery plant bug (*Lygus campestris* L.) in July, 1947, was very small, the second generation in August and September was moderately abundant and control measures were necessary on many celery plantings in eastern Massachusetts.

Life history studies showed the time for development from egg to adult was 18.3 days in August, and 32 days in September, the difference being due almost entirely to the slow growth of the fourth nymphal instar during the cool weather in late September.

Sprays and dusts to control injury by bugs of the second generation were applied August 15 and September 3. DDT wettable powder in sprays containing 0.12, 0.06, and 0.03 percent DDT gave excellent control with no significant differences between the dosages, although reinfestation was prevented in direct proportion to the dosage. A dust containing 0.5 percent DDT and 0.06 percent pyrethrum was as effective as the sprays containing DDT. Dusts containing 40 percent ryania and 5 percent methoxy analog of DDT were unsatisfactory.

The size and weight of the average celery plant were significantly correlated with the injury by the celery plant bug in most control treatments, as shown in the tabulation.

Treatment	Injured Stalks at Harvest	Average Weight of Stalks
Spray	(percent)	(ounces)
DDT 50, 2 pounds per 100 gallons	None	46.4
DDT 50, 1 pound per 100 gallons	2.63	47.0
DDT 50, ½ pound per 100 gallons	3.50	50.2
Dust		
DDT 0.5 percent–pyrethrins 0.06 percent	5.26	50.6
DDT 3 percent	8.77	45.2
Ryania 40 percent	45.61	42.8
Methoxy 5 percent	64.91	47.0
Check	74.34	38.2

Preliminary analyses by A. F. Spelman of the Control Service showed DDT residue well within the tolerance of 7 p.p.m. three weeks after treatment in July. In August the residue on the stalks was satisfactory, although with the stronger sprays the residue was excessive on the leaves but not on the stalks. Further analyses are needed and are planned.

Biology and Control of the Grape Cane Girdler. (W. D. Whitcomb, Waltham.) Grape cane girdler beetles lived an average of 61 days when confined in cages with a supply of fresh grape canes daily, and made an average of 234 feeding scars per beetle. The greatest activity occurred between June 20 and July 15, but feeding was continued to September 19, which was 99 days after the observations were started.

DDT 50 percent wettable powder sprayed on canes in the insectary cages killed 4 pairs of beetles in 3.12 days and permitted 0.87 feeding scars per beetle during their life. Of ten different combinations and dosages of DDT, lead arsenate, and benzene hexachloride, five killed the beetles more quickly and seven prevented as many feeding scars. Benzene hexachloride reduced feeding scars by 57 to 86 percent and was significantly more effective in this respect than DDT or lead arsenate.

Study of Euonymus Scale and Its Control. (W. D. Whitcomb and C. N. Warner, Waltham, in cooperation with the Bartlett Tree Expert Company.) Studies on the Euonymus scale were started early in 1948 with dormant spraying treatments. When an 83 percent white oil emulsion was used in sprays containing 2, 3, and 4 percent actual oil, only the 4 percent dilution was satisfactory.

Reinfestation by crawlers following dormant sprays was reduced 100 percent by Elgetol 1½ percent; 98.7 percent by Elgetol 1 percent; and 86.9 percent by 4 percent oil emulsion.

In 1948 the first crawlers hatched June 14 and maximum activity was reached June 28-July 2 which is considerably later than has been estimated previously. Microscopic examination of female scales showed a maximum of 81 and an average of 61.5 eggs per scale.

An examination of 35 species and varieties of Euonymus growing at the Arnold Arboretum showed 8 species and 8 varieties heavily infested and 5 species and 4 varieties uninfested. No infestation was found on *E. alata* and its varieties, while *E. europea* and its varieties were all heavily infested.

Sprays to Prevent Scolytid Infestation of Elm Logs. (W. B. Becker.) At Springfield a number of sprays were applied once in the early spring when the weather was still cool (March 13, 1947) to the entire bark surface of winter-cut logs of American elm before Scolytids could attack them. Each test involved 20 to 22 square feet of bark with a maximum thickness between 3/8 and 3/4 of an inch and the quantity of spray applied was what the operator estimated to be necessary to thoroughly wet the surface of the bark (66 to 155 ml. per square foot). *Scolytus multistriatus* Marsham is abundant in the vicinity, but only *Hylurgopinus rufipes* (Eich.) infested the unsprayed control logs exposed at this season.

One percent DDT sprays (a wettable powder, an emulsion, and solution in No. 2 fuel oil), orthodichlorobenzene in No. 2 fuel oil (1 to 8 by volume), pentachlorophenol in No. 2 fuel oil (1 to 10 by volume), and monochloronaphthalene in No. 2 fuel oil (1 to 12 by volume) all gave 100 percent prevention, based on the number of exit holes found per square foot of bark in the late fall, as compared with the number in unsprayed check logs. The spraying of frozen or ice-coated logs, of course, may not result in such good control.

Other logs cut at the same time were sprayed as above but during warm weather (June 13, 1947). Each test involved 20 to 24 square feet of bark with a maximum thickness of 3/8 to 3/4 of an inch. Between 104 and 133 ml. of spray were applied per square foot of bark. Apparently the logs had only recently been attacked when the spray was applied, because boring dust was on the logs then; but examination in the fall revealed that eggs had hatched in few to none of the egg galleries in the sprayed logs. While no *S. multistriatus* were found in any of the sprayed logs, the ratio of *S. multistriatus* to *H. rufipes* brood galleries in the unsprayed control logs was 1 to 8.

In comparison with the control logs, 100 percent prevention or control was obtained with No. 2 fuel oil alone, pentachlorophenol in No. 2 fuel oil (1-10 by volume), and monochloronaphthalene in No. 2 fuel oil (1-12 by volume). The one percent DDT wettable powder spray and the orthodichlorobenzene in No. 2 fuel oil (1-8 by volume) gave 91.6 and 84.2 percent prevention, respectively, based on the number of exit holes per square foot of bark; but on the basis of the number of exit holes per egg gallery (with and without hatched eggs) 76.6 and 79.9 percent control, respectively, was obtained.

Spraying to Prevent Twig Feeding by the Smaller European Elm Bark Beetle. (W. B. Becker.) Several new insecticides were tried in four types of spraying applications to prevent twig feeding on American elms by the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, using the method described on pages 41-42 of last year's annual report (Bulletin 441).

1. *With Small Compressed-air Garden Sprayers.* The sprays were applied thoroughly at close range to low-growing branches of elms. Dormant and foliage applications of commercial DDT emulsion and wettable powder sprays at the low strengths found successful against many defoliating insects did not give good protection against *S. multistriatus* twig feeding after many days of weathering. No spray injury resulted to the elms at these low concentrations.

Dormant applications: Higher concentrations of several commercial DDT emulsions gave increasingly longer protection on the sprayed portions of twigs. Good protection for 100 days was sometimes obtained with 1 percent DDT emulsions, but much less often with 0.5 percent; while 2 percent DDT emulsions were effective for 200 days. The addition of lead arsenate to DDT emulsions (38 grams per gallon of 0.5 percent DDT spray) made no great difference in the results obtained at that strength. A 4 percent chlordane emulsion did not remain effective so long as a 1 percent DDT emulsion. No spray injury to the elms resulted from any of these dormant applications.

Foliage applications: In mid-August, 2, 1, and sometimes 0.5 percent commercial DDT emulsion and wettable powder sprays applied to previously unsprayed elms gave complete protection on sprayed parts of twigs for 109 to 113 days, after which these tests were suspended. No spray injury to the elms resulted from the wettable powder sprays, but slight foliage injury resulted from some 1 percent commercial DDT emulsions and moderately severe injury from some 2 percent DDT emulsions. Sugar maples and some other plants growing next to sprayed elms were injured more than the elms by these sprays. Spider mite damage sometimes followed DDT applications to elm foliage. A 2 percent chlordane emulsion gave much shorter protection and caused no injury. Wettable powder sprays of benzene hexachloride (151.4 grams of a 50 percent wettable powder per gallon), Ryania SC50 (76 grams per gallon), and Ryanex (151.4 grams per gallon) gave still less protection but caused no injury.

2. *With High-powered Hydraulic Sprayers* (35 gallons a minute capacity): Only DDT emulsions, commercial and laboratory-prepared, were used in this equipment. On low branches protection was somewhat comparable to that reported for DDT emulsions in the previous section. The principal difficulty lay in obtaining equally long-lasting protection in the upper parts of the elms, even though the spray always reached over the tops of the trees, which were up to approximately 60 feet high. As much as 25 gallons of spray was used on individual elms of medium size for thorough coverage.

Dormant applications: DDT emulsions, 1 and 2 percent, gave good, sometimes complete, protection at the top of an elm 41 days later. After 64 days, protection at the top was poor to fair from the 1 percent emulsion and poor to good from the 2 percent emulsion. After 112 days, protection was practically all poor at the top. No spray injury to the elms resulted.

Foliage applications: In mid-August these same elms were sprayed again and others sprayed for the first time. Special attention was given to spraying the tops. With 1 percent DDT emulsions, protection at the tops was poor to good 67-70 days later, but mostly poor after 117 days. With 2 percent DDT emulsions, protection at the tops was good after 67-69 days and fair to good after 117 days. Little to no injury to the elms resulted from these applications.

3. *With Mist Blowers:* The mist blower described in last year's annual report (Bulletin 441, p. 42) was used again. When the low dosages reported as successful against gypsy moths and other defoliating insects on shade trees (up to 1 quart of a 12 percent DDT solution or emulsion per medium to large elm) were applied in these experiments or with a similar mist blower on a regular municipal tree spraying operation, good protection against twig feeding by *S. multistriatus* was not obtained at any height, even after only a few days of weathering.

Dormant applications: When one gallon of a 12 percent DDT solution (diluted with kerosene) was sprayed at a medium to large elm, protection at the top was poor 43 days later. Two gallons gave somewhat better results then, but very poor results after 73 days. Three gallons gave good results at the top after 71 days but poor results after 148 days. None of these applications caused noticeable injury to dormant elms, but a sugar maple growing close to the elm which received three gallons was severely injured by the spray.

Foliage applications: One gallon of a 12 percent DDT emulsion, applied per tree in mid-August, gave poor results 43 days later at the top of a tree which had not been previously sprayed. Protection at the tops was fairly good from two and three gallons per tree after 44 days, but was poor after 77 days from two gallons and only slightly better from three gallons. Better protection was always obtained in the lower parts of the trees and was in proportion to the amount sprayed at the tree. These mid-August foliage applications caused little noticeable injury to the elms, except on the lower branches of the tree which received three gallons of the emulsion and where the blower passed too close to the other trees.

4. *With an Airplane.* Through the courtesy of the Field Headquarters, Gypsy and Browntail Moth Control, of the U. S. Bureau of Entomology and Plant Quarantine, and the Entomology Department of the Connecticut Agricultural Experiment Station, the effectiveness of airplane applications of DDT against twig feeding of *S. multistriatus* was studied. Deciduous forest areas in Connecticut were sprayed by airplane early in the spring with DDT at dosages used experimentally to combat gypsy moth caterpillars. Flying and spraying conditions were reported excellent, no foliage was yet present, and all glass plates at the site of these experiments, both on the ground and on branches, were well covered with the spray. Prevention of *S. multistriatus* feeding was unsatisfactory throughout the tests, which lasted 48 days. Even after only three days of weathering on a plot sprayed with as much as 2 pounds of DDT (technical grade) dissolved in 2 gallons of liquid (xylene and kerosene) per acre, only 45.4 percent prevention was obtained. All elm twigs used in this test were from branches 20 to 30 feet high in the tree.

DDT Residues on Grass Beneath Elms Sprayed for Elm Bark Beetles. (W. B. Becker and A. F. Spelman.*) The Feed and Fertilizer Regulatory Service cooperated by making DDT analyses of grass collected from pasture areas on which the spray dripped and drifted from elms sprayed with DDT emulsion from high-powered hydraulic sprayers. DDT (technical grade) was used at the rates of 16 and 8 pounds per 100 gallons, and as much as 25 gallons of spray was applied per tree. The residue was determined by the total chlorine method and *based on the oven-dry weight of the grass.*

August 15 application (soon after removal of cut hay); After 4 days with 0.52 inches of rainfall, the residue from the 16-pound application was 6,885 p.p.m. DDT; from the 8-pound application, 4,035 p.p.m. After 68 days with 4.55 inches rainfall, the corresponding residues were 1,658 and 851 p.p.m.

April 25 application: After 96 days with 11.63 inches rainfall, the residue from the 16-pound application was 43 p.p.m. DDT; from the 8-pound application, 45 to 50 p.p.m.

Such high DDT residues would seem to be undesirable and possibly hazardous where food for man or animals is involved. More detailed studies are in progress.

FEED AND FERTILIZER CONTROL SERVICES

John W. Kuzmeski in Charge

The feed, fertilizer and milk testing laws are administered as one service and the operation of each, with the exception of the milk testing law, is reported in annual bulletins.

Under the milk testing law 4,915 pieces of Babcock glassware were calibrated and 177 certificates of proficiency in testing were issued. All milk depots and milk inspection laboratories in the Commonwealth were visited at least once to check apparatus and general conduct of the work.

In addition to the regulatory work the Feed and Fertilizer Control laboratories have examined feeds, fertilizers, and other agricultural materials for citizens of the Commonwealth without charge whenever the results were considered of interest to the general public or to the Control Services.

Considerable work has been done on research projects in cooperation with other departments of the University and Experiment Station. The results of such work are reported by the departments originating the projects.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Variety Improvement and Disease Resistance. (Harold E. White, Waltham.) A dark pink flowered strain of Helen Tobin has been developed into a pure inbred line and seed has been distributed to local growers. The original Helen Tobin, which is a light pink variety, has been reported by several florists to be a good spring blooming variety to follow chrysanthemums. This variety, since its first introduction, has been used very successfully for an outdoor crop by a florist near Tampa, Florida; this year the firm plans to grow a crop of 8,000 to 10,000 plants. George J. Ball, Inc., West Chicago, Illinois, and other commercial growers are using Helen Tobin as breeding stock because it is an excellent seed producer and has other desirable characters.

* Senior chemist, Feed and Fertilizer Regulatory Service.

Excellent hybrids of the Tobin variety have been produced by inter-crossing with other commercial varieties. Local florists have been using these hybrids for two years with fine results. A sufficient quantity of stock seed of Tobin hybrids is being produced at Waltham to supply these growers.

The Waltham Field Station rust-resistant, pink-flowered strain of snapdragon for garden culture is being tested by approximately fifty home gardeners in the State. These tests are being conducted in cooperation with the Garden Club Federation of Massachusetts. The variety will be named and provisions made for introduction through local seedsmen if performance in these tests is satisfactory.

Sodium Selenate as a Red Spider Control. (Harold E. White, Waltham.) Carnation plants growing in benches were treated with selenium-bearing phosphate known in the trade as P-40. Applications were at the rate of 3, 4½, and 6 pounds per 100 square feet of bench area. Two applications of this material were made during the growing season, one in August and a second in November.

All the treatments at the higher dosages, 4½ and 6 pounds per 100 square feet, gave effective control of red spider from November through June, a period of 8 months. Red spider became abundant in May and June on untreated carnation plants and on those receiving the dosage of 3 pounds of P-40 per 100 square feet.

Ageratum, Lantana, Coleus, and Stevia were grown in 5-inch pots and treated with P-40 at the rate of ¼, ½, and 1 teaspoonful per pot. The ¼ teaspoonful dosage did not give effective control over a period of 6 to 8 weeks and the ½ teaspoonful treatment gave only partial control. The dosage of 1 teaspoonful P-40 per pot gave complete control.

Neither carnation plants nor potted plants showed harmful effects from treatments with P-40, even at the high dosage rate.

Samples of soil and plant material were taken monthly from the P-40 treated carnation plants for selenium analysis. The analytical work on these samples has not been completed sufficiently for a report at this time.

It is of interest to note that composted soil used at the Waltham Field Station shows an analysis about 1 to 1½ p.p.m. of selenium. Tests of black swamp peat from the Station farm show that 1 to 2 p.p.m. of selenium occurs in this soil. Soil samples from market garden land near Waltham were taken for further analysis as to presence of selenium.

This project is being conducted in cooperation with the Department of Agronomy and the Waltham Field Station entomologists.

Breeding for Varietal Improvement of Geraniums. (Harold E. White, Waltham.) Two seedling geraniums, derived from inbreeding and hybridizing of commercial varieties, have been named and are being introduced in 1948-49.

The seedling named Dorothy is a cross between Salmon Ideal and Beaute Poitevine. It is a vigorous grower, is salmon pink in color, has large flower trusses, and blooms freely in winter or summer. The flower color does not fade under high temperature conditions of summer.

The second seedling has been named Annette and was obtained by selfing the variety Salmon Ideal. This variety has bright red flowers, is a vigorous plant, blooms very freely, and retains its flower color under high temperature conditions.

These new varieties have been compared with commercial varieties at Waltham for three years. Stock has been released to the firm of H. J. Borowski & Sons, Inc., Norwood, Massachusetts, for propagation and will be introduced to the trade in the fall of 1948.

Sufficient stock of the varieties has been retained by the Waltham Field Station to perpetuate the strains.

Insulation of Flower Shipping Boxes. (Harold E. White, Waltham.) In October, 1947, a new plastic material was obtained from the Dow Chemical Company, Midland, Michigan, to determine its adaptability as an insulant for flower shipping containers. This material was supplied in especially cut boards 1 inch and ½ inch thick for liners to be fitted inside shipping boxes. The product, known as Styrofoam, a plastic, multicellular foam produced by expanding polystyrine 40 times, is snow white in color.

Styrofoam (Type 103.7) has a thermal conductivity K factor of 27-30, is resistant to moisture, absorbing 6 percent or less by volume. Also it is resistant to fire, burning at the rate of 7 to 8 inches per minute, has great structural strength, and is very buoyant. A cubic foot weighs a maximum of 2 pounds. At present Styrofoam is produced commercially for use in refrigeration plants, lockers, storage warehouses, and railroad cars.

Cardboard shipping boxes 36 x 15 x 9 inches and 48 x 18 x 10 inches were lined with Styrofoam boards. Other boxes were lined with 10 sheets of newspaper covering the sides, ends, bottoms, and tops. Styrofoam-lined and newspaper-lined boxes were wrapped with one sheet of manila paper. Two hundred carnation flowers were packed in each box. All boxes were placed outdoors with a maximum exposure period of 18 hours. Hourly temperature readings within the boxes and on the outside were obtained by recording clock thermometers. The lowest outside temperature recorded during the test was between 11° and 12°F.

Experiments on the effect of low temperatures on cut flowers, conducted by the U. S. Department of Agriculture, show that most flowers, including carnations, are injured at a critical temperature of 28°F. or below. The shipping boxes lined with ½ inch Styrofoam boards dropped from an initial temperature of 62°F. to 28°F. in a period of 6 hours, whereas the temperature in the newspaper-lined box fell to 26°F. in 5 hours. The outside air temperature dropped to 12°F. The lowest temperature in the Styrofoam lined box was 26°F., and in the newspaper lined box 24°F.

Interior temperature of boxes lined with 1-inch Styrofoam dropped to 28°F. in 8 hours, whereas the temperature in the newspaper-lined box fell to 28°F. in 4 hours. In these tests temperatures within boxes lined with newspapers dropped more rapidly than in boxes prepared with Styrofoam.

Styrofoam, as an insulant for flower-shipping containers, offers several desirable features, such as lightness in weight and a low moisture factor; it is a sterile medium and has a low thermal conductivity factor. It offers possibilities as an insulation material against low temperatures and as a material to protect flowers from extreme heat during shipment. Its use presents some problems such as production for this specialized field of use, the most satisfactory method of applying the lining to the boxes, and the cost of such an insulant as compared with newspaper.

Polyvinyl Resin Geon 31X Latex as a Flower Preservative. (Harold E. White, Waltham.) Geon 31X Latex is a water-dispersible resin which, when applied to plant material or other objects, forms a thin transparent film. Materials can be treated by dipping them in a solution of the Latex resin or they can be sprayed.

Gardenias, carnations, camellias, cymbidium orchids, geraniums, and passion-flowers were treated with 10, 20 and 30 percent solutions of the Latex. Pigmented flowers, such as red, pink, or yellow, were affected unfavorably by even the 10 percent solution and did not keep as well as untreated blooms. White flowers, such as gardenias and carnations, treated with the 10 and 20 percent solutions, showed great variability in keeping quality as compared with untreated blooms.

Treatment of gardenia flowers did not give consistent results in keeping the petals from turning brown, even for a period of 24 hours. Individual flowers within the treated lot turned brown while others remained in good condition. This reaction took place on blooms when kept under refrigeration and at room temperature. The variable response of gardenia flowers to the treatment seems to be due to physiological differences in the flowers.

Florists' ferns treated with the resin solutions kept in much better condition than untreated ferns. The treated ferns kept for a week at room temperature before the leaflets began to shed, while the check bunches were in poor condition after 24 hours. *Asparagus plumosus* treated with 10 and 20 percent solutions gave excellent results.

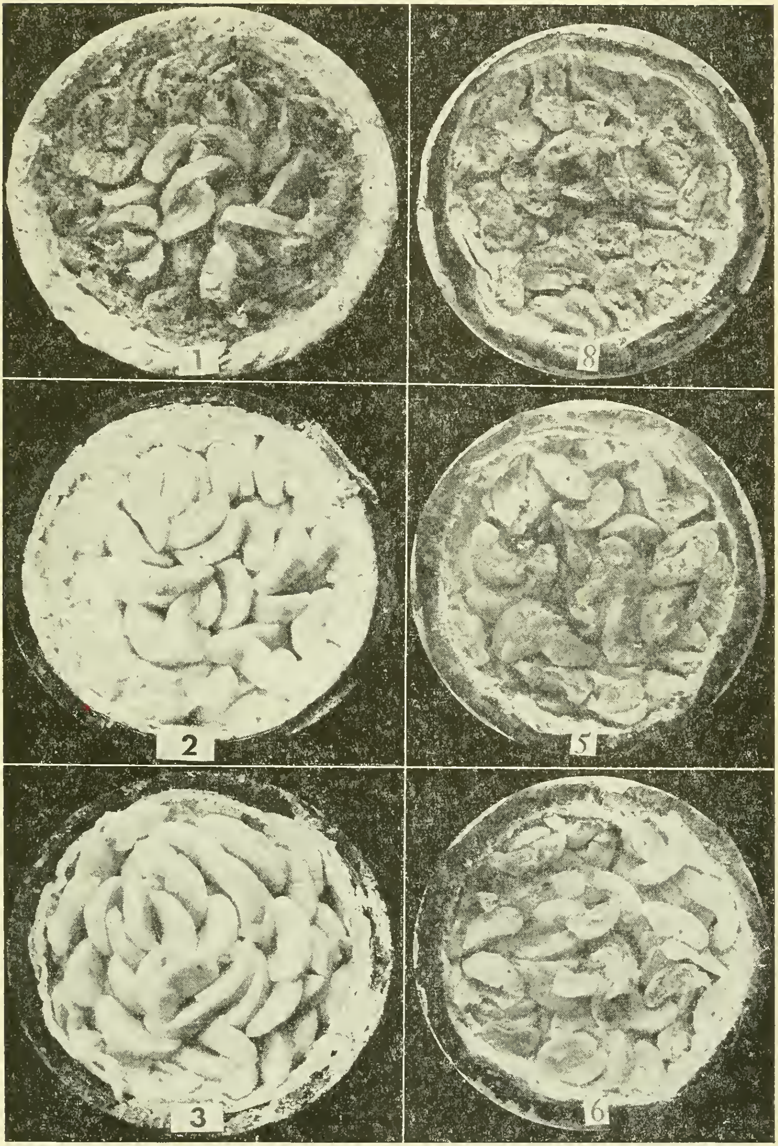
Passionflowers close shortly after they are cut and usually are treated with paraffin to keep them open. Treatment of blooms with Geon 31X Latex in 50 percent concentration was not effective in keeping such flowers open.

DEPARTMENT OF FOOD TECHNOLOGY

C. R. Fellers in Charge

Frozen Apples. (W. B. Esselen, Jr., C. R. Fellers, and J.E.W. McConnell.) On the basis of experiments conducted here during the past three years as well as commercial experience and practice it would appear that there are several procedures which can be employed to produce frozen apples of satisfactory quality. Of the different methods used to prevent darkening, such as blanching, deaeration, sulfurous acid dips, ascorbic acid, syrups, and others, each has certain advantages and disadvantages. The selection of which anti-darkening to use may depend upon the volume of production, plant facilities, and demands of the consumer. For example, apples treated with sulfurous acid may have a residual sulfur dioxide flavor unless care and control are exercised during the operation. Blanching causes some loss of flavor and solids but does not impart off-flavors. The use of ascorbic acid can yield good results if specific procedures are followed which are applicable to the particular raw material and plant operation. The use of sugar or syrup in conjunction with ascorbic acid or other treatments may present a problem because the apples when thawed will have an excessive quantity of syrup and juice. Some consumers may object to this excess syrup as being a waste of sugar and apple flavor. On the other hand the syrup is a valuable adjunct to the frozen apples in providing protection against oxidation during freezing and thawing. It can be used effectively if it is drained from the thawed slices, concentrated, and added to the pie. Some bakers handle the sugar in this manner.

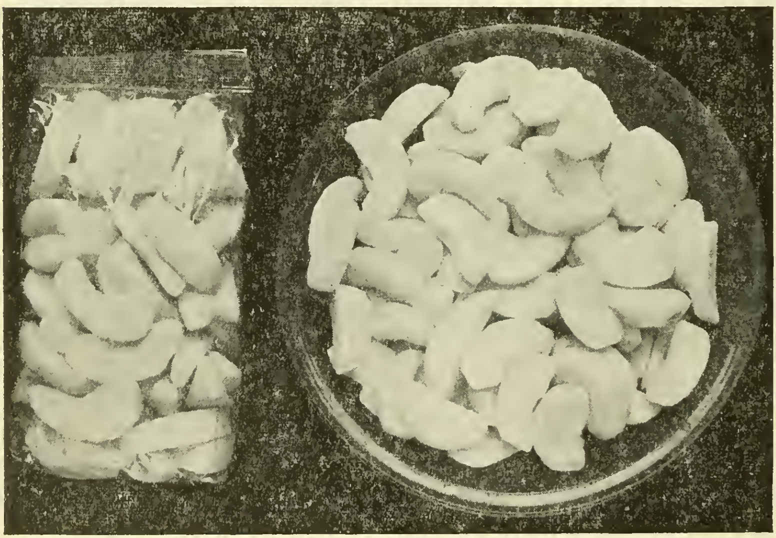
It has been frequently observed that pies made from properly prepared frozen apples were superior in fresh apple flavor and aroma to pies made from untreated fresh apples. The effectiveness of anti-darkening and antioxidant treatments given frozen apples carries through into the finished pie and tends to stabilize the apple flavor. The use of suitable antioxidants in pies made from fresh apples is worthy of consideration from the standpoint of maintaining optimum flavor.



1. Pie Made from Untreated Frozen McIntosh Apples. 2. Pie Made from Frozen McIntosh Apples Treated with Sulfur Dioxide. 3. Pie Made from Frozen McIntosh Apples Treated with Sulfur Dioxide and Calcium Chloride. 8. Pie Made from Freshly Prepared Untreated McIntosh Apples. 5. Pie Made from Prepared McIntosh Pie Apples Treated with Sulfur Dioxide and Calcium Chloride and Stored for Two Weeks at Room Temperature. 6. Pie Made from Prepared McIntosh Pie Apples Treated with Sulfur Dioxide and Calcium Chloride and Stored for Three Weeks at 35° F.

Canned and Frozen Baked McIntosh Apples. (W. B. Esselen, Jr., C. L. Rasmussen, and C. R. Fellers.) Canned and frozen baked McIntosh apples prepared without added calcium chloride were quite soft and mushy and did not retain their shape. They retained a satisfactory degree of firmness when treated with 0.05 to 0.10 percent calcium chloride. In no instance did the calcium chloride cause an off-flavor in the product. The characteristic McIntosh flavor was well retained in both the canned and frozen apples. From the standpoint of appearance glazed apples were rated best, with vacuum-treated and core-filled apples in a descending order of preference. Scoring completely cored apples about the periphery, before baking or glazing, reduced the tendency of the skin to split. Baldwin and Northern Spy apples retained their shape and texture very well without added calcium. In fact, those treated with calcium were considered to be too firm and rubbery.

Prepared Fresh McIntosh Apple Slices. (W. B. Esselen, Jr., C. L. Rasmussen, and N. Glazier.) In the preparation of fresh sliced apples for the bakery or consumer trade there are several factors that must be overcome or controlled in the production and distribution of a good quality product. The objectionable browning or discoloration of the slices may be satisfactorily controlled by treatment with sulfur dioxide or for short periods of time by means of a treatment with an acid and salt solution. While the concentration of sulfur dioxide required to maintain color may vary somewhat depending upon the condition of the apples, etc., a 10-minute dip in a solution containing 1500 p.p.m. has been found to be satisfactory under our conditions. Apples treated in this manner maintained a good quality for from one to two weeks when stored at room temperature and for three weeks or longer when held at 35°F. During storage for a week or longer a considerable amount of liquid tended to leach out of the slices and accumulate in the bottom of the container.



Consumer Package (22 ounces) of Prepared Fresh McIntosh Pie Apples.

A 10 or 15 minute treatment in a solution containing 5 percent salt, 0.5 percent ascorbic acid and 0.4 percent citric or ortho-phosphoric acid gave good results if the sliced apples were to be held for only a short time. Refrigeration is essential for apple slices treated in this manner.

For soft-textured apples such as the McIntosh the addition of 0.10 percent calcium chloride in the dipping solution is effective in maintaining the texture of the slices when they are baked in pies.

Apple-Cranberry Juice. (W. B. Esselen, Jr., K. M. Hayes, and C. R. Fellers.) An attractive and palatable fruit juice can be made by blending from 12 to 15 percent cranberry juice with apple juice. It is necessary to give the apple juice a preliminary flash pasteurization treatment in order to inactivate enzymes which would otherwise destroy the red color of the cranberry juice when the two are mixed together prior to final processing. The enzyme present in the apple juice, which destroyed the red color of the cranberry, was inactivated by heating at 190°F. for 0.5 minute or at 180°F. for 2.0 minutes.

Pre-Packaged Fresh Cranberries. (C. R. Fellers, K. M. Hayes and W. B. Esselen, Jr.) A new development in the merchandising of fresh cranberries has been the packaging of the fruit in transparent bags or packages for the retail trade. During the past year a study has been made of the effect of packaging in small sealed containers on the keeping qualities of cranberries and of the various kinds of packaging material used for the storage and marketing of the fruit.

Of the packaging materials studied, single thickness 450 LSAT cellophane was found to possess the best qualities for pre-packaging fresh cranberries. This type of package had good transparency and permitted the fruit to respire slowly with a minimum loss in weight due to desiccation and respiration. Cranberries in packages stored at room temperature (65°-75°F.) could be held for five to six days without appreciable breakdown, while at 35°F. the packaged fruit remained in good condition for from four to five months. This type of package is being adopted by several cranberry marketing agencies.

Factors Affecting the Viability of Dried Bakers' Yeast. (R. E. Morse and C. R. Fellers.) Methods for the laboratory preparation of dried bakers' yeast were investigated. Yeast was prepared which was similar in chemical composition and leavening properties to good grade commercial dried yeast.

A new method for testing the viability of dried bakers' yeast with triphenyl tetrazolium was developed. A carmine color, developed by reduction of the dye by yeast, is extracted with acetone and measured with a spectrophotometer. Good correlation between yeast viability and color development was obtained.

Exposure to light and type of package showed little or no effect on the viability of stored dried yeast. A low storage temperature and humidity had a pronounced favorable effect on the retention of viability in dried yeast. Nutritional and environmental factors were of paramount importance in causing yeast cells to develop dormancy and longevity in the semi-desiccated state.

The Composition and Nature of Apple Protein. (S. G. Davis and C. R. Fellers.) Apple tissue was found to contain approximately 0.2 percent protein. Isolated apple protein material had a nitrogen content of 8.5 percent. Amino nitrogen amounted to 93.5 percent of the total nitrogen, and the 16 amino acids (leucine, isoleucine, valine, phenylalanine, tryptophane, glutamic acid, alanine, histidine. arginine, threonine, methionine, lysine, aspartic acid, serine, proline and cystine) for which values could be obtained accounted for 83.6 percent of this amount.

Notable amounts of aspartic acid and glutamic acid appeared to exist free or in the form of simple peptides or amides in the apple tissue. Tryptophane could not be detected in either the protein preparations or the apple tissue itself.

Jar Rings for Home Canning. (W. B. Esselen, Jr.) An investigation on the tendency of home-canning jar rings to impart off-flavors to canned foods has been completed. All natural rubber or a combination of natural and synthetic rubber (GR-S) can be used to make jar rings which will not impart undesirable flavors to foods. In using synthetic rubber it is important that the raw material be selected for this particular use. In some cases chemicals added in the fabrication of jar rings such as accelerators or antioxidants can also contribute off-flavors, particularly off-flavors characterized by a bitter taste. Apple sauce was found to be a particularly good canned food for testing jar rings. If the rings which are used to seal the jars have a tendency to cause off-flavors it will sometimes show up after three months storage at room temperature but a six months storage period prior to testing is to be preferred.

Home Freezing. (W. B. Esselen Jr., J. E. W. McConnell, and N. Glazier.) Work is being continued on the quality of different varieties of fruits grown in this area when frozen. The fruit varieties have been provided through the cooperation of the Department of Pomology. The products frozen during the 1947 season included 18 varieties of strawberries, 10 of blueberries, 11 of cherries, 18 of raspberries, 17 of plums, 16 of pears, 27 of peaches, and 8 of currants. A number of the varieties of frozen plums were quite attractive and flavorful but there was a tendency for many of them to have a tough skin. Frozen red currants made a very satisfactory dessert fruit. In general the frozen pears lacked flavor and were not considered satisfactory. Some variation in quality from season to season has been observed in the different varieties of frozen fruits.

Process Times for Glass-Packed Foods. (Cooperative project with the Glass Container Manufacturers Institute, The National Canners Association (Washington, D. C., and San Francisco, Calif., laboratories), and the California State Department of Health.) (J. E. W. McConnell and W. B. Esselen, Jr.) Experimental heat penetration data obtained with bentonite suspensions (1 and 5 percent) in glass jars of different sizes have been used in working out come-up time and cool correction factors which can be used in the application of Ball's mathematical methods for the calculation of process times for low-acid glass-packed foods. The percentage of the come-up time which may be applied as process time for glass containers corresponds very closely to the 42 percent value used for tin cans.

Under conditions of convection heating, jars appear to heat more slowly than cans of corresponding sizes. Heat penetration data indicated no difference in the heating rates of cans processed in steam and in water. In the case of conduction heating, the heating rate is somewhat faster for cans than for jars, in sizes larger than the "baby food" size. This results in a somewhat greater lethality for a given process for cans than for jars of corresponding sizes, with the exception of the "baby food" size.

It was found that rapid cooling of 5 percent bentonite in jars or cans can be brought about by high vacuum and adequate headspace. When the vacuum starts to form in the containers during the cool, boiling of the contents frequently occurs, and with this agitation of the contents, rapid cooling results.

Tin-Treated Glass Containers for Processed Foods. (W. B. Esselen, Jr., and . Fagerson.) Glass containers whose inner surfaces had received a thin coating of a tin compound were compared with similar untreated glass containers to determine the effects of the tin treatment on ascorbic acid, color, and flavor retentions of various foodstuffs packed in these containers. No significant differences were observed in apple juice, orange juice, asparagus, grapefruit juice, strawberries, green beans, and tomato juice, which were the foods selected for the study. The maximum amount of tin recovered from any of the foods packed in the treated containers was 5 p.p.m. from green beans which had been stored at 100°F. for six months.

Spectral studies on amber glass bottles indicated that the tin treatment did not appreciably affect the light transmission characteristics of these containers.

The Effect of Processing Conditions of Time and Temperature Upon The Enzyme Systems of Canned Acid Foods. (W. B. Esselen, Jr., A. M. Kaplan, and J. E. W. McConnell.) Processing times and temperatures for acid fruits, vegetables, and juices have usually been developed with the purpose of destroying or inhibiting the growth of microorganisms present in the food. With the exception of a few isolated foods and enzymes, little thought has been given to the effect of the process upon the enzyme systems involved, the assumption being that the enzyme systems are destroyed during the processing. Since it is known that enzymes play an important role in the deterioration of acid foods, the effect of heat processing on the principal enzyme systems of a representative group of acid foods was investigated. The investigation was further motivated by the possibility that the data obtained could be applied to the development of one of the enzyme systems as an indicator of adequate processing of canned acid foods.

As a result of this investigation a method has been developed for the determination of the thermal destruction conditions of the ascorbic acid oxidase and peroxidase of some acid foods that should find application in thermal destruction studies of the enzyme systems of other foods and biological systems. Thermal destruction curves of the enzyme systems studied follow a straight line within certain temperature limits when plotted on semi-logarithimc paper and are affected by some substances that are added to foods during canning. The processing requirements of time and temperature necessary to inactivate the peroxidase of experimental packs of acid foods processed under practical conditions can be accurately determined through the use of standard methods of process time determinations.

Influence of Food Ingredients on the Heat Resistance of Spoilage Organisms Encountered in Canned Acid Foods. (E. E. Anderson and W. B. Esselen, Jr.) Thermal death rate characteristics of suspensions of selected yeasts and bacteria were observed as they were affected by changes of the pH of the media from 3.0 to 7.0 and by various concentrations of salt (1 to 8 percent). At 140°F. the end-point of destruction (99.99 percent) of a suspension of *Saccharomyces cerevisiae* occurred within seven minutes in McIlvaine's buffer at pH 3.0. At pH 7.0, 40 percent longer time was required to accomplish the same degree of destruction.

Salt (NaCl) added to tomato juice in concentrations ranging from 1 to 8 percent caused a definite drop in pH, amounting to 0.4 to 0.5 pH units in the case of 8 percent added salt. An increased rate of destruction at all test temperatures (200° to 220°F.) was noted for suspensions of *Bacillus thermoacidurans* in tomato juice with added salt, particularly that containing 8 percent salt, in which case 99.99 percent destruction at 212°F. was effected in 60 percent of the time required by control suspensions in plain tomato juice.

Sterilizing Value of Come-Up Time in Processing Home-Canned Foods. (J. E. W. McConnell, N. A. Vanasse, and W. B. Esselen, Jr.) Preliminary investigations have been carried on to determine the percentage of the come-up time which may be applied as process time for home-canned foods processed in a pressure canner at 240°F. The time required, after the completion of the venting period, for the pressure canner to reach the desired processing temperature was taken as the come-up time. Come-up times ranging from 0 to 60 minutes were studied. The test media used were 1 and 5 percent suspensions of bentonite, representing convection and conduction heating products, respectively. Pint home-canning jars were used as containers. With 1 percent bentonite suspensions, 30 percent of the come-up time was equivalent to process time at 240°F.; while 50 percent of the come-up time could be applied as process time in the case of 5 percent bentonite. The effect of the come-up time on the length of the process time was independent of the pressure canner load and of the rate of cooling in the jars.

Trimethylamine Production as an Indication of Spoilage in Fish. (C. R. Fellers, and D. Anderson.) The effect of temperature on trimethylamine production in samples of swordfish stored at 75°F., 40°F., and 32°F. was studied. Trimethylamine formation decreased with a decrease in storage temperature. A correlation of trimethylamine and ammonia formation was noted only at the highest storage temperature used. No correlation was observed between trimethylamine and bacterial content.

A method was perfected for obtaining sterile fish muscle press juice, which was used as a medium for determining that chemical autolysis occurring in fish muscle did not reduce trimethylamine oxide to the amine. Fifty microorganisms isolated from spoiled fish muscle were tested for the trimethylamine oxide reducing characteristic. Those microorganisms which reduced the oxide were identified as members of the coliform group.

Chemical dips of a 0.3 percent solution of sodium benzoate and a 0.2 percent solution of sodium nitrite inhibited the formation of trimethylamine. Acetic acid and sodium chloride dips did not affect trimethylamine amine formation in swordfish muscle.

Stability of Color in Fruit Juices. (J. E. W. McConnell, E. A. Nebesky, and W. B. Esselen, Jr.) The effect of length of storage, and the relationship of oxygen, light, sugar, pH, and ascorbic acid to deteriorative changes in the color of seven representative fruit juices (blueberry, currant, raspberry, tomato, grape, strawberry, and cherry) and strawberry fountain syrup have been investigated. Similar studies were made on solutions of purified anthocyanin pigments isolated from strawberries and currants to observe whether deteriorative changes in juices of these fruits were directly associated with changes in the pigment.

Temperature of storage and oxygen content were the agents most responsible for deterioration of color during storage of both juices and isolated pigments. Exposure to light caused little deterioriation of color in the juices, but exerted a measurable bleaching effect on the isolated anthocyanin pigments. Adjustment of pH values had little effect on deterioration of color in fruit juices, but some effect could be observed in solutions of isolated pigments. Sugar had little effect on stability of color in either juices or pigment solutions. The addition of l-ascorbic acid (50 mg. per 100 ml. of juice) had no protective effect on color stability with any of the juices except blueberry and grape. Addition of similar concentrations to strawberry anthocyanin, resulted in virtually complete decolorization of the pigment.

The Non-Enzymatic Browning of Foodstuffs. (W. B. Esselen, Jr., V. Lewis, and C. R. Fellers.) A study was made of some of the reactions that result in the browning of foodstuffs. A method was evolved for the determination of carbon dioxide production in foodstuffs and in reaction mixtures. All foodstuffs examined produced carbon dioxide spontaneously on incubation. Some of the melanoidin pigments resulting from the reaction between glucose and glycine were isolated, and the degree of pigment production in this system correlated with carbon dioxide production. The Maillard type of reaction was not restricted to amino acids, but reactions of a similar nature were found to occur between glucose and carboxylic acids in general. Oxygen was found to be an important factor in the development of color, and sulfur dioxide was an effective inhibitor of browning. Color produced as a result of caramelization was insignificant as compared with the glucose-carboxylic acid reaction.

The Preservative Effect of Mustard on Fruit Juices. (S. G. Davis, Omer Kosker, and C. R. Fellers.) An investigation was conducted to study the preservative effect of mustard on fruit juices. Apple and grape juice were selected as test media and the relative effects of the active principles of common mustard seeds were investigated as well as of synthetic and natural oil of mustard. The minimum amount of mustard and mustard oil necessary for preserving the juices at varying temperatures was determined. The changes in chemical composition of the juices, as well as in their flavor and appearance, occurring under varying storage conditions were also investigated.

The inhibitory effects of mustard and mustard oil on typical spoilage organisms were determined by inoculating the sterile juice with typical spoilage organisms.

The active principle of mustard, allylisothiocyanate, had definite preservative effect on the fruit juices tested.

Processing Methods for Home-Canned Fruits. (Cooperative Project with the Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.) (W. B. Esselen, Jr., and N. W. Desrosier.) Heat penetration data on home-canned fruits obtained during the summers of 1945 and 1946 were analyzed, and a theoretical "run" representing the slowest heating and the fastest cooling characteristics was established for each of the following products, in pint and quart jars, for water bath and for 1, 5, and 10 pounds steam pressure processing: rhubarb, strawberries, cherries, raspberries, blueberries, peaches, apple sauce, tomatoes, and tomato juice.

Preliminary work showed that the use of pressure processing of fruit products significantly reduced the processing time required to yield a given sterilization value. The use of 1 pound steam pressure in place of water bath processing reduced the process times 25 to 35 percent, higher pressures decreasing the process to partial "come-up times." This is due to the lethality of temperatures over 212° F., when based on organisms with F_{212} of 1.0 or less.

Work with water bath processes showed that the use of high initial temperature (160°-170°F.) in comparison with temperatures in the range of 100°F. reduced the process times 50 to 75 percent.

The fruits processed under 1 pound steam pressure were organoleptically superior to those processed for greater periods of time in the water bath, both yielding the same sterilization value.

Home-Canned Baked Beans, Hominy, and Irish Potatoes. (Cooperative Project with the Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.) (W. B. Esselen, Jr., N. Vanasse, N. W. Desrosier, and A. Sizer.) Work is being carried on to obtain information on the process time requirements for home-canned baked beans, hominy, and Irish potatoes packed in pint and quart glass jars and No. 2 and No. 2½ tin cans. During the past year data on heat penetration, inoculated pack, and thermal death time were obtained for these products. The work is being checked and expanded this year in order to have additional information upon which process times may be based.

DEPARTMENT OF FORESTRY AND WILDLIFE MANAGEMENT

R. P. Holdsworth and R. E. Trippensee in Charge

The Effects of Growth Rate and Wood Density of Plantation-Grown Red Pine on Certain of its Properties and Uses. (James M. Ring and J. H. Rich.) During the summer of 1947 field observations were made in 35 plantations of Red Pine located in New York, New Hampshire, and Massachusetts. Thirty-four samples of pole size were taken from eight of these plantations and one natural stand. Sections ten feet long were subjected to transverse bending tests, and the results were correlated with growth rates. The purpose of the study was to determine the feasibility of shortening the rotation without sacrificing the strength properties of poles.

Results obtained indicate that plantation-grown Red Pine which has made rapid growth during early life, and which has later slowed down forming a shell of dense growth has equally high strength, for use as poles, with Red Pine which has grown slowly from the beginning.

Spacing in plantations can be used to control rates of growth. It was further concluded that Red Pine grown in wide spacing producing low density cores results in stems more free of sweep and crook, and therefore more desirable for poles. This study was supported by the American Creosoting Company.

Gray Squirrel Damage to Lead-Covered Telephone Cables. (Paul A. White.) This work has been carried on since March 1946 and financied by the Bell Telephone Laboratories of New York.

The problem was to find the cause of gray squirrel damage to lead-covered telephone cable and if possible to find a way of preventing the damage. The research was carried on mostly with caged squirrels, but field checks were made in locations of damage, and data collected by the various telephone subsidiaries were analyzed and evaluated. The results of the study indicate that the attack on the cable is due to a nutritional disorder which is similar to the condition in cattle known as depraved appetite. This is caused by lack of calcium and phosphorus in the diet.

It is also possible that lead acts as a partial substitute for the calcium in the diet of the squirrels. The time of damage, of which there are two peaks, seems to indicate that the damage is related to pregnancy or lactation of the adult squirrels or to the time when the squirrel broods begin to feed for themselves.

Of the numerous repellents and cable protectors tried, Glass Fiber Cloth Tape seems to hold the greatest promise.

Pheasant Physiology. (Herman Goodell.) The purpose of this project was to determine whether a strain of pheasants could be developed to meet the needs of growers attempting to raise pheasants for meat.

Pure Mongolians and a Mongolian-Chinese ring-necked cross proved to be less nervous and slightly larger than straight Chinese ring-necked birds.

Sexing of day-old pheasant chicks was successfully accomplished. A pen of eight caponized males did not develop faster than did a pen of normal males handled under similar conditions.

No successful way was found to detect fast-developing birds through the inspection of plumage at an early age. There was enough variation between the development of different individuals to indicate that larger and faster growing birds could be produced.

Seeds in Relation to Rodents. (R. E. Trippensee.) The destruction of tree seeds by rodents prevents the establishment of stands of many trees, both softwoods and hardwoods, by direct seeding methods.

In this experiment, tests were run with pelleted pine and spruce seeds to which forty different chemicals had been incorporated as part of the series of coatings. The list of chemicals used can be furnished on request.

Concentrations of repellent substance varied from 1 to 5 percent. The trials were run with gray and red squirrels, chipmunk, and pine, meadow, house, and white-footed mice. The pelleted seeds were fed in special cages in which the feed was placed in a glass feeding receptacle. No other feed was available during the feeding trials. The test animals were given normal food after intervals of about three days.

These trials indicated that different rodents react differently, but in general none of the forty repellents gave much promise of protecting tree seeds from the rodents tested.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Anne W. Wertz in Charge

The Effect of Certain Factors in Wilson's Liver Fraction L on the Utilization of Thiamine. (A. W. Wertz, L. E. Lloyd, and P. Shaw.) The widespread use of crystalline thiamine in the food-fortification program lends importance to the question of whether the utilization of thiamine may be influenced by other members of the vitamin B-complex. A norit eluate preparation which contained, in addition to pteroylglutamic acid, other factors in the vitamin B-complex was prepared from Wilson's Liver Fraction L. Albino rats fed this preparation stored more thiamine in their tissues than their pairmates which did not receive the eluate preparation but were fed identical amounts of thiamine. The urinary output of thiamine and pyruvic acid did not differ significantly in the two groups. These facts indicate that there was some factor present in the norit eluate preparation that influenced the storage of thiamine in the albino rat. Work is continuing on this project in order to determine, if possible, the factor responsible for this effect on thiamine.

The Effect of Pteroylglutamic Acid on the Appetite and Growth of Thiamine-deficient Rats. (P. Shaw and A. W. Wertz.) Preliminary work indicates that pteroylglutamic acid stimulates the appetite and growth of rats fed a thiamine-deficient ration. The rats fed pteroylglutamic acid consumed their food in a much shorter time and maintained their weight at a higher level than their littermate controls not receiving this vitamin. Further work is in progress on this problem.

The Effect of Alcohol Consumption on the Utilization of Thiamine. (L. E. Lloyd, P. Shaw, and A. W. Wertz.) The similarity between alcoholic polyneuritis and the polyneuritis caused by thiamine deficiency suggests the hypothesis that the metabolism of alcohol in the body increases the need for thiamine. An experiment was designed to test this hypothesis, using albino rats as the experimental animal. Results indicate that the tissues of the rats receiving a daily supplement of alcohol contained more thiamine per gram than the tissues of their littermate controls which were fed an iso-caloric ration containing the same amount of thiamine but no alcohol. Also, the group receiving the alcohol excreted less pyruvic acid in their urine than the controls. These facts indicate that the rats receiving the alcohol were in a better state of thiamine nutrition than the rats not fed the alcohol, and that the consumption of alcohol did not increase the need for thiamine. Work is continuing on the project.

The Nutritional Status of Pregnant Women. (A. W. Wertz, P. Shaw, M. E. Lojkin, and E. Morse.) This project is being carried out in cooperation with the Northeast Regional Cooperative Project, Studies in Nutritional Status, and with the cooperation of Dr. E. M. Holden of Amherst. An attempt is being made to determine the nutritional status of pregnant women by studying their dietary habits and physical condition, and the quantity of certain nutrients in their blood and urine. This project is also concerned with the determination of the most suitable methods for use in studies on nutritional status. This project is to be continued for approximately three years. No results are as yet available.

The Amount of Certain Nutrients in the Cord Blood in Relation to the Amount of these Nutrients in the Pre-natal Maternal Diet. (A. W. Wertz, M. E. Lojkin, and P. Shaw.) This project is being carried on with the cooperation of Dr. E. M. Holden of Amherst. At parturition samples of the cord blood are obtained and the serum analyzed for protein, ascorbic acid, thiamine, riboflavin, niacin, vitamin A, and carotene. The amounts of these nutrients found in the serum are compared with the amounts present in the pre-natal maternal diet and any correlation noted.

The Validity of the Values in Food Composition Tables for Use in the Calculation of Nutrients in Specific Diets. (M. E. Lojkin, P. Shaw, E. Morse, and A. W. Wertz.) Food composition tables are used extensively for the calculation of the adequacy of dietaries in respect to specific nutrients, especially vitamins and minerals. As these tables are compiled from experimental results obtained all over the United States, it is pertinent to know whether the tables are valid for calculation of dietaries in Massachusetts.

A composite sample of a day's food intake is analyzed in the laboratory for protein, fat, thiamine, riboflavin, niacin, ascorbic acid, vitamin A, carotene, calcium, phosphorus, and iron. The analytical results are compared with the values obtained by calculation of these nutrients from the table of food composition. The degree of agreement or discrepancy in the figures is noted. A suitable number of dietaries will be analyzed in order that statistical methods may be applied in the interpretation of the result.

Rodenticide Investigations. (L. R. Parkinson.) Studies are under way to investigate the reason for the variation in the resistance of rats to red squill. Early results indicate that this variation may be due largely to the nutritional status of the rats. Heredity may also be an important factor. The apparent seasonal variation in the toxicity of alpha-naphtha-thio-urea (ANTU) is also being studied.

DEPARTMENT OF HORTICULTURE

Clark L. Thayer in Charge

Study of Herbaceous Perennial Material. (C. J. Gilgut, Waltham.) The test garden of herbaceous perennial flowering plants was visited throughout the season by many people from Massachusetts and from other States. It will remain in its original location now that another site has been chosen for the proposed new laboratory and administration building.

A good blanket of snow, soon after the ground froze in the fall and during the winter, protected the plants so that few were lost by winterkilling. Some replacements of plants lost for various reasons, and of old varieties superseded by newer and more desirable varieties in the trade, have been made; but much more replacement needs to be done, especially of Hemerocallis. Already a good start has been made on a collection to include in this group of plants the newer colors such as reds, pinks, apricots, and bicolors, and also plants of better habit and more garden value.

A buyer of phlox plants at present has no assurance that he will receive true to name or even good phlox. On one order of eight named phlox from a mail order nursery doing business nationally, six plants were the same—a worthless, small-flowered, magenta-colored scrub seedling. Similar mixtures and also misnamed plants have been received from other nurseries.

The Delphinium collection has been augmented by addition of several strains and by selections from our own plantings.

Foliar nematode is a serious pest of outdoor chrysanthemums and the effectiveness of sodium selenate in several forms, varying dosages, different methods and time of application, as well as spraying at weekly intervals with wettable DDT powder were tested. The results were inconclusive and the test is being repeated this year.

Control of Weeds in the Nursery by Chemical Sprays. (C. J. Gilgut, Waltham.) Sovasol No. 5 was found to be a more desirable and effective weed-killer in the nursery than 2,4-D ester formulations (Weedone, Weed-no-more 40, Weeded, and Esteron) or the ammonium and sodium salts of the 2,4-D acid with which it was compared. It killed grass and other weeds quickly and, when properly controlled so that the spray did not strike nursery plants, caused no injury. Concentrations of 2,4-D necessary to kill grass caused delayed injury to nursery plants, sometimes serious, from direct spray as well as from drift of vapors of the volatile ester formulations, especially in hot weather.

Early-season applications of Sovasol No. 5, when weeds were 4 inches high or smaller, often gave weed control for as long as six weeks. In several cases two or three applications were sufficient for the season, but in most cases applications were needed at intervals of about four weeks. Late March and early April applications, when temperatures were 60° F. or less, gave good weed kill but not as good nor as quick as later in the season when temperatures were above 70° F.

In a nursery block of large plants, 5 to 6 feet high, large weeds were killed by first scything and then spraying with Sovasol in hand sprayers at one-third the cost of hoeing.

Spraying rows of gladiolus corms and cormels at the first sign of emergence of shoots through the soil gave excellent results and eliminated the first hand weeding. The spraying was done with a 3-gallon pump-up hand sprayer, and the spray applied at a moderate walk, as compared with hand weeding done tediously and always on hands and knees. Hand weeding was necessary after the plants were up because gladiolus is easily injured by Sovasol.

Factors Influencing the Rapidity of Growth of Nursery Stock. (C. J. Gilgut, Waltham.)

Rhododendron Leaf Bud Cuttings. Leaf bud cuttings of *Rhododendron roseum elegans* taken in November rooted 87 percent by May, of which 58 percent had very good roots; 16 percent good, and 13 percent fair. Lined out in the field, these plants have grown to fine salable 2-foot plants in three years. Best rooting was of cuttings from firm current wood treated with Hormodin No. 2 powder and placed in horticultural peat moss or Sanisoil (shredded redwood bark). Care was taken that the peat moss was kept moist but not wet. Other highly desirable varieties of named evergreen rhododendrons did not root well under combinations of conditions and treatments tried.

Effect of pH, Nitrogen, Phosphorus and Potassium on Growth of Yews. The preliminary work was carried on in pots in the greenhouse and treatments were as reported in 1947. This year the same treatments were given plants in the field. As yet there are no clear-cut results.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Asparagus Investigations. (Robert E. Young, Waltham.) The year's results with the second generation lines of asparagus breeding material showed a continuation of the biennial bearing effect reported in 1946. The crop was very poor, being 25 percent below that of the previous year but only 6 percent below that of 1945. The relationship between the selected strain and the commercial strain remains the same as previously reported. No rust appeared on any of the plants.

The nineteen strains and varieties of asparagus that make up the third generation planting were cut for the first time for two weeks in 1947. Although the cutting period was short, the yield, comparatively considered, was good. The best strain produced .36 pounds of asparagus per plant. The yield of the two commercial strains was only half of this. There was a similar range in the size of spears, from 19 to 28 per pound. While the highest yielding strain happened to be the one producing the largest spears, in general there did not seem to be a very close relationship between size of spears and yield. The strains which produced small spears came from parents that had a record for high yield but small spears.

There existed a good relationship between the number of stalks produced in the summer and the number of spears harvested. The relationship between the stalk counts and weight of spears was not as good as in previous crops.

Only 14 plants died during the year as compared with 46 the previous year. Some strains still have 100 percent plants while others have lost as many as 15 percent. This seems to be an hereditary character.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding work was conducted with broccoli, celery, New York type lettuce, greenhouse tomatoes, trellis and field tomatoes, carrots, cabbage, and Butternut squash. Progress has been made in the development of strains of lettuce and cabbage better adapted to local use. Work was along the lines previously indicated, but new developments are not conclusive enough to warrant detailed report at this time.

Carrots.—During the year a search was made to find a carrot variety which would have better color than the Hutchinson but still retain the strong top, resistance to carrot blight, and, of course, the long slim root. Fifty different varieties and strains were collected from many seedsmen in both the United States and Europe. These varieties were grown as spring, summer, and fall crops.

The nine varieties obtained from Europe either were too short or produced light-colored roots. The various strains of Imperator, which is the variety grown in the West, produced a weak, small top when grown in New England. In our soil the roots of this variety are not as long as those of Hutchinson. The color is good but the tops are very susceptible to carrot blight. All of the other varieties failed to meet the standard in one way or another.

Since no variety was found to replace the Hutchinson, the breeding program to produce better-colored roots, which has been under way, will be enlarged and intensified. Roots that most nearly fit the standard were produced from material that came from crosses of Hutchinson and Turkey Red or Imperator. Considerable testing is necessary to determine adaptability, resistance to disease, and market acceptance.

Broccoli.—Spring and fall broccoli trials again indicated that Waltham No. 7 is suited for planting in the spring, while strain No. 29 must be grown in the fall so that the plant can develop during warm weather. Waltham No. 11 has proved adaptable for both spring and fall growing.

During the late fall of 1947, the weather was such as to demonstrate the value of strain No. 29. It is slow growing and does not easily push up to flower. Production averaged slightly more than 1 pound per plant.

There was wide variation among the many varieties in the trials to freezing damage. On some varieties 70 percent of the crop cut November 3, 1947, following a sharp freeze, was unmarketable; Waltham No. 11 had 55 percent not marketable; and Waltham No. 29 only 22 percent. This hardiness factor is important since the harvest continues well into late fall.

In 1948, cold wet weather for several weeks following transplanting of the spring crop to the field caused the plants to produce a small button of a head before obtaining their proper size. Subsequent warm weather caused these small buds to push up rapidly, forming either a worthless head or one only about one-fourth the usual size. This is the first time in ten years that the weather has been so adverse as to affect almost all varieties and strains. Waltham No. 7 made the most rapid recovery and proved the best. In 1947 it produced 1.1 pounds marketable broccoli per plant and this year only 0.77 pound. Waltham No. 11 produced 1.0 and 0.62 pound respectively for the same periods.

Celery.—The fifth generation of plants from a cross between Summer Pascal and Cornell No. 19 was grown. Fifty single-plant selections from the 1945 crop were tried. Along with these were trials of stock seed lots of our strain of Summer Pascal, and Summer Pascal from various seedsmen as well as new varieties recently introduced.

None of the new varieties was as good as Summer Pascal under our conditions. From the breeding material, four lots of green and one of semi-green proved sufficiently good to warrant further trial.

On some types of soil Summer Pascal has been too short, and one selection was made of a taller type to fit this need. One selection was made on the basis of its performance in the hotbed where the crop is left for early maturity. The other two have other points of superiority over Summer Pascal. Trials over several years are necessary to prove adaptability.

Trellis Tomatoes.—In order to bring the highest prices on the Boston market, tomatoes must have the following characters: (1) firmness, not only while ripening but when completely ripe; (2) smoothness and uniform size; and (3) uniform, deep red color. Not only do tomatoes with these characters meet with acceptance in Boston, but other New England cities and New York City have paid premiums for such fruit.

Trials of tomato varieties and hybrids have been judged with the firmness character in mind. Results indicate that many hybrids, while satisfactory in other respects, do not meet the firmness requirement. Crosses between Trellis No. 22 or Waltham Forcing and such varieties as Bonny Best, Stokesdale, Earliana, and Pritchard produced fruit that was too soft. Red Cloud, Harkness, Michigan State Forcing, and Quebec No. 5 have proved fairly satisfactory as parents.

The average early yield (first three pickings) of 10 hybrids was 3.94 pounds per plant compared to 2.78 from Trellis No. 22. Where the plants were not trellised but grown flat, the hybrids showed to better advantage. Trellis No. 22 X Red Cloud produced 5.91 pounds of fruit per plant compared to 2.39 from Trellis No. 22. This hybrid is probably sufficiently firm to satisfy the market.

Two new varieties showed to sufficient advantage to warrant recommending them to growers for trial. These are Quebec No. 5, from Laval University, Quebec, and Early Trellis, a sister selection of Trellis No. 22.

Waltham Scarlet, a variety for the home gardener and roadside stand operator that was released last year, proved to be earlier than in previous trials, being equal to Trellis No. 22 when trained up and 75 percent as good when grown flat. Total yields under both methods of culture were about equal to those of Trellis No. 22. Its advantages are larger size and better interior color and texture, while still retaining most of the firmness of Trellis No. 22.

Greenhouse Tomatoes.—A spring crop of greenhouse tomatoes was grown for comparison of Waltham Forcing with other varieties and hybrids.

A hybrid between Waltham Forcing and Michigan State Forcing produced 10 percent more fruit than the Waltham Forcing. While this increase in yield is sufficient to justify continued interest and trial, the fact that 33 percent more of the fruit graded No. 1 is more impressive. At prevailing Boston Market prices, cash returns amounted to $2.39 per plant for the Waltham Forcing and $3.06 for the hybrid.

The hybrid had larger fruit, requiring 4.84 to weigh one pound as compared with 5.38 for Waltham Forcing, and more vigor, and the plants remained greener than the Waltham Forcing. Limited trials in growers' greenhouses have aroused favorable comment, and seed production will be increased so more extensive trials can be made. More information is also being obtained about the cost of producing the hybrid seed.

Butternut Squash.—During the year a crop of Butternut squash was grown in the greenhouse in an effort to make up for the small number of selfed fruit obtained in 1946. This crop was grown on trellis, in the same manner as cucumbers, and produced very satisfactory fruit. Even though seed was started on February 15, only a part of the crop had matured by May 25, the time for planting seed outside.

The summer crop was satisfactory as regards yield, with the best strain producing over 500 boxes per acre. Insufficient data were obtained from many lines because of inadequate stand. It was necessary to replant some rows because of failure of greenhouse-grown seed. Planting June 15 reduced the tota yield 16 percent, and the yield of No. 1 squash 8 percent, and there was a slight reduction in the number of culls, also of cracked squash. The late planting increased the percentage of crooked squash from 6.4 to 12.4 percent.

An analysis of the data indicates a complex interrelationship between the percentages of the various grades the strains produced and the weather during the growing season. In 1946 the average percentage of cracked squash was 17.1, and in 1947, 25.8 percent.

Inbred lines are being obtained that have one and sometimes two desirable characters fairly well fixed.

Storage tests were made of all inbred lines in search of material that would have lower weight losses in storage and keep for a longer time. None of the lines kept significantly better than others. Some squash within all lines kept until January 15. The average loss in weight in this period was 22 percent, not counting the loss due to disease. When the squashes were waxed with a wax emulsion, the loss in weight was reduced 45 percent. The loss in weight was further reduced (30 percent) when the squashes were wrapped in pliofilm. The wrapping was done not as a practical method of storage but as a means of investigating weight loss.

Breeding Sweet Corn, Peppers, and Field Tomatoes for Massachusetts. (William H. Lachman.)

Sweet Corn.—Approximately 4,000 plants were self-pollinated during the year to further stabilize inbred lines in the process of development and to increase the seed supply of lines that are homozygous. Two crops were grown in the greenhouse in an effort to speed up the program and while the fall crop was not satisfactory the early spring crop was quite successful. With supplementary artificial lighting, a crop has been grown early in the spring for three years. It is true that inbreds do not mature in their proper season in relation to one another when grown indoors but sufficient benefits have resulted from this process so that the work has been greatly facilitated. One large seed producer in Idaho has cooperated in testing our inbreds in the production area, which has also proved to be a valuable adjunct to the project.

Ten extra early inbreds are now ready for testing in hybrid combination. These have been produced through back-crossing extra early types with later, more desirable, market types. A program of eventually combining sixteen superior inbreds into one hybrid has also been initiated. When this has been accomplished the potential mixture of germ plasm should provide some very desirable types upon self-pollination.

Several hundred experimental hybrids were grown and studied as to their general adaptability for this area. Thirty-two of these were noted as being desirable and will be included for further study.

One outstanding hybrid named Pilgrim has been introduced to the trade. This is produced by crossing Massachusetts 32 with Connecticut 27, is midseason in maturity, and the plants produce an excellent yield of large attractive ears. Approximately twelve tons of seed were sold by seedsmen to farmers for production this year.

Two new hybrids will be released in 1949. One is an extra early sort resulting from a cross of Connecticut 3 and Massachusetts 2410-191. The other is a second-early, high-quality variety resulting from crossing Massachusetts 2412-2 x 2412-1 by Maine 2.

Peppers.—The production of sweet peppers is greatly hampered in this area by the poor setting of fruits among the standard varieties. Serious infestations of tobacco mosaic also take their toll. Several strains of Worldbeater have shown themselves to be resistant to this disease but they are variable within these strains as to productiveness. A number of single plant selections appear to have considerable merit. Seed is now being increased so that they may be sent out for trial.

Tomatoes.—A number of F_1 hybrids introduced by seedsmen and experiment station workers indicate that this type variety may have considerable merit. One of the hybrids developed and tested here, Pennheart by Firesteel, performed exceptionally well in the trials last year. Several selections now in the F_6 generation from a cross of Bounty by Stokesdale also look very promising. One of the lesser known varieties, Firesteel, and selections from this variety were among the best of the early varieties. These plants were especially prolific and the fruits were large, solid, and smooth.

Weed Control in Vegetable Crops. (William H. Lachman.) The use of Stoddard Solvent as a weed control agent in fields of carrots and parsnips is now considered standard practice by commercial vegetable growers. There is a tendency to apply this material rather late in development of these crops with the result that a rather severe necrosis develops in the crown of the roots. This is particularly disturbing since these roots do not keep well in storage.

The results from studies designed to find selective weed killers for set onions have been most promising. Recently some investigators have recommended the use of a .5 percent solution of sodium pentachlorophenate for this purpose. This material was not effective in killing annual grasses, however, and the yields from these plots were the lowest among the treatments. Dinitro compounds such as Sinox and Dow Selective Herbicide were also ineffective in controlling annual grasses but did not damage the onion tops as much as the previous treatment. The yields from these plots were also significantly lower than those from the cultivated plots. Plots in which the weeds were controlled with a hand weed burner also yielded less than the checks, although not significantly so. Good weed control but with rather severe damage to onion foliage resulted from several applications of Aero Defoliant Chemical Dust (Cyanamid) at the rate of 60 pounds per acre. The average yields from these plots were also lower than from the checks although the difference was not significant. Some preliminary work with Aero Cyanate Weed Killer (potassium iso cyanate) indicates that this material is well adapted as a weed killer in the culture of onions. It is relatively harmless to onion foliage in low concentrations (1 to 2%) and is toxic to most small weeds until they have developed to about ¾ inch high. Lamb's quarters is especially resistant to this material after it has passed the cotyledon stage.

Isopropyl n-phenyl carbamate at the rate of 5 pounds per acre was particularly effective in controlling annual grasses in a late summer planting of spinach and beets. Overwintered spinach on these plots was completely free from chickweed whereas the check plots were badly infested with this weed. In a cooperative experiment with one vegetable grower isopropyl n-phenyl carbamate at the rate of 5 pounds to the acre was very effective in controlling chickweed in a planting of early spring lettuce.

Pre-emergence application of No. 2 fuel oil prevented the growth of weeds in sweet corn for a period of 5 weeks. 2, 4-D, in pre-emergence applications to fields of sweet corn at rates of 1½ to 2 pounds per acre, was particularly effective in preventing growth of weeds except for smartweed which is apparently very resistant to this treatment. Post-emergence applications of 2, 4-D were ineffective in controlling grasses. Pre-emergence applications of Dow Contact Weed

Killer at the rate of 2 to 3 gallons per acre were very effective in controlling weeds in fields of sweet corn as well as snap beans. Granular cyanamid at the rate of 600 pounds per acre prevented weed growth in sweet corn for about 4 weeks.

The Culture and Nutrition of Vegetables. (William H. Lachman.)

1. Tomato plants mulched with manure produced fruits higher in soluble solids, nitrogen, and phosphorus than those mulched with straw or sugar cane fiber or unmulched. Plots mulched with sugar cane fiber produced lower yields than any of the other treatments, but fruits from these plots were highest in total sugars, carotene, ascorbic acid, calcium, phosphorus, and potassium. The soil in the plot mulched with manure was in the best physical condition, and the organic matter and nitrogen were higher than in the other treatments. (In cooperation with Dr. Holmes of the Chemistry Department.)
2. Defoliation in determinate varieties of tomatoes such as Pennheart is very serious just as ripening of the fruit begins. Through experiments with varying degrees of blossom removal at anthesis, it was found that an inverse relation exists between fruit load and retention of the foliage.
3. A chlorotic condition found on the older leaves of greenhouse tomato plants has been diagnosed as magnesium deficiency. Experiments using soil known to be deficient in magnesium indicate that this chlorotic condition may be alleviated by applications of magnesium sulfate or dolomitic limestone. More response from this treatment results if it is combined with a heavy application of manure. Applications of potash aggravate the chlorotic symptoms.
4. The use of a plant hormone applied as a spray was effective in increasing the early set of tomatoes. Fruits set well on flowers that had been emasculated before anthesis and were entirely seedless.
5. Automatic surface watering of greenhouse tomatoes has a distinct possibility but the proper level of soil moisture content has not been determined. A layer of sand about one inch deep on the surface of the soil was found to be of value in distributing water laterally over and through the beds.

DEPARTMENT OF POMOLOGY

A. P. French in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties. (W. D. Weeks and F. W. Southwick.) Although frost reduced the 1947 crop in the large stock-scion orchard, the crop was the largest to date. Eight-year-old trees of Red Spy on Malling II averaged over a bushel of fruit per tree, while trees on Malling XVI averaged less than one-tenth bushel. In general, the yields of other varieties were greater on Malling I and II than on other stocks.

Seeds of two ornamental type crabapples, *Malus sikimensis* and *Malus toringoides*, which show promise as rootstocks, were obtained from the Arnold Arboretum. Seedlings of these will be budded to several commercial varieties for testing as to their value for root-stocks.

Lethal Incompatibilities Between Clonal Stocks and Varieties of Apples. (W. D. Weeks.) More evidence was obtained to show that the lethal factor in McIntosh strain R can be transmitted to the congenial McIntosh strain G. It was also demonstrated that the lethal factor in strain R does not depend on any material manufactured in the leaves. Spy 227 stock budded to strain R buds which were sheared off in November died in typical fashion the next summer. Although the trouble appears to be caused by a virus there is no evidence that it can be transmitted except by budding. New combinations of varieties or strains budded on Spy 227 reveal that Red Spy, Foster Gravenstein, Whitcomb Gravenstein, Mead Gravenstein, Rhode Island Greening, Baldwin, and Galbraith Baldwin all died in typical fashion; while Northern Spy, Milton, Kendall, Early McIntosh, and Macoun made normal growth. A paper will be published in the Proceedings of the American Society for Horticultural Science.

Magnesium Deficiency in Massachusetts Apple Orchards. (W. D. Weeks.) Leaf samples for chemical analysis were taken again during 1947. Analyses of the 1946 samples indicate that mature apple trees which had received 30 and 60 pounds of magnesium sulfate per tree did not have their magnesium content increased appreciably over check trees. The low magnesium content of the leaves of the 1946 samples indicates that many of these trees were deficient in magnesium but they failed to show any typical deficiency symptoms during the growing season. Analysis of the 1947 samples is not complete at this time so we do not know whether heavy soil applications of magnesium sulfate have been successful in increasing the magnesium content of mature apple trees. No typical magnesium deficiency symptoms were observed on these trees during the 1947 season.

Influence of Chemical Treatments on Flowering and Fruiting of Fruit Trees. (F. W. Southwick and W. D. Weeks.) Chemical thinning tests were conducted at Amherst and in three commercial apple orchards using the dinitro materials (DN#1 and Elgetol) at blossom time and the sodium salt of naphthaleneacetic acid (App-L-Set) at calyx time and two and four weeks after calyx. One test on Halehaven peaches was conducted using three dinitro materials (DN#1, DN#289, and Elgetol) at blossom time.

Although the bloom was heavy, the weather, except for the first two or three days when apple flowers commenced to open, was not conducive to a heavy set. During the bulk of the blooming period cool, rainy weather limited the extent of pollination. Under these conditions the set was not nearly as great as the bloom indicated it might be. Elgetol applied to Red Astrachan, Baldwin, and Duchess resulted in much more thinning and foliage injury than similar single or double applications of DN#1. Where the set was heavy enough to warrant thinning on Yellow Transparent, Wealthy, Duchess, and Early McIntosh, DN#1 gave satisfactory results. It no longer seems desirable to consider the liquid dinitro materials for blossom thinning of apples. In the peach test DN#289 reduced the set more than equivalent concentrations of either DN#1 or Elgetol.

Applications of 8 ounces of App-L-Set per 100 gallons of spray at calyx time eliminated the crop on Duchess apple trees and resulted in severe leaf dwarfing and distortion. Calyx applications of this material to Wealthy, McIntosh, and in some instances Early McIntosh, thinned satisfactorily at calyx time with much less foliage injury. App-L-Set appears to be more injurious to apple foliage when applied shortly after bloom than when used at the same or higher concentrations two and four weeks after calyx. Tests at Amherst and in one grower's orchard, using up to 16 and 20 ounces of App-L-Set per 100 gallons of spray four weeks after calyx on McIntosh, Golden Delicious, and Early McIntosh, show that chemical thinning can be accomplished at this late date. A treatment that can be made as late as four weeks after calyx has a distinct advantage over bloom or calyx applications, since the extent of fruit setting and the necessity for thinning can be rather accurately determined by that time. Of course, the earlier thinning can be done the greater are the chances of obtaining desirable commercial size with the least reduction in yield and of making alternate-bearing varieties bear more uniform annual crops.

The Nature of Winter Hardiness in the Raspberry. (J. S. Bailey and A. P. French.) By bringing raspberry canes into the greenhouse during the winter and observing the rate at which they started into growth it was found that the raspberry had a very short rest period and that there were varietal differences. This suggested that there might be a relationship between the length and intensity of winter rest and cold resistance.

To test this possibility canes of six varieties were brought into the greenhouse at regular intervals during three winters. The varieties Chief and Latham were selected as cold-resistant varieties, Marcy and Washington as tender varieties, and Milton and Taylor as intermediate in cold resistance. It was found that the cold resistant varieties go into a deeper rest and come out more slowly than the tender varieties. A report on this work will appear in the Proceedings of the American Society for Horticultural Science.

The raspberry planting used in this work was set in the spring of 1942. The planting was divided in half. One half was given a heavy mulch of hay or straw, whichever was available, and additional mulch added annually. The other half is cultivated with a cover crop sown in midsummer. These plots were subdivided, making a total of four plots. One mulched plot receives no additional nitrogen and the other $NaNO_3$ annually at the rate of 225 pounds per acre. One of the cultivated plots receives $NaNO_3$ annually at the rate of 225 pounds per acre, the other at the rate of 450 pounds. Until the winter of 1947-48 there was no indication of differential winter injury between the mulched and cultivated plots. During the winter of 1947-48 there was definitely more winter injury on the mulched plot.

Since the type of mulch used results in high soil nitrates, it was thought that nitrogen supply might be a factor. However, when the data were broken down according to the four plots varying in nitrate application, there was no relation between winter injury and the amount of $NaNO_3$ applied.

During the winter of 1947-48, freezing tests were made to determine the rate of hardening of raspberries. The only low-temperature rooms available were in a large room held at 0° F. for storing frozen foods and in a sharp freeze room ordinarily held at −15° F. Canes of the Chief and Latham varieties were used to represent cold-resistant varieties and canes of Marcy and Washington to represent varieties lacking cold resistance. On November 18 and December 1 canes of all four varieties were severely injured by 24 hours' exposure to 0° F. On January 13, following a period of several days with temperature near 32° F., sudden exposure to 0°F. resulted in less injury than in previous tests. By shutting off the ammonia and opening the door, the temperature in the sharp-freeze room was raised to 30° F. Lots of canes were placed in the room and the door shut. The temperature dropped to +9° F. in one hour and fifteen minutes and to +7° F. in 24 hours. This treatment resulted in slightly less injury than sudden exposure to 0° F.

Another lot of canes was brought in for test February 19. At this time there was evidence that injury had occurred outside. Exposure to 0° F. caused some injury, but the difference between treated and check was not great because of the injury which occurred before the canes were brought in. Exposure to 0° F. caused less injury than earlier in the season. The hardy varieties, Chief and Latham, withstood the temperature drop better than the tender varieties, Marcy and Washington.

Chemical Control of Weeds. (J. S. Bailey.) In 1946 and 1947 it was found that ammonium sulfamate and a proprietary weed killer containing sodium chlorate and a deflagration agent could be used around apple trees four years of age to control weeds. A report of this work appeared in Vol. 51 of the Proceedings of the American Society for Horticultural Science.

To see whether these materials could be used around year-old apple trees and how much, applications were made in August, 1947. Ammonium sulfamate was used at ¾, 1½, 3, and 6 pounds per gallon and the proprietary mixture at 1, 2, and 4 pounds per gallon. One gallon of each concentration was sprayed in a circle about 6 feet in diameter around a tree. Treatments were made in quadruplicate.

Ammonium sulfamate at 6 pounds per gallon caused the trees to lose all their leaves in the late summer of 1947. A new crop of leaves started to appear later but these trees all died during the winter. The other concentrations caused a dwarfing of the trees roughly proportional to the amount used. Also, they caused in 1948 a chlorosis of the leaves which varied from a yellowing of the margins to a yellowing of the entire leaf.

One and two pounds of the proprietary mixture caused a slight dwarfing of the trees. Four pounds caused considerable dwarfing.

Since a circle 6 feet in diameter contains an area of about 28 square feet, the quantity of each concentration applied was nearly four times the amount which would ordinarily be used.

All concentrations of both materials killed all weeds including quack grass (*Agropyron repens*). A considerable growth of clover and some annual weeds in 1948 indicate that the soil was not sterilized for any great length of time.

In the spring of 1947 experiments were started on the control of weeds in strawberry beds with 2,4-D. A comparison was made between 2,4-D acid put in solution with Carbowax 1500, the sodium salt of 2,4-D, and an ester formulation. The ester formulation appeared to be too toxic to the strawberry plants. The 2,4-D acid and the sodium salt appeared about equally effective in the control of broad-leaved weeds and the effect on the strawberry plants was slight and temporary. The sodium salt is much easier to put into solution.

In the spring of 1948 these experiments were continued and expanded. One series of plots was laid out in a renovated bed where the sodium salt of 2,4-D, isopropyl-N-phenyl carbamate, dinitro-ortho-secondary-butylphenol, phenylmercuri acetate, Stoddard solvent, and some combinations of these are being tried. Another series of plots was laid out in a newly set bed where the sodium salt of 2,4-D, isopropyl-N-phenyl carbamate, phenyl-mercuri acetate, phenylmercuri triethanol ammonium lactate, and ammonium sulfamate and combinations of some of these are being tried.

Nutrition of the High-Bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) Leaf symptoms, which were very similar to those produced in sand cultures by withholding magnesium, appeared on a few of the blueberry bushes in the University planting at Amherst. In order to find out whether this was magnesium deficiency and whether or not it could be corrected by application of magnesium, a series of plots was laid out on some of which magnesium sulfate at 500 pounds per acre was broadcast on the soil and on others it was sprayed on the plants.

Leaf samples were obtained from these plots before and after treatment and from normal appearing bushes in the Cape Cod section. These samples were analyzed for P, K, Mg, and Ca by Mr. C. Tyson Smith of the Feed and Fertilizer Control Service. Compared with apple leaves, the content of P, K, and Ca was low, but Mg was not dangerously low. From July to September Ca increased, K increased in some cases and remained about constant in others, Mg changed little, if at all, and P decreased in some cases and remained about constant in others.

Blueberry Culture. (J. S. Bailey.) The spraying experiments for the control of mummy berry were continued through 1947. Bordeaux mixture was not effective in controlling this disease. Fermate alone gave some control, but best results were obtained when Goodrite p.e.p.s., a spreader and sticker, was added to the Fermate. P.e.p.s. alone appeared to have a little fungicidal value. A report of these results will appear in the Proceedings of the American Society for Horticultural Science. In the spring of 1948 diligent search for mummies producing apothecia was made on numerous occasions. Only one such mummy was found although numerous mummies in apparently good condition were present. In spite of the apparent absence of apothecia, a considerable number of infected berries appeared in early summer. Because of severe winter injury and the prospect of an extremely small crop, plans for continuing the spraying experiments in 1948 were abandoned.

In the spring of 1948 a commercial test of a dormant application of D-542 was tried for the control of a Lecanium scale. It appears to be effective and safe. A dormant application of D-289 was effective in controlling the scale but was very toxic to the blueberry bushes.

In July, 1947, several bushes of the varieties Cabot and Pioneer which were covered with bindweed were sprayed with the sodium salt of 2,4-D at 1,000 ppm. This one application killed the tops of the bindweed but some regrowth occurred late in the season. In the summer of 1947 there was no evidence of injury to the blueberry bushes except a slight twisting of some of the new shoots. However, in the spring of 1948 there was slight evidence that the sprayed bushes were winter injured more than adjoining unsprayed bushes.

Although the blueberry stunt disease has been present in Massachusetts for a number of years, no indication of its spreading was found until the summer of 1947. At that time evidence was found that it was spreading slowly in Plymouth County. In the early summer of 1948 a Grover bush definitely infected and a June bush which looks suspicious were found in the University planting at Amherst. These are definitely new cases and show that the disease is spreading here, too.

There are 20 U.S.D.A. selections in the University planting. Ten of these were set in the spring of 1948. Of the other ten, five, which were budded on Rubel stocks several years ago, have fruited. Of these five V-20 looks the most promising. GN-87 looks good enough to warrant further trial. F-72, R-86 and U-85 are of doubtful value.

Studies of Varieties of Fruits. (W. D. Weeks and Staff.)

Apples.—Galbraith Baldwin, a red sport of Baldwin, which originated in one of the experimental blocks, was introduced to growers and 16 eastern nurseries for their consideration. This strain shows considerable promise and both growers and nurserymen are anxious to obtain propagating wood of it.

A bud sport of McIntosh, obtained from Roger Kimball of Littleton, has been found by federal workers to be a tetraploid and offers promise as a parent for breeding.

Peaches.—The following varieties have been dropped from the trial list:

Hardee is not outstandingly hardy under Massachusetts conditions, and the fruit is unattractive in shape, color, and general appearance, and is poor in texture and flavor.

Duke of York is too small, too poor in quality, ripens too unevenly and is clingstone. It has nothing but earliness to recommend it and cannot compete with other varieties of its season.

Fisher has not been outstandingly hardy. The fruit ripens very unevenly, sometimes at one end first, sometimes on the outside, leaving the center hard and underripe. The quality is variable and no better than fair at its best.

Champion, although it has many fine qualities, has flesh which is too soft for shipping. Even for the back yard better varieties are available.

Polly is almost an exact duplicate of Champion. Like that old variety, it has many good qualities but the flesh is too soft.

Blueberries.—Among the U.S.D.A. blueberry selections which have fruited, V-20 looks the most promising. The berries, which ripen late midseason to late, are large and fine flavored and have a good blue color. However, the scar is rather large and watery and they seem rather susceptible to the mummy berry disease. The bush bears heavy crops for its size but is a bit small. Cold resistance of both wood and buds appears good.

GN-87 is good but probably not quite good enough. The berries are usually large and have had a very good blue color in most years. The scar is usually good but the flavor is often too mild. Berries ripen late and are slightly susceptible to mummy berry. The bush is vigorous and yields well. Cold resistance of buds and wood appears good.

The fruit of F-72 is very large, dark colored and tart, ripens late, and is slightly susceptible to mummy berry. The bush is moderately vigorous. The crop has been good in some years but very light in others probably as a result of spring frost.

R-86 usually produces a good crop which ripens late but the berries are small. Their flavor is fair to good and the scar is good. The bush lacks vigor.

U-85 has produced large berries but very few of them. They ripen late, are very firm, have good color and good flavor, but are very susceptible to mummy berry. The bush is only fair in vigor.

Grapes.—A new blue grape, the Cook, which ripens between Worden and Concord, appears to be a worthy addition to the list of blue grapes.

Raspberries.—The Milton red raspberry is the most promising of the New York introductions in every respect except winter hardiness. In this characteristic it is definitely inferior to Latham or Chief. Taylor is too seriously injured by virus diseases to be desirable.

Strawberries.—Among the newer varieties of strawberries under trial, the Midland, Temple, Fairland, and Sparkle look promising. All are good producers of better than average quality and firmness. Temple, Fairland, and Sparkle are also resistant to the Red Stele root disease. On the other hand, Robinson (Scarlet Beauty), which has been highly advertised, has not shown much promise in our trials so far.

DEPARTMENT OF POULTRY HUSBANDRY

F. P. Jeffrey in Charge

Broodiness in Poultry. (F. A. Hays and D. W. Talmadge.) The last generation in the non-broody line included 80 females. One individual exhibited broody behavior in the first laying year with but a single broody period. Most of these females have been retained to test for deferred broody behavior. This generation again demonstrated our inability to completely eliminate the broody instinct by selective breeding.

In the fall of 1947 about 80 females of different ages in the non-broody line were given prolactin injections to test for broody inheritance. Each female was in active laying and received 50 Internatonal units of prolactin intramuscularly. With very few exceptions, egg laying stopped within two days and was not resumed for 15 or 20 days. This treatment failed to initiate broody behavior in any of the birds.

Another lot of prolactin that is believed to be free of other hormone fractions is now being used to test all females in this line as a guide to future breeding operations.

Genetic Laws Governing the Inheritance of High Fecundity in the Domestic Fowl. (F. A. Hays and D. W. Talmadge.) Several phases of the fecundity problem have been investigated and results published during the year.

Selective breeding has considerable value in developing high and low viability lines of Rhode Island Reds. Further evidence has been presented on the inheritance of intensity of laying. Progeny testing emphasizes the scarcity of superior sires and demonstrates their importance in breeding for high fecundity. Rather extensive colorimetric stuaies of feather pigments in Rhode Island Reds suggest that dense feather pigmentation depends on a series of recessive genes. The decline in egg weight in warm weather is definitely associated with decreased body weight and reduced feed consumption. This decline in egg weight is insignificant in this latitude. Hatchability has been shown to decrease with increased age of parents and the decline appears to be associated in part with higher embryonic mortality.

A Study of Fertility Cycles in Males. (F. A. Hays and D. W. Talmadge.) Pregnant mare serum has not been effective in activating old males to high fertility in natural matings. Thyroxine gave no positive effects for the same purpose. Artificial light appears to offer possibilities and further tests are being made concerning amount and duration.

An extensive study in females has demonstrated that as viability increases fertility decreases. Apparently high concentration of the female sex hormone concerned with fertility renders the bird more susceptible to diseases such as the paralysis complex.

Secondary and Adult Sex Ratio in Relation to Hatchability. (F. A. Hays.) High and low hatchability lines started in 1945 have been continued and complete hatching records have been secured. The search for lethals has been continued and the first to appear was the type of chondrodystrophy first reported by Hays in 1944. There is evidence that females are likely to predominate in early embryonic deaths while males are more abundant in dead embryos from the eighteenth day on.

Considerable success has accompanied the establishment of high and low hatchability lines but further selective breeding appears to be necessary.

Breeding for High and Low Incidence of Internal Defects in Hen's Eggs. (F. P. Jeffrey and C. E. Walker.) Breeding results indicate that the inherited tendency to produce meat spots in fresh laid eggs is largely independent of the inherited tendency to produce blood clots. Egg shell color in the low meat spot line is now considerably lighter than in the high meat spot line.

Breeding White Plymouth Rocks for Eggs and Meat. (F. P. Jeffrey.) A new sex linkage relationship has been discovered in a strain of White heavies. This autosomal dominant plus the factor for silver allows the production of 100 percent white offspring when white males are mated with Rhode Island Red females.

The reciprocal mating yields red daughters (with no black in plumage) and white sons. It has not yet been determined whether this "new" factor for dominant white is identical with the well-known dominant white as found in the Leghorn, is an allele of it, or is a new independent factor.

SEED CONTROL

Frederick A. McLaughlin in Charge

Enforcement of the Seed Law, together with the desire of seedsmen to comply with requirements of this Act, and a growing interest of the public in good seed, has greatly increased the number of service samples sent to the seed laboratory for testing. From July 1, 1947, to June 30, 1948, 6958 service and inspection samples of seed were received and worked at the laboratory, an increase of 1105 samples over the previous year. The laboratory also received and cleaned 101 lots of tobacco seed.

Analysis of inspection samples shows that most seedsmen have complied with label requirements of the Seed Law. A large part of the violations found are technical in nature rather than flagrant.

Operation of the Seed Law is reported in an annual bulletin issued for that purpose.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, G. H. Snoeyenbos, O. S. Flint, F. G. Sperling, M. K. Clarke, O. M. Olesiuk, and E. M. Allen.)

1. *Pullorum Disease Eradication.* During the 1947-48 testing season 605 flocks (including chickens and fowl other than chickens) were tested in 12 counties. A total of 1,272,547 chicken blood samples was tested, of which 0.10 percent were positive. A total of 24,564 blood samples from fowl other than chickens was tested. None of these were positive. Sixteen "breaks" were detected and of this number 13 revealed less than 0.5 percent reactors. The majority of the "break" flocks were retested until the flocks obtained a negative status. Non-reacting chicken flocks numbered 476 and represented 1,185,852 birds or 97.20 percent of all birds tested.

The testing results reveal further progress in the establishment and maintenance of pullorum-free flocks. A more detailed discussion on the pullorum testing work will be given in the Twenty-eighth Annual Report of Pullorum Disease Eradication in Massachusetts.

2. *Salmonella pullorum Antigenic Forms.* During the 1947-48 testing season *S. pullorum* cultures were isolated and typed for antigenic form from 34 birds selected from 20 flocks in the State in which pullorum infection was detected by routine flock testing. Twenty-three birds from thirteen of these flocks were found to be infected with a Standard form of *S. pullorum* (IX, XII, $\mathrm{XII}_2\pm$, $\mathrm{XII}_3\frac{+}{+}$). Six birds from three flocks were found to be infected with a Variant form (IX, XII, $\mathrm{XII}_2\frac{+}{+}$, $\mathrm{XII}_3\pm$). The remaining five infected birds from four flocks yielded cultures with antigenic characteristics between those of Standard

and Variant forms and apparently were in active form variation at the time of isolation. This was supported by the fact that after several transfers on artificial media their antigenic form tended to become Standard. It is of interest to note that to date all infected flocks (including Standard, Intermediate, and Variant forms of infection) were originally identified by the Standard form antigen. Variant form infection has not been a problem in the establishment and maintenance of pullorum-free flocks in Massachusetts thus far.

Previous to March 31, 1948, twenty-seven *S. pullorum* cultures, isolated from specimens representing acute infections in nine flocks, were typed for antigenic characteristics. One culture was Variant in form. Cultures from eleven birds from two chick flocks, both of which were hatched from eggs laid by a flock infected with an Intermediate form organism, showed mixed culture forms, Standard, Intermediate, and Variant forms being found in individuals. The remaining fifteen cultures from six flocks were of Standard form.

Additional work is being done to determine the practical significance of form variation in *S. pullorum* as it affects antigenic response and agglutination reactions.

3. *Diagnostic Service.* During the calendar year of 1947, 4,627 specimens were received in 1,010 consignments, of which 660 were delivered in person. This represents a considerable increase in the number of consignments, 146 of which were for immunity tests in order that the flocks might be included in the infectious bronchitis and Newcastle disease programs. The specimens were classified as follows:- 4,116 chickens; 393 turkeys; 30 canaries; 12 canine feces; 11 each of mink, and rabbits; 10 pheasants; 6 each of fish and pigeon; 4 rats; 3 each of bovine semen, ducks, and ruffed grouse; 2 each of bovine feces, equine semen, grosbeaks, guinea pigs, and swine; and one each of bovine, bovine fetus, bovine organs, bovine pus, goat feces, meat, ovine organs, rabbit liver, and swan.

Tumors (110), coccidiosis (82), and fowl paralysis (57), which in past years have been consistently among the most common diagnoses, were displaced by infectious bronchitis (150) and Newcastle disease (115). In 113 cases of respiratory infection a definite diagnosis was not made. Avian tuberculosis was identified on two premises. Fowl cholera was diagnosed on 18 premises. Eleven of these represent new known foci of infection, and on two others there had been no evidence of infection for four and seven years, respectively. Fowl typhoid was identified in 24 outbreaks on 20 premises, 15 of which represent new known foci of infection.

The number of outbreaks of fowl typhoid during the past four years suggests that this disease, if not checked, may become a serious problem to the industry. During the past two years, each flock was visited or the owner was otherwise contacted to assist in formulating an eradication program. Agglutination tests are conducted in flocks which are not depopulated and where testing seems indicated. The flock owners are contacted during the year following the outbreak to obtain information on the success of the eradication program. Attempts are being made to inform those engaged in the poultry industry concerning the prevalence and potential dangers of the disease. Infection reappeared in 1947 on four of the 19 premises which were known to have been infected in 1946. The effort to eradicate infection on two of these premises was believed to have been insufficient. Infection on the third was believed to have been carried over in an uncleaned pig pen adjacent to the range. An explanation was not found for the reappearance of infection on the fourth premise.

A severe conjunctivitis and keratitis in young chickens was present in five consignments. This apparently is a relatively new condition as only five cases were observed in the previous four years and five cases were observed in the spring of 1948. Affected birds were two to 18 weeks of age (average 11 weeks). The percentage of birds affected averaged about 12 percent. The birds keep the eyelids closed, sometimes manifesting marked irritation by rubbing the eyes on their wings. There is slight lacrimation with marked congestion and moderate edema of the conjunctiva. Ulceration of the cornea varies from small areas on the posterior surface to almost complete involvement. Affected birds sit quietly for one to two weeks, eating and drinking very little, with resultant rapid loss in weight. Improvement is gradual thereafter, requiring one to three months, and, in some birds, there remains some cloudiness of the cornea. The cause of the condition has not been established.

Pox was observed in two canary flocks with a resultant mortality of approximately 35 and 65 percent respectively. Available information indicates that only vaccine of canary origin is of value in immunizing canaries. Vaccine supplied by Dr. F. R. Beaudette of the New Jersey Agricultural Experiment Station was introduced into each of these flocks at a time when entirely favorable results could not be expected. The vaccination apparently influenced the course of the disease favorably in one flock and was used too late in the other flock.

The 393 turkeys were received in 77 consignments, representing about 40 percent less material than was received in each of the previous two years. Paratyphoid infection, enterohepatitis, and coccidiosis were the conditions encountered most frequently. Erysipelas, which was quite prevalent the previous year, was identified in only one case. Newcastle disease was identified in two outbreaks. The mortality in poults, apparently infected when received, was about 40 percent over a four weeks' period. In an affected breeding flock, which manifested only mild respiratory symptoms, the egg production declined approximately 50 percent and the egg shell quality was definitely affected. Field evidence indicated that the poults hatched were not affected.

4. *Flock Mortality Studies.* No significant new information was obtained in this continuation of examinations on the flock maintained at the University for genetic studies. The number of birds examined was much smaller than in previous years, reflecting in part lower mortality in the flock. Up to January 1, 1948, necropsies were made on 117 birds (92 females and 25 males) from the flock hatched in the spring of 1946. *Pasteurella avicida* was recovered from lesions of the feet of one male. The last previous isolation of this organism in the flock was in 1939 and it was not causing serious trouble at that time. No unusual disease outbreaks were noted. Reproductive disorders, cannibalism, tumors, and kidney disorders were the principal causes of mortality. Gross examination revealed lymphocytoma in only one female and one male, fowl paralysis in three females and one male, and myelocytoma in four females.

5. *Infectious Bronchitis Control.* During 1947 a total of 263 flocks was enrolled in the infectious bronchitis control program, an increase of 46 flocks over the previous season. The results continue to be satisfactory and more flock owners are beginning to realize the value of a flock immune to bronchitis. During the past year 177 flocks were tested for immunity to infectious bronchitis, 133 of which were found to be immune, 27 susceptible, and 17 questionable.

The poultry bronchitis laboratory also tested flocks for Newcastle disease. A total of 300 flocks was tested, 115 of which were found positive and 185 negative.

Thirty-six flocks were found to be positive for both Newcastle disease and infectious bronchitis. Newcastle disease was identified in all but one county

(Dukes) during 1947. Both infectious bronchitis and Newcastle disease are very prevalent in Massachusetts and represent a serious economic menace to the industry.

During 1947 a Newcastle disease immunization project was initiated. A preliminary report of the results has been published as Contribution Number 645, Massachusetts Agricultural Experiment Station. The encouraging results have permitted the development of a State-wide flock vaccination program on an investigational basis.

During the past year the viability of Newcastle virus in infertile eggs held at incubator temperature (99° F.) and humidity (wet-bulb reading 90° F.) has been investigated. Preliminary results reveal that the virus may remain viable under those environmental conditions for at least 29 days.

The resistance of the virus to formaldehyde fumigation was also investigated. Preliminary results reveal that whole egg shells with only one end broken and the outer surface contaminated with Newcastle virus require at least one hour of triple strength fumigation (105cc. formalin and 52½ grams potassium permanganate per 100 cubic feet of space, at a temperature of 99° F. and a wet-bulb thermometer reading of 86°) to destroy the virus. However, when egg shells were finely crushed and contaminated with virus, one-hour fumigation was insufficient to kill the virus.

These investigations on the behavior of the virus under various physical, chemical, and thermal influences are being continued.

Mastitis Testing Laboratory. (W. K. Harris.) Laboratory examination of milk samples for the diagnosis of bovine mastitis was first reported by the laboratory on samples received March 24, 1947. Following the examination of samples, group segregation of the cows is recommended according to the results of the test. The group numbers shown on the report of test and their significance are as follows:

Group I—Negative.

Group II—Positive for mastitis not due to *Str. agalactiae.* Such cases are most commonly due to infection with Staphylococci, *Str. uberis, Str. dysgalactiae,* or coliform organisms. This group includes cows having non-infectious mastitis.

Group III—Positive for *Str. agalactiae.*

During the period from March 24 to June 30, 1947, inclusive, 4,607 samples from 1,166 head in 21 State-owned herds were tested. Of these, 691 cows were placed in Group I, 236 in Group II, and 239 in Group III. No tests on private herds were completed during the period. During the fiscal year of 1947-48 a total of 13,645 milk samples was tested. There were 102 samples submitted that were unsuitable for testing. From cows in State-owned herds 9,113 samples, and from private herds 4,532 samples were examined. The above figures include both partial and complete herd retests.

In order to determine the incidence of mastitis in the private herds tested, a summary of the initial tests was made. Initial tests were made on samples from 1,157 head, representing 75 herds, of which 56 had less than 20 cows each and 19 had 20 cows or more. The percentage of cows found infected is shown as follows:-

	Herds	Head	Percentages in Groups I	II	III	Percentage Infected
Under 20 cows	56	465	59	24	17	41
20 cows or more	19	692	47.5	19.5	33	52.5
Combined	75	1,157	52	21.5	26.5	48

It appears significant (1) that the percentage of Group III cows in the 19 herds is approximately twice as great as in the 56 smaller herds, and (2) that nearly one-half of all the cows tested had mastitis on the initial test. A study of the test results of the 75 herds revealed that 81 percent of the herds had some cows in Group II, 47 percent had some cows in Group III, and 37 percent had cows in both of these groups.

The percentage of cows having mastitis in the 22 State-owned herds was found to be approximately the same as in private herds, but a higher proportion of the cows, 38 percent, was in Group III. In Group II there were 11.5 percent. The average number of cows milked in the State-owned herds was 54, while in the private herds it was 15.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon, In Charge

The members of the research staff of the Waltham Field Station are assigned to this branch by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to reports of these Departments for results of investigations conducted at this Station.

PUBLICATIONS

Bulletins

440 Apples as Food. By William B. Esselen, Jr., Carl R. Fellers, and Marie S. Gutowska. 32 pp. August 1947.
Apples owe their widespread popularity to their attractiveness and palatability. Now with recognized food values assigned to them, apples also assume importance as a "protective food" in the American diet. This bulletin summarizes information on composition and nutritive value.

441 Annual Report for the Fiscal Year Ending June 30, 1947. 72 pp. September 1947.
The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

442 Mortality Studies in Rhode Island Reds, II. By F. A. Hays. 8 pp. July 1947.
Mortality from all causes is one of the most important problems of poultrymen. This report gives the final results of an attempt to breed lines of Rhode Island Reds resistant or susceptible to mortality from all causes.

443 The Inheritance of Intensity of Laying in Rhode Island Reds. By F. A Hays. 12 pp. July 1947.
Intensity of laying is one of the most important characters associated with high fecundity. Particular attention is given in this report to different methods of measuring intensity and to evidence regarding its inheritance.

444 Fertilizer Experiments on an Abnormal Orchard Soil. By J. K. Shaw. 16 pp. illus. December 1947.

This bulletin reports the response of fruit plants to a long-continued fertilizer program of nitrogen, phosphorus, potash, and lime. The conditions were unusual; but the results are of value in suggesting right and wrong fertilizer programs in the orchard.

446 Septic Tank Studies. By James E. Fuller. 19 pp. illus. February 1948.

This bulletin reports a study of the operating efficiency of septic tanks when sewage is retained for periods less than the 24 hours usually recommended. Management observations and chemical and biological tests gave evidence in favor of the conventional practice of holding sewage in tanks for 24 hours or more.

447 Cranberry Growing in Massachusetts. By Henry J. Franklin. 44 pp. illus. April 1948. (Revision of Bulletin 371.)

Massachusetts produces more than half the cranberries grown in the world. It is, therefore, considered desirable to issue a bulletin dealing with the cultural practices of this important crop.

448 The Valuation of Dairy Farm Property for Local Tax Purposes in Massachusetts. By Alfred A. Brown. 16 pp. April 1948.

Valuations indicate the community's estimate of the property owner's obligation to it; yet they are frequently overlooked in the constant concern over taxes. This report attempts to give to valuations the importance they deserve and to suggest ways of increasing the objectivity of the valuation process.

Control Bulletins

132 Inspection of Commercial Feedstuffs. By Feed Control Service Staff. 36 pp. June 1947.

133 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 20 pp. July 1947.

134 Twenty-Seventh Annual Report of Pullorum Disease Eradication in Massachusetts. By the Poultry Disease Control Laboratory. 11 pp. July 1947.

135 Seed Inspection. By F. A. McLaughlin. 33 pp. November 1947.

Meteorological Bulletins

703-714, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By H. N. Stapleton. 4 pp. each.

Reports of Investigations in Journals

Numbered Contributions

553 Immunization against a lymphoid tumor of the chicken. IV. Use of miscellaneous tests. By Carl Olson, Jr. Cornell Vet. 37 (3):231-240. 1947.

582 The hemicelluloses of maize cobs and rye straw. By Emmett Bennett. Jour. Agr. Res. 75 (1):43-47. 1947.

600 Variation in composition of winter squashes. By Arthur D. Holmes, C. Tyson Smith, and William H. Lachman. Food Res. 13 (2):123-127. 1948.

611 Role of kaolin in anion sorption and exchange. By Dale H. Sieling. Soil Science Soc. Amer. Proc. 11 (1946):161-170. 1947.

612 Some characteristics of mare's colostrum and milk. By Arthur D. Holmes and Harry G. Lindquist. Jour. Amer. Diet. Assoc. 23 (11):957-961. 1947.

613 The use of oil sprays as selective herbicides for carrots and parsnips III. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 49:343-346. 1947.

614 Pre-emergence spraying for weed control in vegetables. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 49:339-342. 1947.

615 Development time from bloom to maturity in cultivated blueberries. By J. S. Bailey. Amer. Soc. Hort. Sci. Proc. 49:193-195. 1947.

617 Stability of reduced ascorbic acid in mares' milk. By Arthur D. Holmes and Carleton P. Jones. Jour. Nutrition 34 (1):113-119. 1947.

622 Testing quaternary ammonium sanitizers as used in the dairy industry. By W. S. Mueller, D. B. Seeley, and E. P. Larkin. Soap and Sanitary Chemicals for September 1947.

623 Ascorbic acid content of hen's eggs. By G. H. Satterfield, T. A. Bell, F. W. Cook, and Arthur D. Holmes. Jour. Amer. Dietet. Assoc. 23 (12):1052-1054. 1947.

624 Male sex hormones and artificial light as activators in the spermatogenesis of adult males. II. By F. A. Hays. Poultry Sci. 27 (1):3-6. 1948.

625 Vegetative propagation of kudzu. By W. L. Doran and A. B. Beaumont. Jour. Amer. Soc. Agron. 39 (9):834-835. 1947.

626 Plumage color genes in White Plymouth Rocks and White Wyandottes. By F. P. Jeffrey. Poultry Sci. 26 (5):526-528. 1947.

627 Antioxidants in vegetable oils. By John E. W. McConnell. Amer. Perfumer and Essential Oil Rev. 50 (3):241-243; (4):346-349. 1947.

631 Further studies on the use of calcium chloride to maintain firmness in canned and frozen apples. By W. B. Esselen, Jr., W. J. Hart, Jr., and C. R. Fellers. Fruit Prod. Jour. and Amer. Food Mfr. 27 (1):8-15. 1947.

632 The freezing of swordfish. By Antonio Lopez-Matas and C. R. Fellers. Quick Frozen Foods 10 (3):72-75. 1947.

633 Thyroxine and artificial light as activators in the spermatogenesis of males. By F. A. Hays. Poultry Sci. 27 (1):84-86. 1948.

636 Permanency of synthetic ascorbic acid added to milk. By Arthur D. Holmes and Carleton P. Jones. Jour. Dairy Sci. 31 (2):99-102. 1948.

637 Viability and fertility in Rhode Island Red females. By F. A. Hays. Poultry Sci. 27 (2):186-193. 1948.

638 Extraction of copper from soil as affected by soluble components of oat straw and alfalfa meal. By Charles Hurwitz. Soil Sci. 65 (3):275-280. 1948.

641 The value of the progeny test in males. By F. A. Hays. Amer. Nat. 81:454-460. 1947.

643 Some studies using isopropyl n-phenyl carbamate as a selective herbicide. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 51:541-544. 1948.

644 Some effects of blossom removal on vegetative development and defoliation in determinate tomato plants. By William H. Lachman. Amer. Soc. Hort. Sci. Proc. 51:341-345. 1948.

645 Immunization of chickens against Newcastle disease. By H. Van Roekel, F. G. Sperling, K. L. Bullis, and O. M. Olesiuk. Jour. Amer. Vet. Med. Assoc. 112 (851):131-132. 1948.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN 450 JULY 1948

Weather in Relation to Cranberry Production and Condition

By Henry J. Franklin and Chester E. Cross

Weather studies have been continued at the Cranberry Station since Bulletin 433 was issued in 1946, and the results, presented here, seem to justify prompt publication.

UNIVERSITY OF MASSACHUSETTS
AMHERST, MASS.

WEATHER IN RELATION TO CRANBERRY PRODUCTION AND CONDITION

(Supplement to Bulletin 433)

By Henry J. Franklin, Research Professor in Charge, and
Chester E. Cross, Assistant Research Professor, Cranberry Station

Weather studies have been continued at the Cranberry Station since Bulletin 433 was issued in 1946, and the results are presented here. The junior author should be credited with the studies of cranberry size and cranberry production in Massachusetts, while the senior author is responsible for the material on cranberry keeping and on production in New Jersey.

Table 1 was prepared after careful inspection of a variety of weather data, those items which seemed to have influenced cranberry keeping most being included. There is some opinion that July and August rainfall may have an important effect on cranberry keeping quality,[1] but the evidence, except that relating to drouth in conjunction with high temperatures and excessive sunlight (see Footnote 5, Table 1), is no longer convincing. The figures in the summation column (column 7), which are a reflection of those in columns 2 to 6, show a marked and consistent relation to the keeping qualities shown in columns 8 and 9, except as related to the material in footnote 5, the large sums indicating good keeping quality and the small ones poor quality. Judging by the material in the table, there are two important and very different causes of poor condition in cranberries as they come from the bogs, as follows:

1. *Development of Putrefactive Fungi.* This is the more common and important of these causes, and it may be considerably controlled by proper bog treatments.[2] The summations in Table 1 suggest that the general importance of this factor may be determined with considerable confidence early enough in the growing season to indicate reliably whether treatments are likely to pay. A forecasting service in this connection probably should be undertaken presently. Such a service might also be a helpful guide to a wise division of the crop for disposal as fresh or processed fruit.

The factors included in Table 1 seem to suggest that the susceptibility of cranberry vines to fungus attack during the growing season is very largely determined by the first of March, the main influence being the amount of sunshine the year before and, less importantly, in February. All this is probably due to a sugar relation. On the other hand, the spring weather items shown in the table seem related mainly to the early development of the fungi concerned and appear to be of decreasing importance in the following order: Spring temperature, spring rainfall, March sunshine. As the sunshine of March seems significant here while that of April and May does not, and as the rainfall of March seems to be rather more important than that of either April or May, it appears that the weather of March leads that of any other single month in its relation to the fungus infection of cranberries.[3] Since most of the cranberry

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[1] Mass. Agr. Expt. Sta. Bul. 402, pp. 73, 74, 76, 77, 1943; and Bul. 433, pp. 10, 23, 1946.

[2] Control of Cranberry Fruit Rots by Spraying. U. S. Dept. Agr. Cir. 723, 1945.

[3] The apparent tendency of high March temperatures to reduce production in the year in which they occur (Bulletin 433, pp. 5, 13, 24) while the temperatures of April and May show no such effect tends to confirm this.

TABLE 1.—WEATHER CHIEFLY AFFECTING THE KEEPING OF MASSACHUSETTS CRANBERRIES.

Crop Year	Year before Year of Crop—Hours of Sunshine[1] less than Average[2]	Year of Crop: Hours of Sunshine[1] February Less than Average[2]	Year of Crop: Hours of Sunshine[1] March More than Average[2]	Year of Crop: Number of Months, March through June, with Mean Temperature below Threshold[3] X2	Year of Crop: Number of Months, March through May, with Rainfall less than Normal[3]	Summation	Keeping Quality[4] Early Black	Keeping Quality[4] Howes
1889	?	?	?	0	1	1?	Very poor	Very poor
1912	0	0	2	2	1	5	Poor	Poor
1913	0	0	0	4	2	6	Good	Good
1914	0	0	0	2	0	2	Very poor	Very poor
1915	4	0	2	6	3	15	Fair[5]	Poor[5]
1916	0	1	2	8	1	12	Good	Good
1917	0	0	2	6	0	8	Good	Good
1918	4	0	2	4	2	12	Good	Good
1919	0	0	0	2	1	3	Poor	Poor
1920	4	1	2	6	0	13	Very good	Very good
1921	4	1	0	2	1	8	Fair[5]	Fair[5]
1922	0	1	0	0	1	2	Very poor	Very poor
1923	4	1	0	2	1	8	Good	Good
1924	4	0	2	4	1	11	Good	Good
1925	0	1	0	2	3	6	Good	Good
1926	0	1	0	8	2	11	Good	Poor[5]
1927	4	1	2	4	3	14	Good	Fair[5]
1928	0	0	2	6	2	10	Very good	Good
1929	0	1	0	0	1	2	Poor	Poor
1930	0	0	2	2	3	7	Poor[5]	Poor[5]
1931	0	0	0	0	1	1	Very poor	Very poor
1932	0	1	2	4	2	9	Good	Good
1933	0	0	0	0	1	1	Very poor	Very poor
1934	4	0	2	2	3	11	Good	Good
1935	4	1	2	2	2	11	Good	Good
1936	4	0	0	2	2	8	Good	Good
1937	0	1	2	2	2	7	Good	Good
1938	4	1	0	2	2	9	Fair[5]	Fair[5]
1939	4	1	0	6	1	12	Good	Good
1940	4	1	2	8	1	16	Good	Good
1941	4	0	2	2	3	11	Good	Good
1942	0	0	0	0	2	2	Very poor	Very poor
1943	4	0	2	2	2	10	Good	Good
1944	4	0	0	2	1	7	Fair[5]	Fair[5]
1945	0	0	2	2	2	6	Good	Good
1946	4	0	2	0	2	8	Good[6]	Good[6]
1947	0	0	2	4	1	7	Fair[5, 6]	Fair[5, 6]

[1] The figures in these three columns indicate the positions relative to the averages, not numbers of hours.

[2] Average hours of sunshine at Boston, from Annual Meteorological Summary of the Weather Bureau for Boston for 1946: Annual, 2562; February, 166; March, 213.

[3] Averages of temperature and rainfall taken as in Tables 11 and 12 of Mass. Agr. Expt. Sta Bul. 433. The temperature thresholds used here are March, 34°; April, 44°; May, 56°; June, 64° F.

[4] Most of these appraisals are from page 36 of Bulletin 433.

[5] Appraisals notably inconsistent with the summations. In 1915, 1921, and 1930 the inconsistencies were probably caused by the devastating effect of extremely high temperatures backed by excessive sunlight and drouth in September. The inconsistencies of 1938, 1944, and 1947 are probably due to the effect of these factors operating together in August. The Howes inconsistency of 1927 may be a result of the very high mean temperatures of October and November that year. The 1926 Howes appraisal seems unsound.

[6] Appraisals by the writer after extensive investigation.

bogs are completely flooded during March and usually have more or less ice on the water the first part of this month, it is hard to see clearly why this is so. It is believed, however, that high temperatures and abundant moisture in March may have the influence noted by causing an early development of the cranberry fungi on the uplands around the bogs. This seems to be a more reasonable explanation than those given tentatively at the bottom of page 23 in Bulletin 433. The advancement of cranberry growth by high spring temperatures with its probable effect of lengthening the period of fungus infection of the new growth may also be a factor, but it seems likely that the moisture relation is most closely connected with fungus development.

The sharp difference between the effects of sunshine in February and in March suggests a very fundamental change in the relation of this element from one month to the other. It is believed that February sunshine is important mainly as a factor in maintaining oxygen sufficiency in bog waters toward the end of the winter,[4] while the influence of March sunshine is due to its reduction of moisture from rains by increasing evaporation. The apparent effect of February sunshine on cranberry production is interesting here. (See p. 7.)

2. *Injury by Heat, Sunshine, and Drouth.* These factors combined in August or September, with all three extreme, sometimes do immense damage to the condition of the Massachusetts cranberry crop It appears from Table 1 that 1915, 1921, 1930, 1938, 1944, and 1947 were years in which this sort of injury was severe. As none of these crops were large and half of them were very small, it seems that the impairment in the condition of the fruit was accompanied by considerable reductions in yield. More soft berries than usual are gathered from the bogs, but generally the amount of further softening in storage as a result of this injury[5] is not great. Proper bog irrigation in August and September seems to be the best method of prevention, for a reasonable amount of moisture in the surface soil eliminates drouth and, by evaporation, lowers the temperatures toward the tops of the cranberry vines about 4 degrees F. under these conditions.[6] It is believed that in New Jersey, where summer bog temperatures are considerably higher than they are on Cape Cod, cranberries gathered from grassy areas are often in definitely better condition than those grown near by without such shade.[7] It is easy to believe this from what has been mentioned as sometimes happening on Massachusetts bogs late in the summer. The experience of cranberry growers in the State of Washington, where sprinkling systems have been used on the cranberry bogs everywhere in recent years, is that irrigation by sprinkling on hot days prevents sun-baking of the berries and definitely improves their storage qualities. (D. J. Crowley).

The figures in the columns of Table 2 headed with the names of the months indicate the positions relative to mean rainfall at Indian Mills, New Jersey,[8] the precipitation of May and August being given a double weight as compared with that of June, September, and October. On the whole, the summations show a close enough relationship to the crop departures to be of some value in the early estimation of New Jersey production. The relation of the annual rainfall of the year before the crop year to the mean is also a fair though not infallible index, the more rain the smaller the crop.

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[4] In relation to the oxygen supply, this is probably the most critical period in the long winter flood.

[5] When the softening is due mainly to the activity of putrefactive fungi, on the other hand, it is much more likely to continue noticeably throughout the time of storage.

[6] Mass. Agr. Expt. Sta. Bul. 293, p. 23, 1933.

[7] R. B. Wilcox. Proceedings of the 78th Annual Meeting of the American Cranberry Grower Association, 1948, pp. 25, 28, and 32.)

[8] Mass. Agr. Expt. Sta. Bul. 433, p. 32, 1946

TABLE 2.—PRECIPITATION AND CRANBERRY PRODUCTION IN NEW JERSEY.

Year	Precipitation Year Before Crop Year: Less Than Normal				More Than Normal	Summation	Potential Production Departure from Smoothed 9-Year Average* (Percent)
	May	June	August	September	October		
1902	0	1	0	0	0	1	− 45.7
1903	2	0	2	0	1	5	+ 37.3
1904	2	0	2	1	1	6	+ 24.0
1905	2	1	2	0	0	5	+ 8.0
1906	2	1	0	0	0	3	− 10.2
1907	0	0	0	1	1	2	− 18.4
1908	0	0	2	0	1	3	− 49.3
1909	0	1	0	1	0	2	+ 18.0
1910	2	1	2	1	0	6	+ 57.3
1911	2	0	2	1	1	6	+ 13.4
1912	2	0	0	0	0	2	− 26.2
1913	0	1	2	0	0	3	− 31.2
1914	0	1	2	0	1	4	+ 24.7
1915	2	1	2	1	0	6	+ 10.6
1916	0	1	0	1	1	3	+ 1.7
1917	0	0	2	1	0	3	+ 1.7
1918	0	0	2	0	1	3	− 12.1
1919	0	1	2	1	0	4	− 8.7
1920	0	1	0	1	0	2	− 9.2
1921	2	0	0	1	0	3	+ 1.2
1922	2	1	2	1	0	6	+ 12.9
1923	2	0	2	1	0	5	+ 11.6
1924	2	1	2	0	0	5	+ 29.3
1925	0	0	2	0	0	2	− 21.7
1926	2	1	2	1	1	7	+ 29.6
1927	2	0	0	0	0	2	− 4.7
1928	2	1	0	1	1	5	− 6.7
1929	2	0	0	0	0	2	− 34.7
1930	2	1	2	0	1	6	+ 14.0
1931	0	0	2	1	0	3	+ 10.1
1932	0	0	0	1	1	2	− 30.3
1933	2	0	2	1	1	6	+ 31.8
1934	0	0	0	1	0	1	− 35.1
1935	0	0	0	0	0	0	− 17.5
1936	2	0	0	0	1	3	− 15.6
1937	2	0	2	0	0	4	+ 66.3
1938	0	0	0	1	1	2	− 14.0
1939	0	0	2	0	0	2	− 12.9
1940	0	0	0	1	1	2	+ 25.1
1941	0	1	0	0	0	1	− 7.3
1942	2	0	2	1	0	5	+ 12.4

* Mostly from Table 2, page 19, Mass. Agr. Expt. Sta. Bul. 433, 1946.

Sunshine and the Size of Massachusetts Cranberry Crops

Franklin[9] has shown that the sunshine[10] of the year before the crop year is an important factor in the production of the crop. He also showed that the sunshine of April through September of the year before the crop year gives the same degree of correlation to the size of the crop as the sunshine of the whole year. No relation was found between the sunshine of any part of the crop year and the size of the crop. The relation of the sunshine of each of the twenty-one months preceding the crop to the size of the crop has been determined and is given in Table 3.

[9] Mass. Agr. Expt. Sta. Bul. 433, 1946.

[10] Unless otherwise stated, "sunshine" in this paper refers to sunshine hours as measured at Boston, Mass.

Table 3.—Monthly Sunshine at Boston and Massachusetts Cranberry Production.

(Correlation coefficient and probable error for each month.)

Year Before	Year of Crop	Year of Crop	
January	+ .0409 ± .0989	January	− .0848 ± .0969
February	+ .0409 ± .0971	February	+ .2211 ± .0916
March	+ .0499 ± .0960	March	+ .0455 ± .0961
April	+ .1601 ± .0957	April	− .0462 ± .0961
May	+ .3288 ± .0867	May	+ .1001 ± .0953
June	+ .0264 ± .0972	June	− .1062 ± .0952
July	+ .1481 ± .0951	July	+ .0533 ± .0960
August	+ .2777 ± .0898	August	− .1219 ± .0948
September	+ .2593 ± .0907	September	+ .0742 ± .0958
October	− .0178 ± .0971		
November	+ .3600 ± .0847		
December	+ .0140 ± .0973		

Table 3 includes five months with a correlation coefficient more than twice as large as the probable error. The sunshine of these five months—May, August, September, and November of the preceding year and February of the crop year —seems, therefore, to be responsible to a considerable extent for the size of Massachusetts cranberry crops.

May

On many Massachusetts bogs, the winter flood is retained for a large part of May. The oxygen demand of flooded vines is greater at this time than in preceding months because of the higher temperatures prevailing. Consequently, sunshine is of great value because it contributes to the maintenance of high oxygen content in the flooding water. On bogs from which the winter flood has been withdrawn earlier, the sun contributes substantially toward building the reserves for the coming season's growth.

August, September, November

The value of more than normal sunshine in August, September, and November of the year before the crop year is apparently related to the accumulation of sugars and starches which help the vines to withstand the rigors of winter and provide the necessary supplies for new growth, flowering, and fruiting the following year. Harvesting operations may be responsible for the lack of correlation between the sunshine of October and the size of the crop. The disturbed vines are exposed to drying weather, the leaves lose their orientation to the sun's rays, and the roots are injured so that water rather than sunshine becomes the limiting factor.

February

As a result of careful and prolonged study of the relationship of winter sunshine to flooded cranberry vines, Bergman[11] has concluded that reduced sunshine results in oxygen deficiency in the flooding waters and this in turn affects the vines. Leaf drop and loss of flower buds occur and tend to reduce the crop. The

[11] Mass. Agr. Expt. Sta. Bul. 402, 1943.

TABLE 4.—SUNSHINE AND MASSACHUSETTS CRANBERRY PRODUCTION.

Year	Sunshine at Boston											Potential Production Departure from Smoothed Sliding 9-Year Average* (Percent)
	Year Before Year of Crop								Year of Crop		Sum of Departures Five Months	
	May		August		September		November		February			
	Hours	Departure from Average	Hours	Departure from Average	Hours	Departure from Average	Hours	Departure from Average	Hours	Departure from Average		
1894	219	−52	241	−28	231	+ 3	184	+43	159	− 7	− 41	−24.7
1895	260	−11	275	+ 6	216	−12	143	+ 2	218	+52	+ 37	+19.5
1896	287	+16	289	+20	255	+27	110	−31	167	+ 1	+ 33	+ 9.7
1897	263	− 8	262	− 7	191	−37	110	−31	159	− 7	− 90	−31.7
1898	196	−75	270	+ 1	258	+30	119	−22	142	−24	− 90	−30.4
1899	198	−73	242	−27	266	+38	126	−15	160	− 6	− 83	− 6.3
1900	292	+21	210	−59	216	−12	164	+23	146	−20	− 47	− 8.3
1901	232	−39	261	− 8	225	− 3	120	−21	208	+42	− 29	+22.1
1902	212	−59	223	−46	218	−10	134	− 7	170	+ 4	−118	−15.0
1903	295	+24	304	+35	190	−38	120	−21	174	+ 8	+ 8	+11.2
1904	347	+76	249	−20	289	+61	180	+39	164	− 2	+154	+51.9
1905	281	+10	262	− 7	229	+ 1	141	0	188	+22	+ 26	−19.5
1906	298	+27	271	+ 2	191	−37	179	+38	192	+26	+ 56	− 3.0
1907	307	+36	292	+23	271	+43	130	−11	141	−25	+ 66	−12.2
1908	211	−60	312	+43	159	−69	103	−38	186	+20	−104	−30.1
1909	267	− 4	255	−14	243	+15	166	+25	155	−11	+ 11	+11.4
1910	283	+12	314	+45	213	−15	119	−22	171	+ 5	+ 25	+30.0
1911	233	−38	282	+13	208	−20	101	−40	141	−25	−110	−15.9
1912	329	+58	281	+12	241	+13	171	+30	202	+36	+149	+11.0
1913	281	+10	301	+32	224	− 4	170	+29	203	+37	+104	− 5.1
1914	272	+ 1	287	+18	224	− 4	150	+ 9	192	+26	+ 50	+11.9
1915	252	−19	201	−68	274	+46	148	+ 7	166	0	− 34	+ 2.6
1916	299	+28	256	−13	275	+47	160	+19	144	−22	+ 59	−11.6
1917	274	+ 3	306	+37	275	+47	160	+19	171	+ 5	+111	−1.0
1918	214	−57	307	+38	267	+39	193	+52	170	+ 4	+ 76	+41.3
1919	311	+40	264	− 5	207	−21	143	+ 2	213	+47	+ 63	− 3.1
1920	276	+ 5	260	− 9	193	−35	125	−16	143	−23	− 78	−25.0
1921	252	−19	246	−23	226	− 2	88	−53	159	− 7	−104	−34.4
1922	288	+17	339	+70	269	+41	94	−47	114	−52	+ 29	+ 0.4
1923	332	+61	224	−45	252	+24	139	− 2	160	− 6	+ 32	+17.5
1924	291	+20	286	+17	222	− 6	145	+ 4	199	+33	+ 68	+ 7.5
1925	225	−46	275	+ 6	222	− 6	171	+30	156	−10	− 26	+21.8
1926	274	+ 3	294	+25	209	−19	160	+19	126	−40	− 12	+ 3.7
1927	283	+12	200	−69	215	−13	160	+19	118	−48	− 99	−10.4
1928	218	−53	233	−36	266	+38	132	− 9	201	+35	− 25	−20.3
1929	262	− 9	242	−27	193	−35	105	−36	162	− 4	−111	+ 4.1
1930	326	+55	296	+27	205	−23	136	− 5	181	+15	+ 69	−4.0
1931	271	0	294	+25	275	+47	155	+14	170	+ 4	+ 90	+ 9.2
1932	284	+13	240	−29	243	+15	149	+ 8	137	−29	− 22	+ 2.2
1933	338	+67	339	+70	268	+40	165	+24	207	+41	+242	+18.4
1934	282	+11	239	−30	200	−28	149	+ 8	183	+17	− 22	−27.3
1935	311	+40	241	−28	120	−108	130	−11	132	−34	−141	− 5.3
1936	254	−17	267	− 2	163	−65	90	−51	167	+ 1	−134	− 8.1
1937	320	+49	254	−15	212	−16	148	+ 7	163	− 3	+ 22	+24.8
1938	244	−27	257	−12	259	+31	141	0	114	−52	− 60	−21.7
1939	279	+ 8	326	+57	213	−15	160	+19	135	−31	+ 38	+ 4.9
1940	276	+ 5	260	− 9	230	+ 2	170	+29	153	−13	+ 14	−12.1
1941	221	−50	305	+36	224	− 4	96	−45	170	+ 4	− 59	+14.6
Average	271		269		228		141		166			

* From Mass. Agr. Expt. Sta. Bul. 433, Table 1.

Coefficient of Correlation: May, August, September and Noevember, year before year of crop, and February, year of crop $= +.5449 \pm .0684$

correlation coefficient between February sunshine and the Massachusetts crop is evidence in support of these conclusions. Although the coefficient of .2211 ± .0916 is not very impressive, it actually represents a strong correlation obscured by the fact that excessive sunshine in February can contribute little to the preparation of the crop; but scanty sunshine in this month will reduce the crop by forcing the vines to draw upon their reserves of carbohydrates. Since 1893, a large crop has never followed a February in which the hours of sunshine were 150 or less.

Table 4 shows in detail the relation of the sunshine of the five significant months mentioned above to the size of Massachusetts Cranberry crops.

Management Considerations

It is a difficult matter to decide on the best procedure for any one bog. No definite recommendations based on these weather studies are in order, the following remarks being suggestions only.

In May, when the vines are actively growing, it seems inadvisable to flood the bog for a long period. Flooding waters greatly reduce the intensity of the sunshine reaching the vines and seriously restrict the amount of oxygen available for respiration. Similar considerations are applicable to August, September, and November, when sunshine is important to the building-up of reserves for winter and the coming year. Though flooding in September and October is an important cultural practice, the flooding period should be no longer than necessary.

The obvious conclusion to be drawn from the February correlation is that the flood should be withdrawn from under the ice during this month if heavy snow cover or lack of normal sunlight reduces the oxygen content of the water. Before this is done, the grower should consider the following: (1) the possibility of replacing the flood when the snow and ice cover melts; (2) the possible increase in fruitworm infestation; and (3) the probable lessening of the spring frost hazard, since vines exposed to low temperatures in the winter develop more slowly in spring than vines that are protected by flooding waters all winter. Over 3500 acres of flooded bogs in Massachusetts had the flood withdrawn during January, 1948.

Temperature and the Size of Massachusetts Cranberry Crops

Franklin[12] has set forth the more important temperature relations. He has shown that low temperatures in March, July, September, and October of the year of the crop favor the size of the crop. In relating temperatures in May to the keeping quality of the coming crop, he has observed that high temperatures in that month apparently tend to increase the size of the crop.

May temperature of the crop year shows a correlation of + .2494 ± .0903 with size of crop, thus confirming Franklin's observation. This is the only month of the crop year with a positive and significant temperature coefficient. The relation of the mean temperature of various groups of months in the crop year to the size of the crop is set forth in Table 5.

The correlation coefficient for March, − .2557 ± .0900, is slightly greater than that for May, + .2494 ± .0903. However, it is clear from Table 5 that the addition of March temperatures to those of any other month or months lowers the correlation coefficient of those months, while the addition of May temperatures to those of any other month or months raises the coefficient. It would appear, therefore, that May temperatures are more directly related to the size of the crop than those of March.

[12] Mass. Agr. Expt. Sta. Bul. 433, 1946.

Monthly temperatures of the year before the crop year show no significant relation to the size of the crop.

TABLE 5.—TEMPERATURE AT MIDDLEBORO, PLYMOUTH, AND HYANNIS AND MASSACHUSETTS CRANBERRY PRODUCTION.

(Correlation coefficient and probable error.)

March and July	– .3767 ± .0826
March, July, and September	– .4415 ± .0775
March, July, September, and October	– .4818 ± .0739
March, May (+), July, September, and October	– .5140 ± .0708
July and September	– .4629 ± .0756
July, September, and October	– .4953 ± .0726
May (+), July, and September	– .5521 ± .0669
May (+), July, September, and October	– .5717 ± .0648

Precipitation and the Size of Massachusetts Cranberry Crops

Working within the crop year, Franklin[13] has indicated a significant correlation between the rainfall of March and April and the size of the crop. His figures also show that 2 to 4 inches of rain monthly in May, June, July, and August help to produce a large crop, but that more than 4 inches or less than 2 inches in these months is detrimental.

Because very scanty or very abundant precipitation appears to be detrimental while a moderate amount is beneficial, the type of correlation used in this paper cannot well be applied in studying the relation of rainfall to Massachusetts production. However, the correlations were calculated for the twenty-one months preceding the crop, and only one coefficient stands out enough to be considered here.

The rainfall coefficient for October of the year preceding the crop is +.2968 ±.0836, indicating that rainfall in this month is very important to the crop of the coming year. The probable reasons for this dependence upon water are given in the discussion of October sunshine following Table 3.

Table 6 brings together those weather items which now seem to have the most influence on cranberry production in Massachusetts. They are:

1. Sunshine the year before the crop year. (Table 6; also Table 4 and Figure 2 in Bulletin 433.)

2. Rainfall the year before the crop year. Rainfall in July seems to be especially important, its lack being favorable to the crop of the following year (Table 6) and its abundance unfavorable.[14] While drouth in the growing season (May to August, inclusive) clearly tends to reduce the crop of the year in which it occurs (Mass. Agr. Expt. Sta. Bul. 271, p. 250, 1931; and Bul. 433, fig. 13); drouth, whether it comes in the growing season or in the fall, seems to be related to conditions considerably favorable to the crop of the following year.

3. Rainfall in the growing season of the crop year, this being most important in July. (Bulletin 433, pages 14 and 15.)

4. February sunshine (Table 6). Since recording of sunshine was begun in Boston, there have been thirteen years in which February sunshine was less than 150 hours; and the Massachusetts cranberry crop has been small to moderate in all of them.

[13] Mass. Agr. Expt. Sta. Bul. 433, 1946.

[14] The table shows six years in which the July rainfall was over five inches, and the cranberry crop was small to moderate in all of them and also in all of those next after them.

TABLE 6.—MAIN WEATHER CONTROLS OF MASSACHUSETTS CRANBERRY PRODUCTION.

Crop Year	*More than 906 Hours of Sunshine in May, Aug., Sept., and Nov. of Year Before Crop Year[1]	*Rainfall in July of Year Before Crop Year Less than Normal[2]	*Rainfall in July of Crop Year Two to Four Inches[2]	Summation[3]	Drouth Period (Months inclusive)	Potential Production Departure from Smoothed 9-Year Average[4] (Percent)
1888	?	1	1	2?		+ 0.2
1889	?	0	0	0? r		− 25.7
1890	?	0	0	0?		− 6.9
1891	?	1	1	2?	May—Sept.	+ 15.6
1892	?	1	0	1?	June—Oct.	+ 10.7
1893	?	1	1	2?		+ 21.9
1894	0	1	0	1	June—Sept.	− 24.7
1895	0	1	1	2		+ 19.5
1896	1	1	1	3		+ 9.7
1897	0	1	0	1		− 31.7
1898	0	0	0	0 rs		− 30.4
1899	0	0	1	1		− 6.3
1900	0	1	0	1 s	June—Sept.	− 8.3
1901	0	1	1	2		+ 22.1
1902	0	0	1	1	May—Aug.	− 15.0
1903	1	1	1	3		+ 11.2
1904	1	1	1	3		+ 51.9
1905	1	0	1	2		− 19.5
1906	1	1	0	2 r		− 3.0
1907	1	0	0	1 s	June—Aug.	− 12.2
1908	0	1	1	2	May—Sept.	− 30.1
1909	1	1	0	2	May—Aug.	+ 11.4
1910	1	1	1	3		+ 30.0
1911	0	1	0	1 s		− 15.9
1912	1	0	1	2		+ 11.0
1913	1	1	0	2	May—July	− 5.1
1914	1	1	0	2		+ 11.9
1915	0	0	1	1		+ 2.6
1916	1	1	0	2 rs	Aug.—Nov.	− 11.6
1917	1	0	1	2	July—Sept.	− 1.0
1918	1	1	0	2		+ 41.3
1919	1	0	0	1 r		− 3.1
1920	0	0	1	1 s		− 25.0
1921	0	1	0	1 r	Aug.—Oct.	− 34.4
1922	1	0	0	1 s	Sept.—Nov.	+ 0.4
1923	1	0	1	2		+ 17.5
1924	1	1	0	2	May—July	+ 7.5
1925	0	1	1	2	May—Aug.	+ 21.8
1926	1	1	1	3 s		+ 3.7
1927	0	0	0	0 s		− 10.4
1928	0	0	0	0		− 20.3
1929	0	0	1	1		+ 4.1
1930	1	1	1	3	May—Sept.	− 4.0
1931	1	1	1	3		+ 9.2
1932	1	0	0	1 s	May—July	+ 2.2
1933	1	1	1	3		+ 18.4
1934	0	0	0	0		− 27.3
1935	0	1	0	1 s		− 5.3
1936	0	0	0	0	May—July	− 8.1
1937	1	1	0	2		+ 24.8
1938	0	1	0	1 s		− 21.7
1939	1	0	0	1 s	May—Sept.	+ 4.9
1940	0	1	0	1	June—Aug.	− 10.7
1941	0	0	0	0	Sept.—Nov.	+ 14.6
1942	1	0	1	2		+
1943	0	1	0	1		Average
1944	0	0	0	0	May—Aug.	Small
1945	1	1	1	3	July—Sept.	Average
1946	0	1	0	1	Sept'—Nov.	Large
1947	1	1	1	3	Aug.—Oct.	Rather large

* The figures in these columns merely show the positions relative to the matters in the headings.
[1] From the 1946 Annual Meteorological Summary for Boston published by the Weather Bureau.
[2] As in Table 12, page 30, Mass. Agr. Expt. Sta. Bul. 433.
[3] The letter "r" in the summation column marks the years in which the July rainfall was more than 5 inches, and the letter "s" marks those since 1892 with February sunshine less than 150 hours.
[4] As in Table 1 of Bulletin 433.

The following matters, supplementary to the material in Table 6, may deserve attention:

1. Springs much colder than normal have never been followed by a large cranberry crop. The springs of 1888, 1907, 1916, 1917, 1920, 1926, and 1940 are noteworthy here.

2. Temperatures of March, July, and September–October and rainfall of March–April show some correlation with size of crop. (Bulletin 433, pages 13, 24, and 26.)

Sunshine and the Size[15] of Massachusetts Cranberries

In 1943 Franklin[16] pointed out that sunshine in December and January preceding the crop favors the size of berries. After further studies[17] he also found that the total sunshine of the calendar year preceding the crop is strongly related to the size of berries; and in Table 18 of Bulletin 433 he has related the sunshine and temperature of March to the size of berries in the coming crop.

Table 7 presents a month-by-month analysis of the relation of sunshine to size of berries for each of the twenty-one months directly preceding the crop.

TABLE 7.—SUNSHINE AND THE SIZE OF MASSACHUSETTS CRANBERRIES.

(Correlation coefficient and probable error for each month.)

Year Before Year of Crop		*Year of Crop*	
January	$- .1259 \pm .1448$	January	$+ .4195 \pm .1213$
February	$+ .1712 \pm .1428$	February	$+ .1408 \pm .1442$
March	$+ .4280 \pm .1202$	March	$- .0854 \pm .1461$
April	$+ .3093 \pm .1330$	April	$- .1401 \pm .1442$
May	$- .0447 \pm .1469$	May	$- .0594 \pm .1419$
June	$- .3973 \pm .1239$	June	$+ .1652 \pm .1432$
July	$- .0013 \pm .1471$	July	$- .1003 \pm .1457$
August	$+ .1723 \pm .1428$	August	$- .2612 \pm .1371$
September	$+ .3069 \pm .1333$	September	$- .0478 \pm .1470$
October	$+ .5976 \pm .0946$		
November	$+ .0114 \pm .1471$		
December	$+ .1801 \pm .1424$		

It is clear from Table 7 that the sunshine of March, April, June, September, and October of the year before the crop year and of January of the year of the crop is most important in developing the size of berries. Of these six months, only June has a negative coefficient; apparently the more sunshine, the smaller the berries.

Table 7 gives $+ .1801 \pm .1424$ as the insignificant coefficient derived from the relation of December sunshine and the size of berries of the following crop. In 1943 Franklin[18] reported a coefficient of $+ .442 \pm .128$. The discrepancy is due to the inclusion in this report of data for 1944. This year, which produced the smallest berries on record, was preceded by a December with 24 hours in excess of normal sunlight.

[15] The data on size of berries used in this paper come from C. D. Stevens. See Franklin, Mass. Agr. Expt. Sta. Bul. 433, 1946.

[16] Mass. Agr. Expt. Sta. Bul. 402, 1943.

[17] Mass. Agr. Expt. Sta. Bul. 433, 1946.

[18] Mass. Agr. Expt. Sta. Bul. 402, 1943.

In January of the crop year most cranberry bogs are flooded and the vines are relatively dormant. This condition must be considered in any attempt to explain the relation of January sunshine to the size of berries. Reduced sunshine in this month often induces a deficiency of oxygen in the winter flooding waters.[19] When this happens, carbohydrate reserves are diminished and the vines are injured to such an extent that small berries characterize the following crop. Since 1925, a crop of large berries has never followed a January in which there was less than 130 hours of sunshine. However, more than normal sunshine maintains sufficient oxygen in the flooding waters, merely preserving the stored carbohydrates with little chance of adding to them. Excessive sunshine in January is, therefore, followed by a crop of either small or large berries, the size being determined by other factors.

The relation suggested by Franklin[20] of the sunshine and temperature of March to the size of berries in the following crop now appears to be due to temperature alone.

Table 8 shows in detail the relation of the sunshine of the six most important months to the size of cranberries.

The data in Table 8 give the following correlation coefficients between sunshine and the size of cranberries:

September and October	$+ .6317 \pm .0884$
October and January	$+ .6746 \pm .0802$
March, October, and January	$+ .6757 \pm .0799$
September, October, and January	$+ .6724 \pm .0806$
March, April, and June (−)	$+ .5793 \pm .0978$
March, June (−), October, and January	$+ .6963 \pm .0758$
March, April, June (−), September, and October	$+ .7233 \pm .0702$
March, June (−), September, October, and January	$+ .7480 \pm .0648$
March, April, June (−), September, October, and January	$+ .7176 \pm .0714$

The coefficients, ranging from $+ .5793 \pm .0978$ to $+ .7480 \pm .0648$, indicate that sunshine is more responsible for the size of berries than any other weather element.

[19] Bergman, Mass. Agr. Expt. Sta. Bul. 402, 1943.
[20] Mass. Agr. Expt. Sta. Bul. 433, Table 18, p. 36, 1946.

TABLE 8.—SUNSHINE AND THE SIZE OF MASSACHUSETTS CRANBERRIES.

Crop Year	Sunshine at Boston: Year before Year of Crop: March: Hours	March: Departure from Average (+)	April: Hours	April: Departure from Average (+)	June: Hours	June: Departure from Average (−)	September: Hours	September: Departure from Average (+)	October: Hours	October: Departure from Average (+)	Year of Crop: January: Hours	January: Departure from Average (+)	Sum of Departures Six Months	Size of Berries Departure. of Index from Average[1]
1925	234	+19	224	−10	289	−12	222	+ 3	251	+52	141	− 5	+ 47	+34
1926	210	− 5	261	+27	311	−34	209	−10	145	−54	106	−40	−116	−33
1927	211	− 4	236	+ 2	270	+ 7	215	− 4	196	− 3	133	−13	− 15	+15
1928	255	+40	343	+109	306	−29	266	+47	253	+54	191	+45	+266	+15
1929	247	+32	279	+45	249	+28	193	−26	230	+31	171	+25	+135	+16
1930	211	− 4	182	−52	346	−69	205	−14	193	− 6	113	−33	−178	−21
1931	236	+21	293	+59	306	−29	275	+56	195	− 4	208	+62	+165	+35
1932	193	−22	275	+41	268	+ 9	243	+24	223	+24	96	−50	+ 26	−11
1933	222	+ 7	257	+23	291	−14	268	+49	174	−25	175	+29	+ 69	+33
1934	195	−20	197	−37	289	−12	200	−19	218	+19	118	−28	− 97	− 8
1935	237	+22	278	+44	287	−10	120	−99	187	−12	142	− 4	− 59	+ 5
1936	225	+10	162	−72	207	+70	163	−56	251	+52	175	+29	+33	+ 8
1937	204	−11	192	−42	289	−12	212	− 7	198	− 1	121	−25	− 98	− 8
1938	236	+21	208	−26	241	+36	259	+40	162	−37	121	−25	+ 9	0
1939	176	−39	233	− 1	302	−25	213	− 6	178	−21	119	−27	−119	−14
1940	180	−35	177	−57	295	−18	230	+11	150	−49	174	+28	−120	−39
1941	214	− 1	197	−37	275	+ 2	224	+ 5	213	+14	127	−19	− 36	− 6
1942	217	+ 2	257	+23	259	+18	290	+71	205	+ 6	181	+35	+155	+26
1943	183	−32	214	−20	208	+69	214	− 5	215	+16	133	−13	+ 15	+ 5
1944	222	+ 7	240	+ 6	315	−38	192	−27	140	−59	161	+15	− 96	−65
1945	204	−11	211	−23	217	+60	187	−32	209	+10	170	+24	+ 28	+17
Average	215		234		277		219		199		146			

[1] From Table 5, page 22, Mass. Agr. Expt. Sta. Bul. 433.

Temperature and the Size of Massachusetts Cranberries

Franklin[21] has shown that high temperatures in March favor the development of large berries in the following crop.

Table 9 presents a month-by-month analysis of the relation of temperature to the size of berries for the twenty-one months directly preceding the crop.

TABLE 9.—TEMPERATURE AND THE SIZE OF MASSACHUSETTS CRANBERRIES.*

(Correlation coefficient and probable error for each month.)

Year Before Year of Crop		*Year of Crop*	
January	+.3362 ± .1306	January	+.0554 ± .1467
February	−.2722 ± .1363	February	−.0065 ± .1471
March	−.2302 ± .1394	March	+.5633 ± .1005
April	+.1582 ± .1435	April	+.4599 ± .1161
May	+.0126 ± .1469	May	−.2364 ± .1389
June	−.4353 ± .1193	June	+.1401 ± .1443
July	−.1808 ± .1423	July	−.1194 ± .1262
August	−.1853 ± 1421	August	−.1154 ± .1452
September	−.0261 ± .1471	September	+.0701 ± .1465
October	+.0210 ± .1471	March and April	+.6037 ± .0936
November	+.2677 ± .1366	June** (−), March, and April	+.6902 ± .0770
December	+.1222 ± .1450		

*Mean temperature at Middleboro, Mass. See Bulletin 433, p. 29.
**Year before year of crop.

Six monthly coefficients in Table 9 are at least twice their probable errors. Of the six, those of January, February, and November of the year before the year of the crop indicate a weak and dubious relation between temperature and size of berries. However, the coefficients of June of the year before the year of the crop and of March and April in the year of the crop are strong enough to require further consideration.

June

Low temperatures in June of the year before the year of the crop appear to favor large berries. A similar negative relation between June sunshine the year before the year of the crop and the size of berries appears in Table 7. The reasons for these apparent relations are obscure.

March

As noted above, Franklin has already discussed the importance of high temperatures in March to the development of large berries in the following crop.

April

It is clear from Table 9 that the influence of high temperatures in March on the size of berries is continued and supported by that of high temperatures in April. It seems that an early start in the growing season is favorable to the development of large berries.

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[21] Mass. Agr. Expt. Sta. Bul. 402, pp. 85-88, 1943.

Precipitation and the Size of Massachusetts Cranberries

Franklin[22] has pointed out that the amount of rainfall in July and August is important to the size of berries in the following crop.

Table 10 presents a month-by-month analysis of the relation of precipitation to the size of berries for each of the twenty-one months directly preceding the crop.

TABLE 10.—PRECIPITATION* AND THE SIZE OF MASSACHUSETTS CRANBERRIES.

(Correlation coeficient and probable error for each month.)

	Year Before Year of Crop		*Year of Crop*
January	+ .0670 ± .1465	January	+ .1876 ± .1420
February	+ .1173 ± .1451	February	− .2083 ± .1408
March	− .1634 ± .1432	March	+ .1243 ± .1449
April	− .2682 ± .1366	April	− .1837 ± .1422
May	− .3904 ± .1248	May	+ .1322 ± .1446
June	+ .1394 ± .1443	June	+ .0944 ± .1459
July	− .1768 ± .1426	July	+ .3209 ± .1320
August	+ .1301 ± .1447	August	+ .4287 ± .1201
September	− .0988 ± .1457	September	+ .1198 ± .1450
October	− .2605 ± .1372		
November	+ .2974 ± .1341		
December	+ .0155 ± .1471		

* Averages of precipitation at Middleboro, Plymouth, and Hyannis, Mass. Mass. Agr. Expt. Sta. Bul. 433, p. 30. 1946.

Table 10 lists only one coefficient for the months of the year before the year of the crop which is large enough to be considered significant, that of May. However, close inspection of the relation of May rainfall the year before the year of the crop to the size of berries shows that the size of the correlation coefficient is due largely to the figures of one year, 1944. For this reason it seems unlikely that the relation is important.

Apparently the rainfall in July and August of the crop year is more important to the development of large berries than the rain of any other months in the crop year. Since Franklin has already pointed out these relationships, further discussion is unnecessary.

Finally, Table 11 sets forth in detail the relation of sunshine, temperature, and rainfall to the size of berries, and shows that the correlation coefficient for this combination of weather elements is very great.

[22] Mass. Agr. Expt. Sta Bul. 433, p. 8, 1946.

TABLE 11.—SUNSHINE, TEMPERATURE, AND RAINFALL AND THE SIZE OF MASSACHUSETTS CRANBERRIES.

Year	SUNSHINE[1] Sum of March, April, June (−), September, and October, Year before Year of Crop; and January and August (−) Year of Crop		TEMPERATURE[2] Sum of June (−), Year before Year of Crop; and March and April, Year of Crop		RAINFALL[3] Sum of July and August, Year of Crop		Sum of Departures of Sunshine, Temperature, and Rainfall from Average	SIZE OF BERRIES Departure of Index from Average[4]
	Hours	Departure from Average	Degrees F.	Departure from Average X 10	Inches	Departure from Average X 10		
1925	1.655	+ 13	147.6	+ 81	5.38	− 11	+ 83	+34
1926	1,442	− 46	141.9	− 104	6.13	− 4	−154	−33
1927	1,494	+ 52	144.0	+ 59	13.95	+ 74	+185	+15
1928	1,856	+ 284	140.1	+ 14	5.60	− 9	+289	+15
1929	1,665	+ 109	147.0	+ 51	6.97	+ 5	+165	+16
1930	1,544	− 202	143.3	− 36	4.72	− 18	−256	−21
1931	1,753	+ 195	151.7	− 20	8.43	+ 19	+194	+35
1932	1,637	− 43	142.4	− 27	6.49	0	− 70	−11
1933	1,626	+ 100	143.9	0	7.40	+ 9	+109	+33
1934	1,458	− 68	146.1	− 10	3.43	− 31	−109	− 8
1935	1,518	− 56	149.2	− 1	6.38	− 1	− 58	+ 5
1936	1,437	+ 49	150.9	+ 62	7.66	+ 12	+123	+ 8
1937	1,473	− 85	142.1	− 46	5.33	− 12	−143	− 8
1938	1,553	− 47	151.2	+ 45	6.22	− 3	− 5	0
1939	1,481	− 109	141.6	− 49	4.78	− 17	−175	−14
1940	1,511	− 155	136.7	− 66	4.93	− 16	−237	−39
1941	1,544	− 60	144.2	+ 15	8.15	+ 16	− 29	− 6
1942	1,690	+ 144	150.9	+ 48	9.68	+ 32	+224	+26
1943	1,408	+ 44	140.6	− 59	8.29	+ 18	+ 3	+ 5
1944	1,580	− 136	146.9	− 84	2.00	− 45	−265	−65
1945	1,452	+ 44	161.5	+ 140	5.23	− 13	+171	+17

[1] At Boston, Mass.
[2] At Middleboro, Mass.
[3] Average, Middleboro, Plymouth, and Hyannis, Mass.
[4] From Table 5, page 22, Mass. Agr. Expt. Sta. Bul. 433.

The coefficient of correlation between Sunshine, Temperature, and Rainfall and Size of Berries is +.8576 ± .0390.

5M-8-48-24253