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MASSACHUSETTS AGRICULTURAL COLLEGE

THIRTY-SIXTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

REPORT OF THE DIRECTOR FOR THE FISCAL YEAR ENDING NOV. 30, 1923, PUBLISHED IN ACCORDANCE WITH THE PROVISIONS OF SECTION 32 OF CHAPTER 30 OF THE GENERAL LAWS

Publication of this Document approved by the Commission on Administration and Finance

DEPARTMENT OF EDUCATION
THE COMMONWEALTH OF MASSACHUSETTS

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

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Entomology.	Henry T. Fernald, Ph.D., *Professor*. Arthur I. Bourne, A.B., *Assistant Research Professor*. Harlan N. Worthley, M.Sc., *Investigator*. Miss Bridie E. O'Donnell, *Stenographer*.
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Rural Engineering.	Christian I. Gunness, B.Sc., *Professor.*
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Philip H. Smith, M.Sc., *Official Chemist, Feed Control.*
Lewell S. Walker, B.Sc., *Assistant Official Chemist, Fertilizer Control.*
Frank J. Kokoski, B.Sc., *Analyst, Feed and Fertilizer Control.*
—— ——, *Analyst, Fertilizer Control.*
James T. Howard, *Inspector, Feed and Fertilizer Control.*
Miss Cora B. Grover, *Stenographer, Feed and Fertilizer Control.*
Oliver S. Flint, B.Sc., *Analyst, Poultry Disease Elimination.*
Miss Hazel M. Parker, *Laboratory Assistant, Poultry Disease Elimination.*
Miss Rebecca L. Mellor, *Clerk, Poultry Disease Elimination.*

REPORT OF THE DIRECTOR.

SIDNEY B. HASKELL.

NEW WORK INSTITUTED.

The Legislature of 1923 made provision for three additions to the staff of the Experiment Station,—assistant research professors in Agronomy and in Vegetable Gardening, and an investigator at the Cranberry Station. Since funds to care for these new positions did not become available until September 1, little more could be done than to initiate the different phases of work for which these additional staff members were employed.

At the Market Garden Field Station was instituted an investigation entitled "A Study of the Factors Influencing the Heading of Greenhouse Lettuce." This project will be of service to greenhouse lettuce growers. Winter lettuce has until recently been a main crop in the greenhouse industry of the State. Competition of out-door lettuce from California has, however, been very serious, and in some cases has caused the closing of the greenhouse for the winter season. The problem, therefore, resolves itself into an attempt to develop ways and means by which the heading of greenhouse lettuce, grown during the short days of midwinter, may be controlled. There are three main lines of attack: first, through the use of artificial light to lengthen the growing day; secondly, through control of nutrient conditions; third, through breeding lettuce suited to the abnormal conditions of deficient sunlight.

The department of Agronomy has undertaken a comprehensive study of the effect of cropping systems on the growth and development of stalk-cut tobacco. This work will take some years to complete, for despite the fact that need for this study became apparent about a quarter of a century ago, very little has been done. In developing plans for this research, the Connecticut Experiment Station has given significant assistance. It is, in fact, essential that Massachusetts and Connecticut co-ordinate their studies, for the problems in the two states are much the same.

An intensive study of onion thrips control was instituted during the year. This insect has caused serious damage to the onion industry of the Connecticut Valley. During the past two or three years it has been particularly damaging. The results of the first year's study are highly encouraging, for they have demonstrated that a certain degree of control is at least possible, even though somewhat costly.

A survey of current practice in feeding of garbage to hogs was instituted during the year and carried through to successful completion. Mr. Glatfelter of the College had charge of the work. This was most productive in showing that, on account of the varied nature of the industry, a formal study of this problem is impracticable.

On account of the change in work brought about by the retirement of Dr. Goodale and the taking over of this work by Dr. Hays, the projects in Poultry Husbandry were reformulated. The old projects are still being carried on, and in addition three new projects, respectively on "A Genetic Study of Rhode Island Red Color", "Determination of Genetic Laws Governing Results in Inbreeding of Poultry" and "The Hatchability of Eggs", all under the immediate direction of Professor Hays, have been undertaken. These are based largely on records made during the ten years over which the poultry breeding work of the Experiment Station has been continued. As time goes on the data so painstakingly collected will be increasingly valuable.

Other new work undertaken during the year includes a vegetation test to study the availability of the nitrogen in certain grades of mixed fertilizers, under the immediate direction of Mr. Haskins of the Fertilizer Control Service; and, in co-operation with the United States Department of Agriculture, a study of fruit harvesting and storage, under the immediate direction and leadership of Mr. Raleigh of the College Department of Pomology. The Department of Veterinary Science and Animal Pathology has instituted a fundamental study of bacteriophagic specificity with special reference to *B. pullorum* infection and therapeusis, with Dr. Pyle in charge.

A preliminary study of the immediate effect of fertilizer as applied in varying quantities on the germination of onion seed was carried through. Despite the fact that this work indicated occasional delay in germination through the use of large quantities of chemicals, it will not be continued in 1924. The conditions under which the work was carried on are not such as to warrant its continuation.

An indicative feeding test, without formal project organization, has been under way for some months, in testing the value of hydrolyzed sawdust for dairy stock. This work is in co-operation with the Forest Products Laboratory of the United States Department of Agriculture, and supplements work being done in other parts of the country. The indications are that sawdust treated in the way indicated has a definite food value, and that a definite project study of the problem should be undertaken.

MORE IMPORTANT RESULTS OF THE YEAR'S WORK.

Definite proof of the fact that higher food costs of Massachusetts are due to factors within the control of the State, rather than to either the geographical location of the State or the amount of agriculture in the State, was developed in the prosecution of Dr. McFall's project "Boston Food Supply Study." The wholesale costs of food in Massachusetts are but slightly higher than in other competing states. Over against this is the fact that the retail costs of food are from 14 to 17 per cent higher, on an average of costs in a weighted dietary, than in other competing sections. Somewhere in the costs incident to the handling, sale and distribution of food within the State are costs apparently not incurred in the same degree in other sections. This, however, must be considered as merely the starting point for further investigation.

There has been continued progress in the nursery certification work, organized under the Massachusetts Fruit Growers' Association, and based on Dr. Shaw's study, "Tree Characters of Fruit Varieties." About 65,000 nursery trees were certified. This work is not properly experimental, despite the fact that it is a charge against research funds. The only apparent way in which the research studies thus far made can be used to good advantage is in continuing the work until men and organizations can be trained to give service in certification of varieties. Sufficient progress should be made by another season to permit of the Station withdrawing from this commercial service phase of the investigation.

From the Market Garden Field Station as well as from other experiments in Amherst, have come some rather striking contributions to the ever-present problem of fertility maintenance. At both places there have been certain areas of land which have been maltreated over a period of years; in the one case for more than a generation, in the other since the Field Station was first started in 1918. The significant fact developed is that, even when the producing power of the soil drops to a low level through neglect or maltreatment, injury is not permanent. At the Market Garden Field Station areas of land unfertilized for five years, but this last year receiving a heavy application of chemical fertilizers, gave crops nearly as good as those receiving normal treatment. At the home station, the depressing effect of past one-sided fertility treatment was overcome in a single season by what may be called a normal optimum application of manures and fertilizers.

The work carried on in the eastern part of the State during the past three seasons on the control of apple scab has been brought to a successful and satisfactory conclusion. Professor Webster S. Krout was originally in charge of this investigation, more lately his successor Professor William S. Doran. The co-operation extended to the Station by the Nashua Fruit Growers' Association, and by the Farm Bureaus of Worcester and Middlesex Counties was extremely gratifying. The same may be said of the co-operation of those individual fruit growers who placed their orchards at the disposal of the Experiment Station for spraying investigations, and who in other ways co-operated to make the work successful. As a result of this effort, the fact that the destructive apple scab may be controlled, and at an expense but slightly greater than that ordinarily incurred without such control has been convincingly demonstrated.

Another interesting and valuable piece of work which has yielded concrete results is that carried on by Mr. Worthley in his study of the control of the squash vine borer. For years this insect has served to decrease local interest in the production of squashes and to increase the cost of this vegetable regardless of where it was produced. The only methods of control suggested were unsatisfactory, and exceedingly expensive. By the new method the egg of this insect is killed, whereas most previous methods of attack had attempted to kill after the larva had worked its way into the stem of the plant and commenced its destructive attack.

The work in the breeding of poultry as established first by Dr. Goodale and carried on more recently by his successor, Dr. Hays, continues to bring striking and most important results. The building of a house for laying hens enables the Station to project its work to a later age period than was formerly possible. In this and many other ways the project promises even greater service in the future than has been given in the past.

The investigation of the natural vegetation on permanent pastures, as conducted on the Tillson Farm, has given most valuable data. These permanent pastures should be the backbone of the Massachusetts dairy industry. So depleted have they become, however, during the years of continuous pasturage, and so foul with weeds of many different kinds, that many are now liabilities rather than assets. On the Tillson Farm pasture, however, on land not plowed for a generation, perhaps never, the natural vegetation of running cinquefoil, hairy cap moss and other weeds has been absolutely replaced by a perfect carpet of white clover, without plowing or reseeding. The application of these results to pastures in different parts of the State is still an open question. This work, coupled with demonstrational work carried on over a period of several years by the department of Agronomy of the Extension Service, gives a starting point for the improvement of such of our permanent pastures as have not already degenerated into brush lots or open woodlands.

The year's work on onion diseases, carried on under the leadership of Dr. Anderson, concerned itself particularly with control of the onion smut through the use of formaldehyde and other products. There was striking demonstration of the value of repeated experiments. That formaldehyde properly applied prevents smut, even on badly infested land, has long been known. That under certain conditions the formaldehyde may injure germination is a comparatively recent discovery. It therefore became necessary for the Station to determine conditions under which injury from treatment might be more serious than benefit from the use of formaldehyde. The season's work showed that moisture conditions at the time of planting had a dominant effect; and that the formula of concentration and rate of application must be varied on the basis of moisture conditions in the soil at time of planting.

CAPITALIZATION OF STATION WORK.

These few scattered instances of some of the more significant results of the year's work indicate the varied ways in which the State capitalizes the agricultural research of its Experiment Station. A part goes directly to farmers and is used by them. This is particularly true of that work which develops methods of controlling injurious insects, and plant or animal diseases. In the case of the investigation of the white diarrhœa of poultry, however, it was necessary to organize a State control in order that this research work might be made of service to practical poultrymen. Again, it may be necessary to seek a commercial outlet. The plan for the certification of nursery stock is a case in point. Much of the work of the Experiment Station finds its first field of usefulness in contributing facts leading to the solution of fundamental problems of agriculture and agricultural welfare. This is particularly true of certain of the chemical and biological investigations of soil fertility, carried on the past few years, and with certain types of economic studies. With increasing separation of research and extension teaching, it is probable that greater attention must be given to the capitalization of agricultural research in those particular fields where it is found most valuable.

CHANGES IN STATION STAFF, DECEMBER 1, 1922 TO DECEMBER 1, 1923.

During the year there were five resignations from the Station service.

Mr. Raymond W. Swift, analyst in the Control Service, resigned to accept a position with the Pennsylvania State Bureau of Animal Nutrition. This change represented a distinct advance and increased opportunity for Mr. Swift. His service here had been eminently satisfactory.

Professor Webster S. Krout, assistant research professor of Botany, and in charge of apple scab investigations in the eastern part of the State, submitted his resignation April 15, 1923, to enter the Extension Service of the Pennsylvania State College. Mr. Krout first entered the service of the Experiment Station in April, 1917, and during his six years of service with the Station made an enviable reputation along research lines. He was particularly successful in organizing the co-operative work on apple scab control in the eastern part of the State. It was with great regret that his resignation was accepted.

At the end of August, Miss Mildred H. Hollis, laboratory assistant in Poultry Disease Elimination, submitted her resignation. While she had been with the Station for but a year, her work had been highly satisfactory.

Miss Doris Tower, Clerk in the department of Poultry Husbandry, resigned to accept a position in the department of Poultry Husbandry, Kansas Agricultural

College, Manhattan, Kansas. Miss Tower had been with the department for four and one-half years, and had become most efficient in its work.

On November 21, Mr. S. J. Broderick, who entered the service of the Station in January, 1923, to take the place left vacant by Mr. Swift, submitted his resignation, to enter into commercial work.

On January 31, Mr. Arthur P. French, who had been investigator in Pomology for a year and a half, left the Station service through transfer to the teaching force of the College.

The large number of resignations among the more poorly paid members of the staff indicates that in our present salary schedule the Station is not keeping pace with the growth of its men in ability and productiveness. This matter, as was pointed out in a report to the president, submitted in December, 1922, is vital to the welfare of the Station and the work which it represents, and should have definite trustee study.

Appointments to fill positions made vacant by resignations include that of Professor William L. Doran, assistant research professor of Botany, to have charge of the pathological work on fruits and vegetables in the eastern part of the State. Mr. Doran is a graduate of the College in the class of 1915, and received the degree of Master of Science in 1917. He comes to the service of the Station after making an enviable record in his chosen science at the New Hampshire Agricultural Experiment Station.

Miss Alice J. Twible was appointed clerk in Poultry Husbandry to succeed Miss Tower.

Miss Hazel M. Parker was appointed to the position of laboratory assistant in Poultry Disease Elimination left vacant by the resignation of Miss Hollis.

Mr. John S. Bailey was appointed to fill the place made vacant by the transfer of Mr. French as investigator in Pomology.

New appointments include Mr. V. A. Tiedjens, assistant research professor of Vegetable Gardening, who is assigned to the experimental work at the Market Garden Field Station; Mr. John P. Jones, assistant research professor of Agronomy, who is undertaking studies in connection with the tobacco industry of the Connecticut Valley; and Mr. Donald S. Lacroix, investigator, assigned to the Cranberry Station.

PUBLICATIONS OF THE YEAR.

Annual Report.

Thirty-fifth annual report:
- Part I. Report of the Director and other Officers.
- Part II. Detailed Report of the Experiment Station (Bulletins 207–212).
- Combined Contents and Index, Parts I and II.

Bulletins.

No. 213. Tobacco Wildfire in 1922, by P. J. Anderson and G. H. Chapman.

No. 214. Combating Apple Scab. Spraying and Dusting Experiments in 1922, by Webster S. Krout.

No. 215. Pedigree, the Basis of Selecting Breeding Males for Egg Production, by F. A. Hays and Ruby Sanborn.

No. 216. Digestion Experiments with Cattle Feeds, by J. B. Lindsey, C. L. Beals, P. H. Smith and J. G. Archibald.

No. 217. The Value of Buttermilk and Lactic Acid in Pig Feeding, by J. B. Lindsey and C. L. Beals.

No. 218. The Control of the Squash Vine Borer in Massachusetts, by Harlan N. Worthley.

Bulletins, Popular Edition.

No. 216. The Feeding Value of Some Unusual Commercial Feeds, by J. G. Archibald.

Bulletins, Control Series.

No. 23. Control of Bacillary White Diarrhœa, 1922–1923, by G. E. Gage and O. S. Flint.

No. 24. Inspection of Commercial Feedstuffs, by Philip H. Smith and Frank J. Kokoski.

No. 25. Inspection of Commercial Fertilizers, by H. D. Haskins, L. S. Walker, and S. J. Broderick.

No. 26. Inspection of Lime Products Used in Agriculture, by H. D. Haskins, L. S. Walker, and S. J. Broderick.

Meteorological Reports.

Nos. 409–420 inclusive.

Scientific Contributions.

No. 1. Inbreeding the Rhode Island Red Fowl with Special Reference to Winter Egg Production, by F. A. Hays. *In* American Naturalist, Vol. LVIII, No. 654, January–February, 1924.

No. 2. A Study in the Control of Poultry Diseases, by John W. Lentz. *In* Poultry Science, Vol. II, December–January, 1922–23.

No. 3. Tests of Low Lift Pumps, by C. I. Gunness. *In* Agricultural Engineering, Vol. 4, No. 3, March, 1923.

No. 4. An Improved Formaldehyde Tank for the Onion Drill, by P. J. Anderson and A. V. Osmun. *In* Phytopathology, Vol. XIII, No. 4, April, 1923.

No. 5. Relations between Calcium Carbonate, Certain Fertilizer Chemicals and the Soil Solution, by F. W. Morse. *In* Soil Science, Vol. XV, No. 2, February, 1923.

No. 6. Control of Lettuce Drop by the Use of Formaldehyde, by Webster S. Krout. *In* Journal of Agricultural Research, Vol. XXIII, No. 8, February 24, 1923.

No. 7. The Squash Bug in Massachusetts, by H. N. Worthley. *In* Journal of Economic Entomology, Vol. 16, No. 1, February, 1923.

No. 8. Methods of Distribution of Phosphorus Fertilizers, by S. B. Haskell. *In* Journal of the American Society of Agronomy, Vol. 15, No. 4, April, 1923.

No. 9. An Experiment in Ringing Apple Trees, by J. K. Shaw. *In* Proceedings of the American Society of Horticultural Science, 1922.

No. 10. A Study of Bearing Habit of Apple Varieties, by W. B. Mack. *In* Proceedings of the American Society of Horticultural Science, 1922.

No. 11. Determination of Fatty Acids in Butter Fat: II, by E. B. Holland *et al.* *In* Journal of Agricultural Research, Vol. XXIV, No. 5, May 5, 1923.

No. 12. Influence of the Plane of Nutrition on Susceptibility to Injury from Toxic Concentrations, by F. W. Morse. *In* Journal of the American Society of Agronomy, Vol. 15, No. 7, July, 1923.

No. 13. Physiological Study of Azotobacter Chroococcum, Beijerinckii and Vinelandii Types, by Unokichi Yamagata and Arao Itano. *In* Journal of Bacteriology, Vol. VIII, No. 6, November, 1923.

No. 14. Physiological Study of Azotobacter Chroococcum. I. Influence of Vitamine B (?) and Nucleic Acid on Azotobacter, by Arao Itano. *In* Journal of Bacteriology, Vol. VIII, No. 5, September, 1923.

No. 15. The Relation of Soil Moisture to Formaldehyde Injury of Onion Seedlings, by P. J. Anderson. *In* Phytopathology, Vol. XIII, No. 9, September, 1923.

No. 16. Determination of Sulphur Compounds in Dry Lime-Sulphur, by Carleton Parker Jones. *In* Journal of Agricultural Research, Vol. XXV, No. 7, August 18, 1923.

No. 17. Comparative Effects of Muriate and Sulfate of Potash on the Soil in a Long Continued Fertilizer Experiment, by F. W. Morse. *In* Soil Science, Vol. XVI, No. 2, August, 1923.

No. 18. Farm Ownership in Massachusetts, by Lorian P. Jefferson. *In* Journal of Farm Economics, Vol. V, No. 4, October, 1923.

No. 20. Agricultural Research in its Service to American Industry, by Sidney B. Haskell. *In* Journal of the American Society of Agronomy, Vol. 15, No. 12, December, 1923.

No. 21. Notes on the Cape Cod Brood of Periodical Cicada During 1923, by D. S. Lacroix. *In* Psyche, Vol. XXX, No. 6, December, 1923.

REPORT ON PROJECTS.

Projects Completed.

During the year ten projects were completed, as follows:

Agriculture 1. Comparison of nitrogenous fertilizers. *Assistant Professor Gaskill.*
Animal Husbandry 2. Survey of garbage feeding plants in Massachusetts. *Assistant Professor Glatfelter.*
Botany 10. Apple disease control investigations. *Assistant Professor Doran.*
Chemistry 2. Digestion experiments. *Professor Lindsey and Assistant Professor Archibald.*
Chemistry 5. Chemistry of arsenical insecticides. *Professor Holland and Mr. Dunbar.*
Chemistry 6. Lime absorption and acidity of Field A. *Professor Morse.*
Chemistry 7. Effects of sulfate and muriate of potash on the soil of Field B. *Professor Morse.*
Chemistry 12. Attempting to improve the nutritive value of grain hulls. *Professor Lindsey and Assistant Professor Archibald.*
Chemistry 18. To determine the mineral constituents of forage crops. *Professor Lindsey and Assistant Professor Archibald.*
Fertilizer Control 1. Vegetation tests to study nitrogen availability. *H. D. Haskins, Official Chemist.*

In most of the above cases final report has been made, although publication may be delayed until other related work is completed.

Projects Transferred to the Inactive List.

Owing to the inability of the Station to give adequate financial support, the following projects have been transferred to the inactive list:

Botany 5. Study of plant stimulation by formaldehyde.
Chemistry 3. Summer forage crops.
Entomology 2. Economic importance of digger wasps.
Entomology 3. Control of the onion maggot.
Microbiology 1. Microbiological investigations in milk.
Microbiology 3. Canning investigations.

Projects Discontinued.

The Station policy of submitting every project of record to critical analysis of a committee has resulted in certain projects being discontinued, because of unsatisfactory operating conditions. Variation in the soil, inability to secure adequate machinery, lack of personnel — any one of these may be a contributing cause. Based upon recommendations of committees, the following projects have been discontinued:

Agriculture 4. Methods of applying lime and quantity of application.
Agriculture 6. Top-dressing permanent grasslands.
Agriculture 8. Determination of effect of fertilizer on the germination of onion seed.
Botany 12. Potato spraying versus dusting in the control of late blight.
Market Garden Field Station 4. Variety and strain tests of tomatoes.
Market Garden Field Station 5. Growth control by means of intercropping.

Catalog of Active Projects, December 1, 1923.

Plant Nutrition and Soil Fertility.

Chemical Investigations.

Chemistry 14. A study of the availability of soil potash, with the object of developing a system of diagnosis for soils of the State. *Professor Morse.*

Microbiological Investigations.

Microbiology 2. Soil fertility as influenced by micro-organisms in their relation to the presence and disappearance of organic matter. *Assistant Professor Itano and Mr. Sanborn.*

Physiological Studies.

Botany 1. Optimum conditions of light for plant response. *Assistant Professor Clark.*

Market Garden Field Station 7. Study of the factors influencing the heading of greenhouse lettuce. *Assistant Professor Tiedjens.*

Pomology 1. The interrelation of stock and scion in apples. *Professor Shaw and Mr. Bailey.*

Pomology 12. Apple variety fruit spur study. *Professor Shaw, Assistant Professor Van Meter, and Assistant Professor C. P. Jones.*

Pomology 14. Winter injury of brambles. *Professor Shaw, Assistant Professor C. P. Jones, and Assistant Professor Clark.*

Soil Management and Fertilizer Tests.

Agronomy 2. Tobacco cropping system investigations. *Assistant Professor J. P. Jones and Professor Anderson.*

Agriculture 3. Residual value of excess phosphorus applications. *Assistant Professor J. P. Jones.*

Agriculture 7. An attempt to restore productive fertility to wornout and maltreated soils. *Assistant Professor Gaskill.*

Botany 13. Ecological study of pasture vegetation. *Professor Osmun and Director Haskell.*

Market Garden Field Station 1. Manure economy tests. *Professor Tompson.*

Pomology 5. Comparison of cultivation and sod mulch in a bearing orchard. *Professor Shaw.*

Pomology 6. Comparison of clover sod and grass in a sod mulch orchard. *Professor Shaw.*

Pomology 7. Test of fertilizers on a sod mulch orchard. *Professor Shaw.*

Pomology 8. Test of cover crops for apple orchards. *Professor Shaw.*

Pomology 15. Orchard fertilization. *Professor Shaw.*

Pomology 16. Tests of different amounts of nitrate of soda. *Professor Shaw and Assistant Professor Drain.*

Pomology 18. Comparison of cultivation and heavy mulching of apples and pears. *Professor Shaw.*

Pomology 19. A study of the effects of fertilizer limitations on fruit plants. *Professor Shaw.*

Pomology 20. Tests of fertilizers for pears. *Professor Shaw.*

Crop and Crop Management Studies.

Plant Introduction.

Cranberry 5. Blueberry investigations. *Professor Franklin.*

Pomology 17. Study of the cultivation of the high-bush cranberry. *Professor* Shaw.

Strain and Variety Tests.

Agriculture 5. Meadow fescue versus timothy. *Assistant Professor Gaskill.*

Agronomy 1. Investigation of the value of Hubam or annual sweet clover as compared with the biennial sweet clover. *Professor Michels.*

Pomology 2. Study of tree characters of fruit varieties. *Professor Shaw and Mr. A. P. French.*

Pomology 13. Studies of varieties of tree fruits. *Professor Shaw and Mr. Raleigh.*

Breeding and Crop Plant Improvement.

Market Garden Field Station 6. Improvement of Martha Washington asparagus. *Assistant Professor Tiedjens.*

Pomology 3. The genetic composition of peaches. *Professor Shaw and Mr. Bailey.*

Orchard Management.

Pomology 4, 9, 10. Experiments in pruning apples. *Professor Shaw.*

Harvesting and Storing.

Pomology 21. Study of fruit harvesting and storing. *Mr. Raleigh.*

Crop Protection.

Insect Enemies of Vegetation.

Entomology 4. Control of the squash vine borer. *Mr. Worthley.*
Entomology 5. Control of the squash bug. *Mr. Worthley.*
Entomology 7. Study of insect outbreaks in various localities. *Professor Fernald.*
Entomology 8. Pest limits in Massachusetts. *Professor Fernald.*
Entomology 9. Number of generations of codling moth in Massachusetts as related to advisability of spraying for the second generation. *Assistant Professor Bourne.*
Entomology 10. Hatching dates of scale insects. *Assistant Professor Bourne.*
Entomology 17. Control of onion thrips. *Assistant Professor Bourne.*
Cranberry 1. Injurious and beneficial insects affecting the cranberry. *Professor Franklin.*

Plant Disease Control.

Botany 3. Tobacco investigations. *Professor Osmun and Professor Anderson.*
Botany 9. Investigation of carrot blight. *Assistant Professor Doran.*
Botany 5. Experimental spraying for the control of cucumber mildew under glass. *Assistant Professor Doran.*
Botany 6. Investigation of onion diseases. *Professor Osmun and Professor Anderson.*
Botany 14. Investigation of control of tobacco wildfire. *Professor Anderson.*
Botany 16. Relation of soil character to occurrence of onion smut. *Professor Anderson.*
Cranberry 2. Cranberry disease work. *Professor Franklin.*

Spray Materials — Their Nature and Use.

Chemistry 20. A study of the fundamental factors affecting the suspension adhesiveness, toxicity and general efficiency of copper fungicides. *Professor Holland and Mr. Dunbar.*
Entomology 12. Determination of best strength of lime-sulfur. *Assistant Professor Bourne.*
Entomology 13. Study of the possible injurious effects of Scalecide on trees. *Assistant Professor Bourne.*
Entomology 14. Does spraying orchards kill bees? *Professor Fernald.*
Entomology 15. Determination of the efficiency of nicotine sulfate dusts. *Assistant Professor Bourne.*
Entomology 16. Investigation of materials which promise value in insect control. *Assistant Professor Bourne.*
Pomology 11. Test of spray materials that have become commercially important. *Professor Sears and Mr. Raleigh.*

Animal Husbandry.

Animal Nutrition.

Chemistry 17. Attempting to secure a substitute for milk in the growing of young calves. *Professor Lindsey and Assistant Professor Archibald.*
Chemistry 19. The value of inorganic calcium phosphate in the promotion of growth and milk production. *Professor Lindsey and Assistant Professor Archibald.*

Miscellaneous.

Chemistry 4. Record of the station herd. *Professor Lindsey.*

Poultry Husbandry.

Studies in Heredity.

Poultry 1. Broodiness in poultry. *Professor Hays.*
Poultry 2. Breeding poultry for egg production. *Professor Hays.*
Poultry 3. A genetic study of Rhode Island Red color. *Professor Hays.*
Poultry 4. Determination of genetic laws governing results in inbreeding of poultry. *Professor Hays.*
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Meteorological Studies.

Entomology 11. Study of area of the late frosts as shown by insect distribution. *Professor Fernald.*
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CONTROL AND REGULATIVE SERVICE.

In addition to the conduct of agricultural research, the Station administers the State feed and fertilizer control laws, the law for the inspection of dairy glassware, and the poultry disease elimination law; and likewise, in co-operation with the different breed associations, conducts tests for advanced registry. With the single exception of the law relating to the elimination of certain poultry diseases, all of these control functions are self-supporting, are administered by separate staffs, and do not represent a drain on the research funds of the Experiment Station. Full report of the poultry disease elimination work is contained in Control Bulletin No. 23, published in September, 1923. The report on commercial feedstuffs is listed as Control Bulletin No. 24; that on fertilizers as Nos. 25 and 26, the last referring to lime products used in agriculture. In addition these different departments perform a large amount of analytical service for the Experiment Station as well as for certain agricultural organizations and others. Wherever service of this kind is for other than public or community benefit, a fee is charged.

In furtherance of the dairy law, so-called, 81 certificates of proficiency have been awarded, and inspections of apparatus and machinery made in 106 different places. Two machines were condemned and minor repairs ordered on 17. Reinspections were necessary in 6 places. Six thousand, one hundred and twenty-five pieces of glassware were calibrated, of which only 18 were condemned. The very low ratio of pieces of apparatus condemned to the total inspected demonstrates most strikingly the value of a control of this kind. In the first year of full operation under this law, 291 pieces of glassware, 5.77 per cent of the whole number inspected, were condemned.

The report on the advanced registry testing of dairy cows follows:

Summary of Two-Day Test Work, December, 1922, through November, 1923.

Number of Cows tested.

Month.	Number of Supervisors, Whole or Part Time.	Guernsey.	Jersey.	Ayrshire.	Shorthorn.	Holstein.	Totals.
December	12	200	111	96	12	119	538
January	12	215	105	94	13	53	480
February	12	206	113	91	15	74	499
March	12	228	123	99	16	93	559
April	15	217	113	84	16	99	529
May	11	218	86	83	18	103	508
June	10	235	101	88	23	95	542
July	10	236	92	89	24	99	540
August	10	237	99	91	24	90	541
September	10	241	84	76	20	90	511
October	9	226	87	66	25	99	503
November	9	235	91	70	23	101	520
Totals	–	2,694	1,205	1,027	229	1,115	6,270

Number of Herds visited.

Month.	Number of Supervisors, Whole or Part Time.	Guernsey.	Jersey.	Ayrshire.	Shorthorn.	Holstein.	Totals.
December	12	34	12	12	2	13	73
January	12	36	12	11	2	10	71
February	12	36	13	11	2	10	72
March	12	41	15	12	2	10	80
April	15	40	17	10	2	9	78
May	11	44	20	9	2	13	88
June	10	37	20	9	2	10	78
July	10	33	16	9	2	11	71
August	10	37	15	10	2	10	74
September	10	31	13	7	2	10	63
October	9	33	13	8	2	11	67
November	9	37	13	7	2	11	70
Totals	–	–	–	–	–	–	885

The total number of tests made during the year ending December 1, 1923, decreased by 1,172, compared with the previous year.

There were twenty men employed for the seven-day Holstein work, 38 farms visited, and 125 reports turned in.

DIAGNOSTIC AND ANALYTICAL SERVICE.

In addition to the service already reported the Station performs a large amount of diagnostic and analytical work. The department of Veterinary Science examines samples of diseased poultry sent in for examination, makes diagnosis and reports back to the sender. The department of Botany makes similar examinations of diseased plants submitted, and the department of Entomology diagnoses insect injury from such samples of either plant or insect as may be sent in. This work is all of it most important. It is not duplicated by any other agency in the State, and requires a very high degree of skill in its performance. It must be admitted, however, that it is a heavy drain on research funds, and that the same work must be repeated annually for different individuals or communities over a period of many seasons. For this reason the work would be more efficient if it could be organized under the Extension Service.

In the department of Plant and Animal Chemistry, many analyses are made of milks, creams, feedstuffs and other products submitted for examination. This work differs from the foregoing in that more is for the benefit of the individual and less for that of the State or a group of citizens within the State. For this reason a fee is charged for certain parts of this work. The same department has given most valuable service in co-operating with other Station departments through making analyses of soils, fertilizers, feeds, plants, insecticides and fungicides and other materials on which information was needed. The co-operative spirit in which this work has been done is most gratifying.

METEOROLOGICAL OBSERVATIONS.

Department of Meteorology.

PROF. J. E. OSTRANDER, HEAD.

Annual Summary for 1923.

Pressure (in Inches).

Maximum reduced to freezing	30.52, Jan. 22nd, 11 A.
Minimum reduced to freezing	28.98, Dec. 28th, 12 M.
Maximum reduced to freezing and sea-level	30.84, Jan. 22nd, 11 A.
Minimum reduced to freezing and sea-level	29.29, Dec. 28th, 12 M.
Mean semi-daily reduced to freezing and sea-level	30.020
Annual range	1.55

Air Temperature (in Degrees Fahr.).[1]

Highest	97.0, June 19th, 3 P.
Lowest	—12.0, Jan. 31st, 6 A.
Mean hourly	46.6
Mean of means of max. and min.	46.8
Mean sensible (wet bulb)	41.4
Annual range	109.0
Highest mean daily	81.7, June 20th
Lowest mean daily	3.8, Feb. 18
Mean maximum	58.5
Mean minimum	35.1
Mean daily range	23.4
Greatest daily range	49.0, Sept. 23d
Least daily range	3.5, Nov. 7th

Humidity.

Mean dew point	36.9
Mean force of vapor	.369
Mean relative humidity	75.5

Wind.

Prevailing direction	West, Northwest

Summary.

North	12 per cent
North Northwest	11 per cent
South	12 per cent
South Southwest	12 per cent
Northwest	12 per cent
Other directions	41 per cent
Total movement	48,864 m.
Greatest daily movement	405 m., Mar. 5th
Least daily movement	18 m., Nov. 16th
Mean daily movement	134 m.
Mean hourly velocity	5.6 m.

Maximum pressure per square foot, 22.5 lbs., = 67 m. per hour, Apr. 29th, 1 A., S. S. W.

Maximum velocity for 5 minutes, 36 m. per hour, Mar. 28th, 2 P., W. N. W.; Apr. 29th, 1 A., S. S. W.

Precipitation (in Inches).

Total precipitation, rain or melted snow	39.49
Snow total in inches	63.7
Number of days on which .01 or more rain or melted snow fell	125

Weather.

Mean cloudiness observed	45 per cent
Total cloudiness recorded by Sun Thermometer	1,686 hrs. = 38 per cent
Number of clear days	141
Number of fair days	131
Number of cloudy days	93

Bright Sunshine.

Number of hours recorded	2,773 hrs. = 62 per cent

Dates of Frosts.

Last	May 24th
First	Sept. 15th

Dates of Snow.

Last	April 15th
First	Nov. 8th
Total days of sleighing	86

Gales of 50 or More Miles Per Hour.

54 m. Feb. 3d, N. W.; 52 m. Mar. 19th, W. N. W.; 59 m. Mar. 28th, W. N. W.; 52 m. Apr. 24th, N.; 67 m. Apr. 29th, S. S. W.

[1] Temperature in ground shelter.

REPORT OF THE TREASURER.

FRED C. KENNEY.

United States Appropriations, 1922–23.

Dr.	Hatch Fund.	Adams Fund.
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1923, under Acts of Congress approved March 2, 1887 and March 16, 1906	$15,000 00	$15,000 00

Cr.

		Hatch Fund	Adams Fund
Adams:			
By salaries	$14,631 00		
tools and machinery, furniture and fixtures	20 25		
scientific apparatus . . .	10 57		
seeds, plants and sundry supplies	5 95		
chemical and laboratory supplies	21 92		
labor	310 31		
	$15,000 00		$15,000 00
Hatch:			
By salaries	$12,980 00		
labor	1,442 13		
seeds, plants and sundry supplies	35 34		
livestock	35 00		
tools and machinery . .	52 25		
fertilizer	321 97		
chemical and laboratory supplies	133 31		
	$15,000 00	$15,000 00	

State Appropriations, 1922–23.

Cash balance brought forward from last fiscal year	–
Cash received from State Treasurer	$107,410 38
fees	37,522 41
sales	3,983 10
miscellaneous	424 39
	$149,340 28
Cash paid for salaries	$64,462 44
labor	15,962 03
publications	3,198 65
postage and stationery	2,375 96
freight and express	864 95
heat, light, water and power	1,105 72
chemicals and laboratory supplies	3,472 53
seeds, plants and sundry supplies	936 62
fertilizers	781 09
feeding stuffs	1,837 55
library	1,193 57
tools, machinery and appliances	2,224 75
furniture and fixtures	419 40
scientific apparatus and specimens	761 27
live stock	21 45
traveling expenses	5,398 47
contingent expenses	65 00
buildings and land	2,328 93
remitted to State Treasurer	41,929 90
Total	$149,340 28

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 213 JANUARY, 1923

TOBACCO WILDFIRE IN 1922

By P. J. ANDERSON and G. H. CHAPMAN

Wildfire continues to be the most destructive disease of tobacco in the Connecticut Valley. Experiments for the purpose of perfecting the old methods or finding new methods of checking the disease are in progress.

Results of the 1922 experiments and observations on control are summarized in this bulletin. The value of sterilization of seed, soil, sash and sideboards, spraying and dusting of plants in the bed and in the field, destruction of diseased areas in the beds, roguing of plants and removal of diseased leaves from the field are discussed and directions given for the application of these measures. This bulletin also discusses the overwintering of the wildfire bacteria and their dissemination during the summer.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

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CONTENTS

BULLETIN No. 213.

DEPARTMENT OF BOTANY.

TOBACCO WILDFIRE IN 1922.[1]

BY P. J. ANDERSON AND G. H. CHAPMAN.

INTRODUCTION.

Wildfire in the Connecticut Valley.

Wildfire continues to be the most serious menace to the tobacco-growing industry of the Connecticut Valley. The season of 1922 was not less disastrous than that of 1921.

Beginning with the first recorded infection on May 7, fresh reports of infected seed-beds came in from every side with increasing frequency until it was estimated that 30 per cent of the beds of the valley contained some wildfire. No tobacco-growing town in Connecticut or Massachusetts escaped. Continuous rains and cloudy weather during the seed-bed period furnished ideal conditions for the spread of the disease and at the same time made it difficult to apply remedial measures. The same weather conditions continued throughout the setting period of June, and it was not surprising that the disease appeared in the fields almost as soon as the plants were established. It continued to spread there until, by the 4th of July, wildfire was raging in half the fields of the valley. The Broadleaf section was much more seriously affected than in 1921, while, on the other hand, many of the growers of other varieties escaped with less trouble than during the previous year. Growers were discouraged both by the wildfire and by the poor growth of the tobacco during this unfavorable weather, and some of them even plowed up their fields. But after the first week in July the weather cleared, there were no more long-continued rains, and such rains as occurred were followed by hot, clear weather. During the next three or four weeks wildfire spread hardly at all and the tobacco grew rapidly, covering the diseased leaves with healthy ones until many growers felt that the disease had passed. Rainstorms, however, became more frequent during the last few days of July and were accompanied by increased spread of disease throughout the topping period and, with but

[1] A report of co-operative work carried on by the Massachusetts Agricultural Experiment Station and the Tobacco Experiment Station of the Connecticut Agricultural Experiment Station. Published, with a different introduction, as Bulletin 2 of the latter station.

slight interruptions, until the crop was harvested. Many of the growers who had a slight foot-leaf infection profited by their experience of 1921 and did not wait for the tobacco to ripen, but cut it "on the green side" and in this way reduced the damage somewhat. It is probably no exaggeration to say that 90 per cent of the tobacco fields of the valley were more or less affected. Some fields were so badly "fired" that not a clean plant could be found, and the price received for the crop will be but a fraction of the cost of growing.

Wildfire in Other Sections.

During the summer one of the writers had occasion to visit the tobacco regions of New Hampshire and Vermont, where conditions were found to be very similar to those which prevailed in Massachusetts.

A serious outbreak occurred in Wisconsin (Pl. Dis. Bul. 6: 40, 139), from which State the disease had not been reported previously from farms. It was also reported for the first time from New York and Georgia (Pl. Dis. Bul. 6: 62, 63). It occurred with more or less severity in Pennsylvania, Maryland, Kentucky (Pl. Dis. Bul. 6:21) and Ohio. It is rather surprising to find that in North Carolina and Virginia, in which States the disease was first found and where it was very destructive five years ago, there has been no damage from wildfire during 1922. Under date of August 19, Dr. F. D. Fromme, plant pathologist of the Virginia Agricultural Experiment Station, wrote: "We have yet to see a case of wildfire in the 1922 crop in Virginia. We have inspected well over 100 fields in counties where it has occurred in the past year. Plant beds were equally free from it this year." Under date of August 21, Dr. F. A. Wolf, plant pathologist of the North Carolina Agricultural Experiment Station, wrote: " I have not received this season a single authentic specimen of tobacco wildfire from this State."

Previous to this year wildfire was not known to occur outside the United States. It has now been reported from South Africa (2:366–368).[1]

Progress in Investigations.

Investigations with the object of developing some method or methods of preventing loss from wildfire, begun in 1921, were continued by the writers in 1922.[2] Although such methods have not been perfected as yet, nevertheless some improvements have been made on the methods previously recommended, and by another season of work we have been able to confirm more fully some measures which were recommended, while others have been found to be of less importance. Some further studies have

[1] The first number in the parenthesis refers to the bibliography on page 27 of this bulletin, and the numbers after the colon refer to pages of these publications.

[2] Results of the investigations of 1921 are recorded in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin, Chapman has been located at the Connecticut Tobacco Substation in Windsor, but the work has been continued in co-operation between that station and the Massachusetts Agricultural Experiment Station. Valuable contributions to our knowledge of wildfire have been made by Clinton and McCormick in Connecticut, and published during the last year as Bulletin 239 of the Connecticut Agricultural Experiment Station. This bulletin and a number of other important publications on wildfire which have appeared during the last year are freely quoted and referred to here in order that the grower who reads the present bulletin may have the advantage of all that has been learned concerning this problem.

been made in regard to the life history of the causal organism, especially with reference to overwintering and dissemination. The results of the life history and control work of 1922 are briefly presented in the present bulletin.

Valuable assistance in the work has been rendered by Prof. A. V. Osmun of the Massachusetts Experiment Station and Mr. C. M. Slagg of the United States Department of Agriculture. Tobacco growers in both States, too numerous to mention here by name, have co-operated heartily with the writers in the work described in the following pages.

LIFE HISTORY STUDIES.

Overwintering of the Bacteria.

As a basis for control measures, probably no problem in regard to life history of the causal organism[1] is more important than determination of the method or methods by which the bacteria survive the winter and thus serve as starting points for wildfire of the next year. Certain experiments with the object of solving this problem were conducted during the winter of 1921–22, and though some of the results are not conclusive progress to date is reported at this time. Other experiments with the same object are now in progress, and it is hoped that they will be more satisfactory.

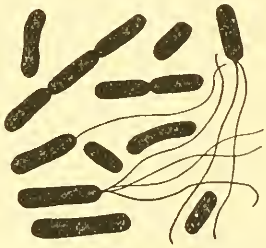

Fig. 1. — A group of the bacteria which cause wildfire. Magnified 5,000 times.

Effect of Freezing the Bacteria.

In studying the problem of overwintering, the first point to be determined is the effect which freezing has on the organisms. If they are not able to withstand the exposure of a New England winter, then the measures of control will be quite different from those which should be tried if they are resistant to cold. Pure cultures of *Bacterium tabacum* on agar were placed out of doors at various times during the winter of 1921–22, some of them being frozen solid for months; but in every case when they were brought back

[1] Wildfire is produced by the parasitic growth of enormous numbers of bacteria (*Bacterium tabacum* Wolf and Foster) in the leaves. Since various investigators who have published concerning the organism do not agree as to some of the morphological characters, Anderson during the past season has made and studied permanent slides on which the bacteria have been stained by (1) the Duckwell modification of the Pitfield method, (2) the Shunk method (Journ. Bact. 5: 181, 1920), and (3) to a less extent by other methods. The organisms are short, cylindrical rods with rounded ends and usually straight sides, but not infrequently individuals are found which are slightly curved or somewhat dumb-bell shaped. Frequently two or three of them remain end to end in a chain on the slide. Those in chains are shorter, indicating immaturity. Only those which were free from each other were used in measuring. The average size of fifty taken from five slides stained in different ways was 2.3x.8 μ. The longest one measured was 3.8 μ and the shortest 1.4 μ. Attached to one end there are one to four flagella several times as long as the body of the bacterium. The bacteria in text, Fig. 1, were drawn from a slide stained by the modified Pitfield method.

into the laboratory and transferred to other media they grew normally. The result was about what one would expect when it is remembered that few species of bacteria are killed by freezing. It is certain from data presented below that freezing does not kill them while in the leaf in the tobacco barn.

On the Seed.

It has been suspected by most workers who have investigated this disease that the bacteria may survive the winter on or with the seed, and that early infections in sterilized beds originate in this way. Although this would seem possible, there is as yet no experimental evidence to prove that such is the case in the Connecticut Valley. In Virginia, Fromme and Wingard (3) find conclusive evidence that the organism of blackfire of tobacco (*Bacterium angulatum*) overwinters in this way. Their evidence for the wildfire organism, however, is not so convincing. A number of experiments were undertaken by the writers for the purpose of determining the possibility of overwintering in this way. In the interest of brevity these experiments need not be given in detail, but the results may be summarized: —

1. All attempts to isolate the organism directly from suspected seed have failed.
2. Suspected seed has been planted and no wildfire has appeared on the seedlings where other sources of infection have been eliminated.
3. Seed inoculated by soaking in a pure culture of the bacteria and kept in a dry room all winter produced only clean plants in the spring.
4. In another experiment seed was artificially inoculated after it had been sterilized and the bacteria killed by heat. The seed remained wet from the culture for two weeks. In the spring it was sprinkled on healthy leaves and wildfire resulted, but the conditions are not the same as where seed is kept in a dry room.

All the evidence in these experiments was negative and has only the weight of such. The possibility is not precluded that there may be conditions under which the bacteria may winter directly on the seed coat.

There is no evidence that in nature a lesion may come in direct contact with the seed. No one has ever reported seeing a lesion on the seed. It is a well-known fact, however, that lesions do occur on the calyx of the flower and on the seed pod. During 1921 in Connecticut and during the late summer of 1922 in Massachusetts, pod lesions were found on plants being kept for seed. Similar lesions were also produced by artificial inoculation. In threshing out the seed small broken bits of the pods remain with the seed as chaff, and no amount of sifting and cleaning will remove every particle of chaff. If the bacteria overwinter in the seed, it is probably not directly on the seed but in these fragments of pods, etc., which are with the seed. Since it is known that they survive the winter in leaf lesions, there could hardly be any doubt that they could live over in similar lesions on the pods. Fromme and Wingard (3: 20) present experimental evidence showing that the percentage of wildfire is increased by top-dressing the seed-bed with chaff from infected pods of the previous year. It seems improbable, however, that any considerable proportion of the spring infection in the Connecticut Valley beds starts from the seed, because (1) growers now know the disease well enough so that few of them would save seed from infected plants; (2) many of the growers during the last season used old seed (grown previous to 1920) and yet they did not escape infection; (3) those who sterilized the seed were apparently no more successful in eliminating the disease from the beds than those who did not;[1] (4) even those who advocate most strongly the sterilization of seed do not present convincing data to prove that the disease organism is carried on the seed.

In the Soil.

From the plant the bacteria may get into the soil in two ways: (1) they may be washed from the plant by the rain during the growing season; and (2) when the leaves or other infected parts are turned into the soil or left to rot on the soil, the bacteria probably remain alive for a long time. It is important that we should know how long they remain alive there and capable of infection and whether they may survive the winter in this habitat.

Experiment 1. — In order to see whether the organisms could be carried from one crop to the next through the medium of naturally infested soil, such soil was taken from three beds of diseased plants at different times during the summer of 1921 and seeded with sterilized seed. The plants grown in this soil did not become infected. On the other hand, in one of the greenhouse beds which had grown a number of diseased crops, sterile seed was planted in the spring of 1922 and the seedlings became diseased before the plants were an inch high.

Experiment 2. — In this experiment one pot of soil was inoculated by spraying a suspension of bacteria over it, while another pot had an equal amount of water sprayed on it. Both were seeded shortly after sprinkling, and wildfire developed in the inoculated pot but not in the check.

During some control experiments in Whately, it was observed that even when all diseased leaves were removed from the plants, others became infected after rains and almost always on the tips which were beaten down into the soil. It appeared as though the bacteria had been washed from the diseased leaves into the soil and then splashed from the soil to other leaves.

In two fields in Hadley and North Hadley which were under constant observation by one of the writers during 1922, the plants became so badly diseased during June that all were pulled and carted from the fields. Both fields were set later with healthy plants, but in both cases there was a very heavy reinfection before the new plants were half grown. The second infection must have come by way of the soil.

Clinton and McCormick (2:404) buried wildfire leaves under healthy plants, and by this means the infection was increased to 63 per cent as compared with 13 per cent on adjacent plants not so treated.

[1] Records were kept on the beds of 11 growers in Massachusetts who treated their seed with mercuric chloride. Wildfire afterward appeared in 5, while the other 6 had no wildfire in the beds.

The above data furnish very strong evidence that the pathogen may be carried from one plant to another or from one crop to another by means of the soil. The failure to get infection in some of the experiments by planting in infested soil shows, however, that infection will not always result necessarily because the soil was infested.

None of the experiments just quoted furnishes evidence of the length of time during which the bacteria may remain alive in the soil or indicates whether they will live through the winter in this habitat. The following experiments and observations throw some light on the latter point: —

Experiment 3. — On July 1, 1921, Erlenmeyer flasks of soil were sterilized and later inoculated with the bacteria. Part were plugged only with cotton, others were paraffined to prevent drying out. At various times during the winter, soil was taken from these flasks and plated out. Then, when bacteria developed about the particles of earth, they were shaken in a suspension of water and atomized on healthy plants. In the flasks which did not have paraffined plugs, the soil became very dry, while in the others it remained muddy. Heavy infection resulted when inoculations were made March 10 and others on March 20, 1922, from the dry flasks, but none from the tightly closed wet flasks. These flasks were kept in the laboratory and were not frozen. In this case the bacteria were still able to produce infection after eight months.

In two instances in Connecticut, wildfire was found starting in the edge of the beds in soil which had been outside the pans when the remainder of the beds were steamed. In both cases wildfire was present in the beds in 1921. The fact that the planks were new and the sash had been sterilized with formaldehyde eliminated these as the source of infection.

In a number of cases, in both States, it was found that those parts of the field which were diseased in 1921 showed the heaviest infection in 1922.

On the other hand, fields have been observed which were badly diseased in 1921 and on which tobacco was free from wildfire in 1922.

On one of the fields at the Connecticut Experiment Station the 1921 crop which was badly infected with wildfire was cut late in September and left lying on the ground over winter with a view to getting data on the overwintering under natural conditions. In this case both leaves and stalks were left to weather. In 1922 this field was planted with Havana and Broadleaf wildfire-free seedlings, the stalks and leaves of the 1921 crop having been disked and plowed under two weeks prior to setting. Throughout the season close examinations were made by Slagg and Chapman for wildfire in this field. Wildfire was not found on this particular field during the growing season, but at harvest an occasional wildfire spot was found, yet nothing to what should have developed if any considerable amount of direct infection occurred as a result of the refuse being left on the field. A careful estimate of the wildfire plants on this plot, made at harvesting, showed that infected plants were not more than one-half of 1 per cent of the total number, and on all of these the infection was light. This slight infection may have come from plants in the wildfire experimental field, since all the station plots — except for the experimental field — showed about this same percentage of infection late in the season.

Clinton and McCormick (2: 376, 419) succeeded in one experiment in infecting tobacco plants in the greenhouse by direct application of over-wintered soil which had been exposed to infection the previous year. Wolf and Moss (4: 30) in North Carolina and Fromme and Wingard (3: 24) in Virginia present considerable evidence that in the South the organism winters in the soil, but we cannot accept this as conclusive proof of the same condition in New England.

Altogether the weight of laboratory data and field observations indicates that *Bacterium tabacum* is able in some cases to survive the winter in the soil and start new infection from this source in the spring. On the other hand, it is apparently possible under some conditions to raise a clean crop of tobacco on a field that has borne diseased crops during preceding years. The evidence as to soil wintering is, however, not so convincing as it should be, and further experiments are now under way which it is hoped will remedy the deficiency.

In Cured Leaves.

That the bacteria do not die when the diseased leaves are cured in the tobacco barn has been demonstrated in a number of our experiments.

Experiment 4. — On March 5, 1922, diseased cured leaves were taken from the Hampshire County warehouse just before they were ready to go into the case. They had been in the tobacco barn under normal conditions all winter. They were ground to a powder in a mortar and the powder was sprinkled on wet plants in the greenhouse. After two weeks the plants developed typical lesions of wildfire. Other leaves were ground and the experiment was repeated with the same result on March 28. On March 8 some diseased leaves were received from Mr. H. C. Wells of Deerfield. Some of them were ground and used for inoculation just as the above. Dilution plates were made from the others and the organism thus isolated used for making inoculations. Wildfire developed on the plants inoculated in both ways.

Experiment 5. — At Windsor, several times during the winter, wildfire spots from leaves kept in the station shed were brought to the laboratory and the wildfire organism isolated in pure culture. Cultures of wildfire bacteria were obtained from these leaves until the middle of March in this way, and no doubt living bacteria could have been found later than this.

These experiments were conclusive and there can now be no doubt that the wildfire organism can overwinter in cured leaves. It might get back from the cured leaves to the next year's crop in any one of a number of ways: (1) Refuse containing lesions from the shed may be thrown back to the land. (2) Sash and plank are sometimes stored in the tobacco sheds. Bits of broken diseased leaves could easily be carried out on such sash and plank and serve to start infection in the seed-bed. (3) While drawing the tobacco to the warehouse across or near the fields, parts of the diseased leaves might be scattered on the land.

Clinton and McCormick (2: 417) isolated *Bacterium tabacum* from tobacco leaves which had been dried and kept in the herbarium for periods ranging from one hundred and ninety-eight to two hundred and ninety-eight days. They were unable, however, to secure the bacteria from other leaves which had been kept for two years.

In Leaves which have been left in the Field.

Sometimes leaves when too badly diseased are picked off and thrown on the ground. At other times the whole diseased plant may be left. The suckers which grow from the old stubs after a diseased crop has been cut are usually infected. These are left on the field all winter. If the bacteria live over in these parts, they might easily start infection the following year. Being subjected to more frequent freezing and thawing and other changes of weather, it is possible that they might not survive in these leaves as they do in cured leaves in the tobacco sheds. We have very little data bearing on this point.

Experiment 6. — On April 24, 1922, diseased leaves, which had been cut down in the fall and left in the field all winter, were collected from plants at Windsor. These leaves were ground to a powder in a mortar, some of the powder was immediately applied to punctured leaves in the greenhouse at Amherst, and some of it soaked in water and the wet material applied after twenty-four hours to other plants. No infection resulted.

Similar tests were made with the same material by Chapman and Slagg, but with negative results. This negative evidence should not be considered conclusive. Further experiments are in progress.

Clinton and McCormick (2: 376, 419) succeeded in one case in infecting tobacco plants in the greenhouse with tobacco refuse which was wintered out of doors.

Occurrence of Lesions on Stalks.

Wildfire lesions have been reported previously as occurring only on the leaves and occasionally on the pods. During the inspection of a field of tobacco at South Amherst, some lesions which were suspected of being wildfire were found on the stalks. On further examination it was found that the lesions were not uncommon, but that they were present on a large part of the stalks in this field. Probably they had escaped previous notice because they are inconspicuous and somewhat different in appearance from the lesions on the leaves. They are commonly one-eighth to one-fourth inch in diameter, white, or, at most, light brown and sunken. The halo is not distinct on most of them, but can be seen about some. A number of them were brought to the laboratory and the typical bacteria isolated from them. Inoculation on leaves with these bacteria produced wildfire spots. In this same field and in various others examined through the summer, it was also observed that lesions were common on the "ears" or clasping bases of the leaves. When tobacco is stripped, these bases remain mostly on the stalk. Clinton and McCormick (2: 416) inoculated stalks and produced elongated blackened lesions. The occurrence of lesions on stalks and attached leaf bases may be important in answering the question as to whether land may become infested by throwing tobacco stalks on it. Since the organism overwinters in the leaves, there is no reason why it should not also remain alive in the stalk.

Occurrence of Lesions on Midribs.

In the process of "stemming" tobacco, the midribs are stripped from the leaf and are sold as fertilizer (incorrectly called tobacco stems). The question has frequently been raised as to whether the land may become infested by the use of "stems" from diseased tobacco. Observations as to the occurence of lesions on midribs were made at various times in fields during the summer. Frequently lesions were found running along both sides and encroaching on the midrib and often extending directly across the midrib. When the leaf was stripped from the midrib, parts of the lesion remained with the "stem." *Bacterium tabacum* was isolated directly from such denuded stems. This does not prove that the disease may be carried back to the land by using stems, since it has still to be demonstrated that the bacteria can survive the sweating process, but there can be no doubt that they occur in the midribs and may survive the winter thus in the tobacco shed. Clinton and McCormick (2: 416) produced lesions similar to those described above by inoculating the midribs with pure cultures of the bacteria.

Relation of the Condition of the Plant to Infection.

No set of experiments has been planned to determine the relation of the growth and vigor of the plant to susceptibility, but incidental to other experiments a number of observations have been made which indicate that a rapidly growing plant is much more susceptible than one which is growing slowly. During the fall of 1921 two beds were planted in the greenhouse at Amherst, — one on very poor soil and one on soil rich in rotted compost. Both were inoculated at various times and the rapidly growing plants of the fertile bed became infected, but all inoculations failed in the other bed until late in the spring, when the plants suddenly began to grow rapidly. In the course of some experiments at the Massachusetts Station during the summer of 1922 numerous unsuccessful attempts were made to inoculate a bed of very slow-growing plants which had received no fertilizer. During the same time other rapidly growing beds in the greenhouse were very readily infected. These experiments are not accurate, but certainly give some strong indications. Also the fact that infection is difficult to secure during the winter months points to the same conclusion. The relation of fertilizers to infection can probably be interpreted by their influence in producing a rapid, succulent growth or the reverse. Other investigators of the disease have made similar observations. Clinton and McCormick (2: 390) state that "the use of any fertilizer that favors rapid growth is more likely to help infection . . . than where the fertilization is such that slower or less satisfactory growth takes place." Fromme and Wingard (3: 27) express essentially the same opinion.

Dissemination.

No experiments directly dealing with dissemination were undertaken during the season of 1922, but observations throughout the year confirm the conclusions of 1921 in most respects. There is one notable exception, — the experiments and observations in 1921 led us to believe that all field infection originated from plants which were diseased when taken from the beds. The majority of the field infections, and the worst ones which we have seen in 1922, did come from that source and could be traced without any question to the seed-bed. On the other hand, a number of cases have come to the writers' attention where the beds were free from disease (if it is possible at all to tell when they are free), but disease developed in the fields set from these same beds. A few cases may be mentioned: —

1. Anderson inspected the beds of a certain Sunderland grower at intervals of three or four days throughout the season and is positive that they were free from disease. Yet parts of the fields set from these beds were very badly diseased.
2. Tobacco fields owned by a grower in South Deerfield, but located near Brattleboro, Vt., became badly diseased, and were visited by A. V. Osmun and Anderson in June. Most of these fields were set from beds near the fields, but some plants were brought from the beds in South Deerfield. A most searching examination of the beds at both places failed to reveal a single diseased plant.
3. A field of tobacco on a farm in Whately was isolated from all other tobacco fields and surrounded on all sides by woods. Plants were taken from the beds on the same farm. During the spring these beds were repeatedly inspected by C. M. Slagg, a wildfire expert, but he failed to find any infection. Yet wildfire became fairly prevalent in the isolated field.
4. The seed-beds of a grower in North Hadley were frequently inspected by Anderson during the spring, and not a trace of wildfire could be found at any time. During August some diseased plants were found in the middle of the grower's field.
5. Wildfire occurred in a field of the Massachusetts Experiment Station farm which was not being used for wildfire work, but not a trace of it had been seen in the beds at the experiment station where the plants were raised.
6. A certain Windsor grower kept his seed-beds covered at all times with copper lime dust, and frequent inspections by Chapman and Slagg showed no infection. He planted two fields, about 3 miles apart, from these beds. One of the fields developed a heavy infection during the growing season; on the other, only a trace of wildfire was found.

Many similar cases were reported by growers, but were not checked by the personal observations of the writers. The evidence is conclusive that not all field infection comes from the seed-bed. We are now confronted with the problem of determining how such infections did start. Rain could not have brought them from other fields because they were too far removed. There is some probability that in the Sunderland field the bacteria were in the soil over winter, since the worst infection occurred in the same place as last year. In the other cases, however, either no tobacco had been planted during the previous year on these fields or no wildfire had been observed there during 1921. Apparently there is some long distance disseminator which we have not yet found. Those that suggest themselves are (1) workmen, (2) insects, and (3) wind. Since many isolated infections were discovered within a week or two after the exceptional windstorm of June 12–13, it is possible that the organisms may have been spread with the dust and sand which were blown in great clouds over the valley at that time. It has been shown above in this report that dry, infested soil dusted over healthy plants may produce infection.

All observations of the summer confirm our previous conclusion that the most important short distance disseminator of the disease in the field is the rain, especially when accompanied by wind. It should be noted here, however, that not every rainstorm is followed by a new outbreak of wildfire. It was frequently remarked, especially during July, that heavy short rains quickly followed by drying weather resulted in very little spread of the disease. The ideal conditions for spread are (1) long-continued rains, (2) rains followed by cloudy weather during which the leaves do not become dry, or (3) periods during which the rains follow each other closely. During June of 1922 we had a long-continued combination of all three of the above conditions, which resulted in the worst spread of wildfire which we have ever seen.

CONTROL MEASURES.

Sterilization of Seed.

Seed sterilization has been recommended by the writers because it was thought possible that the bacteria might be carried on or with the seed. Fromme and Wingard (3: 20) of the Virginia Experiment Station, in fact, are of the opinion that a large part of the infection is started from the seed. Although there is no conclusive evidence in the Connecticut Valley or elsewhere that such is the case, nevertheless the practice was recommended as a precautionary measure. In 1921 formaldehyde was recommended as the disinfectant (1: 75), but this year mercuric chloride was recommended because it was found to be just as efficient and was less likely to cause injury to the seed; therefore the following directions for treating tobacco seed were sent out to tobacco growers before planting time.

> Purchase corrosive sublimate tablets at any drug store. Dissolve one tablet in a pint of water to make a 1/1000 solution. Use a glass jar. Place seed in a cheesecloth bag and soak in the solution for exactly fifteen minutes. Poke or stir occasionally with a stick to insure thorough wetting of all the seed. Remove bag of seed and wash thoroughly in water. Spread out seed in a warm room to dry. Store seed where it will not become contaminated. Germination of the seed will not be affected if directions are followed carefully.

Many of the growers in 1922 used the corrosive sublimate treatment for sterilizing their tobacco seed; and at the Windsor laboratory one hundred and twenty lots of seed were sterilized by this method, and the germination before and after sterilization was tested. In no instance in the laboratory tests was there any injury from such seed treatment.

Some of the growers, however, reported that they injured the seed by the corrosive sublimate treatment. Some said that germination was retarded, others that the percentage of germination was lowered; and others that the seed would not germinate at all. It was at first thought that the failure was due to faulty technique, but laboratory tests showed that even a treatment of thirty minutes was not harmful, and some of the growers omitted the washing of the seed after sterilizing without any bad effect. Some reported lack of germination in seed which was sterilized at the tobacco substation by Chapman. It was certain, then, that the injury could not be attributed to faulty technique in all cases. Inquiry among the growers as to the method by which they sprout the seed revealed one difference between their method and that used at the stations, viz., the custom which many growers have of cracking or sprouting the seed in moist cocoanut fiber or apple punk or between sods for a few days before planting. The seed is kept in a warm room of 70 to 90° F. and from time to time sufficient water is added to keep the fiber or other material slightly moist. It was thought that possibly the fiber might have something to do with the lack of germination and some of the seed was taken to the laboratory for test, using both unsterilized and sterilized seed of different lots. It was found that the unsterilized seed sprouted in the fiber and that the sterilized seed did not show any signs of sprouting even after ten days. Other growers brought in samples of seed which they themselves had sterilized and which had failed to sprout in fiber, and these lots were tested also. Chapman tried varying the conditions under which the seed was kept during the sprouting period and found that under the conditions ordinarily used it was almost impossible to sprout the sterilized seed, although the same seed in Petri dishes would germinate satisfactorily. It was found finally that in order to germinate sterilized seed, whether in punk or fiber, the pans should be kept at a lower temperature and also that the moisture content of fiber or punk must be considerably higher than usual. By close attention to these factors it was possible to sprout the different lots of sterilized seed in either punk or fiber almost as well as before sterilization.

Lack of germination of sterilized seed under usual conditions in punk or fiber appears to be due to the fact that the seed coat is hardened by the washing and drying and there is a much slower softening of the seed coat than is the case with the unsterilized seed. This was tested in the following way: —

Experiment 7. — Of two lots of seed, one was sterilized for fifteen minutes with a solution of 1/1000 corrosive sublimate, and the other treated for fifteen minutes in pure water without any chemical added. Both lots were taken from the jars and washed and dried in the usual manner. It was found to our surprise that both lots reacted the same; i.e., when placed in punk or fiber under normal conditions, the germination was greatly delayed or lacking. This experiment showed that lack of germination was not due to the corrosive sublimate treatment, but to another cause, probably the hardening of the seed coat by the washing process or possibly by the rapid drying.

The age of the seed or storage conditions may possibly play a rôle also, as in many cases growers had no difficulty with their seed. A few cases were brought to our attention where the injury was undoubtedly due to incorrect procedure in the corrosive sublimate method.

Data collected from growers who sterilized their seed during 1922 are not conclusive as to the value of the treatment for preventing wildfire.

As a result of our experience this past year, we are of the opinion that in the Connecticut Valley, seed is, at most, a minor source of infection. Nevertheless, this is a possibility which should not be lightly overlooked, and growers should not save seed from plants which show wildfire infection. If this is found necessary, however, we believe the seed should be treated with the corrosive sublimate. To avoid the difficulties discussed above, the beds should be sown with the dry seed. We do not know how long the bacteria will remain on the seed, but it is unlikely that there would be any alive on seed two or three years old. By the use of old seed the chance of infection from this source would be eliminated.

Sterilization of Soil in the Seed-bed.

Sterilization of the seed-bed soil with either steam or formaldehyde was recommended by the writers (1: 75) because it was thought possible that the organism could live from one season to the next in the soil. Considerable additional evidence that this is one of the ways in which it may pass the winter has been obtained during 1922 and presented in a previous part of this report. It is a common practice for growers to sterilize their beds to kill weed seeds, prevent root rot and for other reasons; and many beds were sterilized before the 1922 seed was sowed, a few in the fall and more in the spring. Careful records were taken on fourteen beds in Massachusetts which had been sterilized this year. Wildfire occurred in seven of them and the others remained free. No conclusion can be drawn from these data except that soil sterilization alone cannot be depended on to give a clean seed-bed. It is unquestionable that sterilization of soil by either steam or formaldehyde if properly done will kill all the wildfire bacteria in the soil treated, but it may not be so easy to eliminate the possibility of getting it contaminated again from infested soil in the walks, surrounding areas, tools, etc. These chances are perhaps greater where soil is sterilized in the autumn. Most growers use steam and consider it cheaper. If steam is used, it should be applied for thirty minutes at 100 pounds pressure. Those who do not have boilers which will produce so high a pressure may determine the proper length of exposure by burying a small potato 4 or 5 inches below the surface of the soil under the pan and applying the steam until it is cooked through. Only one of the fourteen mentioned above used formaldehyde. Formaldehyde at a dilution of 1/50 in water is applied at the rate of one-half to three-quarters gallon to the square foot of surface. Some preferred to change the location of the beds rather than sterilize the soil. In Massachusetts accurate records were kept on eight beds, the location of which had been changed to places where no tobacco was planted last year. Four of them had wildfire this year and four did not. The practice of sterilizing the beds should be continued not only to destroy wildfire bacteria but also to kill other disease organisms and weed seeds.

Sterilization of Sash and Plank.

The writers (1: 76) in 1921 recommended that old sash and plank be drenched with a 1/50 formaldehyde solution, and this was practiced by a number of growers. Some painted the sash and used new plank.

Data as to the benefits from this practice during 1922 are not very conclusive because in most cases other sources of introduction were not eliminated, but in a few cases under the writers' constant observation clean plants were raised in 1922 under the same sash and with the same sideboards (after sterilizing both) which had been used for badly diseased beds in 1921. Danger of infection from contaminated sash is well illustrated by the following experience of a Connecticut grower: His seed-beds in 1921 were so heavily infected in June with wildfire that the plants were destroyed. The sideboards were destroyed, the beds plowed up, and the sash stored over winter in a tobacco barn. The grower in 1922 decided to take no chances of a wildfire infection and contracted with a farmer who did not raise tobacco to grow sufficient plants for his use. The farm on which the plants were grown was remote from any tobacco fields or beds, new land was plowed and fitted, and old seed in which there was no possibility of contamination was used. It might be supposed that these precautions would insure freedom from the trouble; but as the farmer growing the plants had no sash, the sash used on the beds in 1921 were taken from the first farm and used on the beds. They were not sterilized, and shortly after the plants were up a very heavy infection occurred on all the beds on which the sash were used. While the proof is not absolutely conclusive, the inference is justified that the sash carried the bacteria. Unfortunately no beds without sash were grown in this particular instance, but it might be said that the possibility of contamination from other sources was slight indeed.

The following laboratory experiment was made with the object of determining how long the bacteria would remain alive on a piece of dry wood such as a side plank or sash: —

Experiment 8. — Small blocks of pine wood were sterilized and then soaked for eight days in a pure culture of *Bacterium tabacum* in bouillon. Then they were removed to dry, sterile tubes, where they quickly became dry and were kept so for further tests. The experiment was begun July 1, 1921, and the blocks were kept in the laboratory. At various intervals the blocks were tested for live bacteria by dropping one in sterile bouillon. They were still alive on September 10, but were dead on December 3. Sometime between these dates the last of them died. Apparently, then, they are able to live three months or more on dry wood.

In this laboratory experiment, however, the conditions are not the same as they would be in nature: (1) The wood is dried out more rapidly by the laboratory air than by the out-of-door air where they are stored. Sash are usually stored in a tobacco shed or barn, while the planks may even be left out in the weather. The conditions in the shed are more favorable than the laboratory for the survival of the pathogen. (2) If sash are kept in the tobacco shed, it is possible for diseased parts of the hanging crop to become lodged on them. (3) If the plank are kept out of doors, the moisture conditions would be about the same as for soil. In fact, the bacteria might be alive in soil which remains attached to the plank. Since we know that the bacteria can remain alive in the leaves and in the soil over winter, there would seem to be no reason why the sash or plank would not be a source of danger. Wolf and Moss (4: 32) and Fromme and Wingard (3: 22) have presented evidence to show that the germs may be introduced into new beds by the use of old cloth covers which were previously used on infested beds. If such cloth covers or the tent covers used in previous years over wildfire crops are used, they should either be boiled thoroughly in water or soaked in formaldehyde like the sash and planks.

Spraying and Dusting Seed-beds.

Results of the first experiment on the control of tobacco wildfire by spraying or dusting the seed-bed have been published in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin the experiment has been repeated at Amherst four times, using a greenhouse bed 4 x 16 feet for each experiment. The plants were pulled and counted when they were large enough for setting in the field, and then the bed was seeded immediately for the next experiment. The soil was not sterilized between experiments. The greenhouse bed was used in preference to an out-of-door bed because in this way a longer season could be secured and the experiment repeated more times.

Some of the fungicides used in the first experiment were omitted in later experiments because they were found to cause injury to the plants, viz., sulfur dust, lime-sulfur and the Pickering Bordeaux. NuRexo was used in the second experiment but omitted in the later ones, not because it failed to give control, but because it was thought best to confine the tests to one commercial copper spray. The copper-lime dust for the first experiment was furnished by the Riches, Piver & Co.; the dust for the later experiments by the Niagara Sprayer Company; the Pyrox was furnished for all experiments by the Bowker Insecticide Company. In order that all the data may be compared at a glance, the tables of results are first assembled and presented here all together and then followed by the general discussion.

Tests of Fungicides for the Control of Wildfire.

Description of Test.	Fungicides.	Total Number of Plants.	Diseased Plants. Number.	Diseased Plants. Per Cent.	Number of Lesions per 100 Plants.
Experiment 9: June 6 to July 26, 1921. Cloth bed, out of doors. Two applications at intervals of one week. (Bulletin 203.)	Bordeaux 4-4-50 (2 plots)	473	6	1.25	2.5
	Copper-lime dust 20-80 (2 plots)	534	3	.55	.5
	NuRexo (2 plots)	600	3	.48	.5
	Pyrox 10-50 (2 plots)	570	23	4.1	6.5
	No fungicide (4 plots)	1,079	527	48.25	178.2
Experiment 10: Oct. 10 to Dec. 10, 1921. Greenhouse. Three applications at intervals of about a week.	Bordeaux 4-4-50	848	0	0	0
	Copper-lime dust 20-80	771	3	.38	1.2
	NuRexo	747	6	.8	1.2
	Pyrox 12-40	863	5	.58	1.1
	No fungicide	1,092	221	20.2	37.5
Experiment 11: March 17 to May 10, 1922. Greenhouse. Three applications at intervals of over a week. Some infection started before first application.	Bordeaux 4-4-50	1,637	3	.2	.3
	Copper-lime dust 20-80	1,449	152 [1]	10.2	30.1
	Pyrox 12-50	1,375	140 [1]	10.0	25.8
	No fungicide	1,714	1,322	77.0	484.0
Experiment 12: May 17 to June 28, 1922. Greenhouse. Five applications at intervals of three or four days.	Bordeaux 4-4-50	1,176	2	.1	.1
	Copper-lime dust 20-80	821	0	0	0
	Pyrox 12-50	1,005	3	.3	.5
	No fungicide	883	499	57.0	208.0
Experiment 13: July 14 to Aug. 26, 1922. Greenhouse. Five applications at intervals of three to five days.	Bordeaux 4-4-50	1,205	12	1.0	1.2
	Copper-lime dust 20-80	1,056	3	.3	.4
	Pyrox 12-50	1,276	12	1.0	1.2
	No fungicide	938	860	92.0	487.0

[1] The high percentage of infection in this experiment is explained by the long intervals between applications and the fact that the bed was watered every day and inoculated twice a week.

Experiment 14. — In similar experiments at Windsor the beds were on soil which had grown a heavily infected crop of tobacco in 1921. The beds were not artificially inoculated as in the preceding experiments. The fungicides used were Sanders Dust No. 1, Niagara 20-80 copper-lime dust, Dosch 15-85 copper-lime dust, orchard brand Bordeaux lead and Bordeaux zinc. Seven applications were made at intervals of three to five days. A natural infection developed on the untreated plot and in one corner of a plot next to it. No other wildfire developed on the treated plots.

Conclusions from the Experiments and Practical Applications.

Frequency of Application. — The writers recommended in 1921 (1: 81) that the fungicide be applied once a week. Later experiments indicate, however, that this is not sufficient under the following conditions: —

1. When the plants are watered very frequently. On some soils it is necessary to water the beds heavily every day. Most of the fungicide is washed off before the end of a week. This factor was tested in Experi-

ment 11, where the plants were watered and inoculated every day or two. The percentage of infection was fairly high on the Pyrox plot and the dust plot. (The plants in the Bordeaux plot of this experiment were very small and in poor condition on account of accidental burning by cyanide gas which was used to fumigate the house. The low percentage of infection on this plot is not significant.) In the next experiment (Experiment 12) the plants were watered and inoculated less frequently and the fungicide was applied oftener. The infection was thus reduced again to less than 1 per cent.

2. When the beds are exposed to frequent rains. The first rains wash off the fungicide and later rains spread the bacteria. Even when the beds are covered during rains there is usually considerable drip through the sash between the glass.

3. When the plants are growing very rapidly, as they usually are just before setting begins. New leaves are produced so rapidly that many of them will be left unprotected for several days if the application is made only once a week.

No definite interval of time between applications can be regarded as safe. There are too many influencing factors. The only safe rule is to *keep all leaves covered at all times with the germicide.* During the very rainy season of 1922 no less than eight or ten applications would have been necessary. Growers have also found it a good practice to dust or spray the beds each time they are pulled over for setting.

Amount of Material to be applied. — In applying the dust or spray the only safe rule for judging whether enough has been applied is to note whether all leaves are covered. The amount of material required to produce a thorough covering will vary somewhat with the type of machine used and the stage of growth of the plant. In the experiments recorded above, in which a small rotary hand duster was used, it was found that no less than a pound of dust for each application was required to cover a square rod of plants when they were of a size suitable for setting. With the compressed air sprayer which was used, 1½ to 2 gallons of spray material were found to be sufficient to cover the same area.

Relative Cost of Spraying and Dusting. — At the local stores in Amherst and Windsor lime cost $4.90 per barrel of 280 pounds, or, since a little more if in smaller quantities, about 2 cents a pound, copper sulfate 11 cents a pound, Pyrox 20 cents a pound and copper-lime dust 10 cents a pound. Using the amounts per square rod which are indicated above, the cost of materials for eight applications would be as follows: —

Bordeaux 4–4–50	12 cents per square rod.
Pyrox 12–50	58 cents per square rod.
Copper-lime dust	80 cents per square rod.

Thus the cost of materials of a commercial fungicide such as Pyrox is nearly five times as great as that of the home-made Bordeaux, while the cost of the dust is nearly seven times as much. A good compressed air sprayer can be secured on the local market for $7 to $10.50, while a suitable dust blower costs $12.50 to $18.50. The advantage which the Bordeaux mixture has in cheapness, however, is counterbalanced by the increased time and labor involved in its preparation. The copper-lime dust is immediately ready for application when received, and the Pyrox or NuRexo has only to be dissolved in water.

Dust v. Liquid Sprays. — The results of the six series of tests detailed above indicate that the percentage of control is about the same for the liquid spray as for the dust. In beds where very frequent watering is necessary, there might be some advantage in the liquid sprays, because when once dried on the leaves they adhere much better than the dust. The dust, however, has the advantage that it comes up and covers the lower side of the leaves better than the liquid. The dust can be applied more quickly, but thorough dusting with a rotary hand duster is very hard work if continued for any length of time. The dust is also irritating to the nose, eyes and throat. Cheapness of materials and machines is in favor of the liquid sprays. Altogether, the choice between liquid and dust seems to be a matter of personal taste.

Home-made v. Commercial Copper Sprays. — In the control obtained there seems to be very little difference between the results secured by the home-made preparation and the commercial sprays such as Pyrox or NuRexo. Home-made Bordeaux has the advantage of cheapness, while the commercial sprays have the advantage of more rapid preparation for application. If a grower has large beds which require frequent application, certainly it would be more satisfactory to prepare his own fungicide. For small beds the commercial sprays might be more satisfactory. Clinton and McCormick (2: 386), after experimenting with Bordeaux mixture and a number of commercial copper sprays, recommend home-made Bordeaux mixture as being cheaper and more effective than other copper fungicides. They tried dust on only one bed and had no wildfire there on either the treated or untreated plot.

Best Time of Day for Application. — Dust should be applied preferably in the early morning when the plants are wet, or after watering. When the copper sulfate and lime in the dust come in contact with water, they unite to form Bordeaux mixture, which dries on the leaf and adheres with at least a part of the tenacity of the liquid Bordeaux. If, however, the dust is applied to the dry plant and water then applied, even when the Bordeaux is formed it is mostly washed from the leaf before it dries. Liquid sprays should be applied when the plants are dry, because the spray is thus not diluted with water already on there and because less of it drips from the leaves at that time.

Absolute v. Partial Elimination of Wildfire. — It will be noted in the tables given above that in almost all of the sprayed and dusted plots a certain amount of wildfire appeared. Only in a few tests has it been possible to eliminate all infection. In the first five series of tests, however, it should be remembered that sprinkling cans full of water teeming with the parasitic bacteria were sprinkled over all the plants every three or four days. Such a method of inoculation is much more drastic than would occur under natural conditions in the beds of the average tobacco grower. If the treatment here recommended is faithfully carried out by the grower, we believe that in the large majority of cases no wildfire will be found in his beds. Even if there are occasional infected plants in the bed, the treatment is not a failure. The removal of diseased plants from the field will be much easier if there are only a few of them. Even if they are not all removed, the amount of final infection may be expected to be less if there are only a few centers from which it can spread.

Will Clean Beds give Clean Fields? — Clean beds are not an absolute guarantee that no wildfire will appear in the fields planted from such beds. During the season of 1922 in at least six instances the writers had convinced themselves by thorough and frequent inspection that the seed-beds of certain growers were entirely free from wildfire, but the disease developed later in the fields planted from these same beds. (Read the paragraph above on "Dissemination" for more details.) Such cases, however, should not encourage any one to believe that no benefit is derived from keeping the seed-bed clean. The worst and the most wide-spread field infections have usually come from the bed. Starting with clean plants in the field is not the whole measure of success, but it is a long start toward it.

Success by Practical Growers. — During the season of 1922 the writers made frequent inspections and kept careful records on the seed-beds of a number of growers. Untreated checks were not left in any case, and for this reason the results are not entirely convincing. They were unable to find wildfire in any of these beds where the plants were kept constantly covered with the fungicide. On the other hand, it did appear in the beds of many who dusted or sprayed a few times, or started to treat only after the disease became evident, or used only a scant amount of material.

Value of an Arsenical in the Fungicide. — In the first test some of the fungicides, both the dry and the liquid, contained an arsenical. This arsenical not only was found to be of no value for the control of wildfire, but frequently caused injury to the plants. There seems to be no reason for adding an insecticide.

Dust Burn and Spray Injury. — Heavy application of dust or copper spray frequently causes some injury to the plants. It has been commonly noted in the experimental beds at Amherst that the plants in the check plots appear healthier (except for the wildfire) and larger than in the treated plots. Growers have frequently called the writers' attention to this condition in their beds. Sometimes it is much more marked than at other times. Frequently it cannot be observed at all. Certain conditions of the plant or its environment must be responsible for this variation, but it is not as yet known just which conditions favor and which prevent such injury.

Dust burn is evidenced on the leaves by small dead spots of one-eighth inch diameter or less, colored white, brown or darker to black, irregular in outline, commonly bordered by indefinite blanching of the immediately surrounding tissue. This border, however, is narrow and inconspicuous and fades away indefinitely into the normal green leaf. It is quite different and easily distinguished from the halo about the wildfire spot. The leaf area about the spot is also commonly distorted or puckered into radiating wrinkles. Where excessive amounts of dust are used, whole leaves or entire plants may exhibit this wrinkled, distorted appearance without central dead spots. This results in dwarfing.

Spray injury resulting from the liquid fungicides is indicated by larger dead areas in the leaves on the margins, tips or other places where the liquid stands in drops.

Injury from either dust or liquid spray has never been serious and at most has resulted only in slightly slower growth of the plants in the beds. The plants immediately recover after being set in the field. The injury is never of sufficient importance to discourage the application of dust or liquid spray.

Secondary Benefits. — Practical growers have frequently called attention to the absence of flea beetle in the treated beds. One prominent grower has stated that he would spray whether he had wildfire or not because the beds were free from these insects. Copper-lime fungicides are known to repel flea beetles.

Frequently when the plants are thick in the bed and kept damp, they rot off at the base of the stem. It has been commonly noticed that this condition does not occur when the beds are properly treated with a fungicide.

Conclusion. — Any grower who will start when the plants are no larger than a dime and keep the leaves covered at all times with copper-lime dust or any other good copper fungicide can control wildfire in the seed-bed. We agree with Clinton and McCormick (2: 386) in the following quotation except that we would include dusting as well as spraying: —

> We are convinced that spraying of tobacco beds should be made one of the routine practices of tobacco growing as long as there is danger from wildfire. . . . We have evidence that plants thoroughly coated with the spray do not become infected anything like unsprayed plants in the same bed. Spraying to be most effective, however, must start before the appearance of wildfire and be continued until the end of the transplanting season. We would start with the young plants that have just taken root and whose largest leaves are about the size of a thumb nail. . . . *Spraying, we believe, is the only remedy that prevents spread of the wildfire in a seed-bed no matter what the source of its introduction.*

Destroying Diseased Areas in the Bed.

It is characteristic of the disease that when it is first found in the beds it does not occur uniformly over the bed, but is usually found in round spots which may be from a few inches to several feet in diameter, depending on the length of time during which the spot has been spreading. If only one or a few spots are found in a bed, it is sometimes possible by prompt action to keep the rest of the bed clean. This may be done by immediately destroying the diseased spots by drenching them with a 1/10 formaldehyde solution. Not only the spot but all the plants within a foot or two beyond it must be killed. This treatment was successful in preventing further spread in one bed in Sunderland, in one in Hatfield and two in Windsor, all of which were under the writers' constant observation during the summer. Glass should be removed from all plants of the bed which it is desired to save, because if they are left on, the fumes of the formaldehyde will spread through the bed and burn the leaves with which they come in contact. Plants should not be hoed out or pulled out before treatment, since this only serves to spread the trouble. Plants around the burned-out areas should be watched carefully for further spread. Spraying or dusting should also be started at once if it has not been practiced previously.

Removing All Plants from a Diseased Field and resetting with Healthy Plants.

Two fields have been under the careful observation of the writers during 1922 in which this practice was adopted, but in both cases it resulted in failure. In one field in Hadley and one in North Hadley, when the plants were about a foot high, they were found to be practically all infected. All were removed from the field and after it had been harrowed the field was reset with healthy plants. In both cases before the new plants were ready to harvest, they became almost as badly infected as the old ones. Apparently the pathogen remains in the soil and under favorable conditions will infect the new crop. The grower can gain by this practice only when the weather changes for the better during the growth of the second crop. The same principle would apply also to the restocking of a field where only a part of the plants were diseased. This was tried on a large scale by a grower of shade tobacco at North Hadley, who removed only the diseased plants (about 10 per cent) and restocked with healthy plants, but failed to control the disease. The following experiment bearing on this point was tried at the Windsor station: —

Experiment 15. — In one plot nineteen diseased plants were found ten days after setting. They were all removed and replaced by healthy plants. Eleven out of the nineteen resets developed wildfire later.

During 1921 a number of growers practiced either partial or complete restocking with healthy plants after diseased ones were removed, and little or no wildfire appeared later in the field. The same was true of some Connecticut fields in 1922. This apparent control may have been due to weather conditions which were not favorable for infection of the plants of the second setting. At any rate the results were contrary to most of our experience of 1922. In view of the latter it seems questionable whether restocking should be recommended.

Roguing without Resetting.

When only a few plants in a field are diseased, it is probably best to remove them from the field and leave empty the places from which they were taken. This was tried with success by three growers in North Hadley whose fields were under the writers' observation during the present season. Other growers have told the writers that they kept wildfire in check by this method.

Experiment 16. — In a plot at the Windsor Station, where five plants were found to be diseased ten days after setting, they were all removed and the places not filled. The surrounding plants were inspected regularly and in two cases they became infected later.

In a later experiment, where the plants were about 1½ feet high, the diseased ones were removed and not replaced. Before harvesting, however, wildfire had appeared on the adjacent plants and had spread through four to six plants to the windward and along the row.

It is reasonable to believe that bacteria which came into the soil from the original diseased plant would have less opportunity for further infection if no plant replaced the diseased one which was removed. Certainly the danger of surrounding plants becoming infected is diminished by removal of infected ones from the field. On the whole, there is no question but that this practice of roguing will help to a great extent where there is only a light infection in the field, especially if the plants are pulled when small. After plants are half-grown, however, under favorable conditions the disease may spread in its customary manner, and it may be necessary to remove plants or infected leaves from plants for some distance around the original point of infection.

Picking off Diseased Leaves.

If the plants are large and infection is light, a certain amount of benefit may be derived from removing all diseased leaves and carrying them from the field. The principle of this measure is the elimination of as many as possible of the centers of spread. Then when the rains come the number of bacteria splashed to the healthy leaves will be greatly reduced. This method was tried by Anderson on a 4-acre field in Whately.

Experiment 17. — Infection in this field started from about six to eight rows near the east side, which had been planted from a diseased bed. At the time when the experiment was started a majority of the plants in these rows were diseased, and it had spread more or less to plants on adjacent rows. There was practically no infection on the west half. On June 30 all diseased leaves were picked from the east half (forty-eight rows). No attention was paid to the west half. On the badly infected rows mentioned above a large basketful of leaves was taken from each row, some of the plants being left almost without leaves. It was picked again four days later, the weather having been very rainy during the last month. Probably as many leaves were removed the second time as during the first picking. It was picked over at short intervals five times afterward, and with each picking the number of diseased leaves decreased, until on July 26 hardly a diseased leaf could be found. After the heavy rains of the last few days of July and the first of August, however, wildfire began to appear again on the picked side of the field, but to a greater extent beyond the forty-eighth row, where no picking had been done. The field was harvested on August 8. On that date the picked and unpicked sides of the field were inspected by Mr. Arthur Hubbard, W. H. Davis, D. Potter, C. M. Slagg, Dr. James Johnson and the writer, and it was the opinion of all that the unpicked side showed much more wildfire than the picked side. Mr. Hubbard was of the opinion that the east half would not have been worth harvesting if the disease had been left to take its natural course. The loss in weight from removal of the diseased leaves was not serious. As previously mentioned in this report there was good evidence that when infection began again during the first few days of August it came from bacteria which were in the soil. This source of infection cannot be eliminated and will probably prevent this method of control from ever being entirely successful. In view of the fact, however, that the season of 1922 was usually favorable to the spread of wildfire, the results of the experiment are encouraging.

A similar experiment was conducted on a Round Tip plot at the Windsor Station and with similar results. Growers who tried picking off affected leaves are divided as to their opinion of the practical value of the method. The degree of success varied according to the kind of tobacco and method of harvesting. Chances of success are better in primed tobacco because after harvesting starts the leaves are picked so rapidly that the disease does not have an opportunity to get a good start, and it also becomes increasingly difficult for the germ-laden soil to splash to the first leaves. Field observations on the picking of leaves during 1922 lead to the following conclusion: —

On the Shade Cuban, favorable results were almost uniformly obtained and the disease was practically eliminated. On Havana and Round Tip, where diseased leaves were removed, there was a considerable variation in the results, with a majority of fields showing decided benefit. On Broadleaf there did not seem to be anything gained by picking off the leaves.

For any one who contemplates this method of control it is recommended that (1) the first inspection be made as soon as the plants are established in the field; (2) the leaves be picked off twice a week as long as any diseased ones can be found; (3) sand leaves of diseased plants be picked also.

Clinton and McCormick (2: 396) also experimented with removal of diseased leaves and as a result were somewhat doubtful as to the benefits.

Dusting the Plants in the Field.

The value of dusting the plants in the field with copper-lime dust was tried by two Massachusetts growers under the writers' supervision during the season.

Experiment 18. — Twenty-four acres in Hadley were first dusted with a four-row traction duster, which was furnished by the Niagara Sprayer Company, on July 6, when the plants were 12 to 18 inches high. The infection was bad in parts of the field when the experiment was started. Four rows were left without dust. There were very heavy rains on the 8th and the second application was made on the 13th and 18th. During July there was very little spread of wildfire in any fields and the plants grew enormously. By the first of August the plants had grown until the machine could not be drawn through the field without serious damage to the plants, and therefore no more applications were made. There was considerable spread of the disease during August, until the crop was harvested about the middle of the month. A comparison of the treated and untreated rows at that time showed no difference in the amount of disease. No accurate counts were made, but a cursory examination while walking between the rows did not indicate any benefit from the two applications of dust. It was also noticed that there were dust-burn spots on the treated leaves similar to those which have been previously described as occurring in the beds. The owner feared that if the dusting were continued, the spots might affect the market of the crop.

Experiment 19. — Another grower in North Hadley dusted two fields with the machine used in Experiment 18, but more frequent applications were made. Wildfire was not controlled, the results being similar to those of Experiment 18.

Experiment 20. — On one of the Windsor Station plots Round Tip tobacco, which showed a heavy mixed infection of wildfire and angular leaf spot on the bottom two or three leaves when the plants were from 1 to 1½ feet in height, a copper-lime dust was twice applied to four rows, with a five-day interval between the first and second treatments, no rain falling in the interim. Six rows were left untreated for comparison. For about two weeks after treatment, the spread of the disease in the dusted rows was practically nil, while in the undusted rows it spread steadily and very rapidly. After this time three rainy days ensued, but purposely no more dusting was done. At harvest time it was found that the amount of wildfire on the dusted rows was only 15 per cent (estimated from partial count on cured tobacco) less than on the rows which had not been dusted.

No doubt, if the leaves in the field could be kept covered with dust all the time, the disease could be controlled, but this would require more frequent applications, and when the plants become large it cannot be done without considerable breaking of the leaves. Control by this method is probably possible, but not economically so. Further experiments, however, are planned. It was found that the dust adhered much better if applied early in the morning while the plants were still wet with dew.

Spraying with Bordeaux Mixture in the Field.

Bordeaux mixture was tried with the idea that it would adhere to the leaves more tenaciously and hence so many applications would not be necessary as when dust was used.

Experiment 21. — A field of 12 acres in North Sunderland was sprayed on July 11 with 4-4-50 Bordeaux. No further applications were made because the owner feared that the material would remain permanently on the leaves and affect the sale of the crop. An examination on August 14, when the crop was being harvested, showed that it was present in large enough quantity on many of the leaves to give them a decidedly blue cast. A comparison of the sprayed and unsprayed rows showed no difference in the amount of the disease.

Clinton and McCormick (2: 395) experimented with Bordeaux mixture in a preliminary way and found that it retarded spread of the disease, but they did not consider it practical because of cost and unknown effect of the spray on the quality of the mature leaf.

A few Connecticut growers tried spraying in the field in 1921 and reported good control. This year several growers of sun as well as shade grown tobacco sprayed plants in the field from one to six times, until the plants were too large to permit of further treatment, but the results have not been encouraging in the case of sun-grown tobacco. While the treatment seemed to check the disease for a time, later in the season after the plants had grown too large to continue the treatment, wildfire spread rather rapidly, and at harvesting little difference could be observed between the sprayed and unsprayed areas in the same field. In the case of one grower who had a rather bad field infection when the plants were small, the use of a Bordeaux mixture applied twice on part of the field when the plants were small checked for a long time any further spread of the disease, and at harvesting time the part of the field sprayed twice showed much less wildfire than the unsprayed part of the field.

Bordeaux mixtures are cheaper and under field conditions remain on the leaves a longer time, which is of course desirable from the infection protection standpoint, but a disadvantage when the plants are more than half-grown, as it remains on the leaves and the blue color is undesirable after the cure.

Another factor operating against the efficiency of dusts or sprays in the field is that after the plants are about half-grown it is a practical impossibility to operate a duster or sprayer to advantage, and one is obliged to stop the treatment at what might be termed the critical period, as it is well known that there is often a heavy wildfire infection just prior to maturity.

It is believed, however, that some benefit might be obtained from dusting or spraying when the plants are small and until they are about a foot high, particularly if spraying or dusting were combined with picking off diseased leaves, and the spraying or dusting repeated at very close intervals, say two or three times a week for a period of two weeks or so.

It is believed that the application of dusts or sprays to tobacco in the field is worthy of further consideration both by the growers and the station, and next season more detailed experiments along this line will be carried on.

At present, however, the evidence at hand is not very favorable for this method of control.

THE OUTLOOK FOR 1923.

The question now most frequently asked by the grower is: What can we expect from wildfire in 1923 and in the following years? Will it continue as prevalent and troublesome as it has been in 1922? Will it become worse after our land is thoroughly infested with the germ? Or will it gradually disappear? Frequently tobacco growers have told the writers that they would stop raising tobacco if they thought the disease would continue to be as serious as it has been during 1922. No man can predict its future behavior with certainty or anything which approaches certainty, but we can base some judgment on (1) what we know about its relation to weather conditions and (2) its behavior in States where it has been present longest.

We know that the disease can spread only when the rains are long continued or follow each other in close succession, i.e., when the water remains for long periods on the leaves. The summers of 1921 and 1922 were for the most part ideal in this respect for the spread of the disease. They have not been average summers for the Connecticut Valley. The disease will not be as destructive during an average growing season. We do not believe that wildfire will soon disappear from the valley, but during a dry summer it might not cause any damage. After a succession of unfavorable seasons the sources of infection might be so reduced that it would cause little trouble even with the return of a summer favorable for its spread. The above opinion is supported by the course which the disease has taken in the South. Five years ago it was destructive there. In 1921 the season was very dry and the injury from wildfire was slight. The season of 1922 is said to have been not unusually dry, but the disease has not returned to any extent. Our advice to the Connecticut Valley grower is to plant as usual, take a chance on the weather, but to omit no precaution recommended against wildfire.

CONDENSED RECOMMENDATIONS FOR CONTROL.

There is no one measure by the use of which a tobacco grower may be assured of raising a clean crop. As long as wildfire is in the valley, he must start before the seed is planted, be ever on the alert and ready to put into practice any part or all of the season's program which may now be briefly summarized: —

1. Select seed only from plants known to be free from the disease. If possible, go a step farther and take only from fields known to be disease-free. Protecting the flower heads with bags may be useful. Old seed is less likely to be contaminated.

2. If there is doubt about the seed being sterile, soak it in a cheesecloth bag for fifteen minutes in 1/1000 corrosive sublimate, wash and spread out to dry.

3. If possible, locate seed-beds only on land where there was no wildfire during the previous year and where there has been no opportunity for contamination.

4. Sterilize soil with steam at 100 pounds pressure for thirty minutes, or with formaldehyde 1/50 at the rate of one-half gallon to the square foot. It is safer to sterilize walks also. Spring sterilization is safer than fall sterilization.

5. Drench boards and sash with formaldehyde 1/50. If cloth is used, it should either be new or should be boiled in water or treated like the boards and sash. If sash and plank are new or have never been used for tobacco beds, they need not be sterilized.

6. Keep the plants covered with copper-lime dust or a copper spray such

as Bordeaux mixture at all times, from the stage when they are as large as the finger nail until setting is completed.

7. Remember that the germs can be carried from one bed to another on the hands, tools, sash, etc., and avoid such chances.

8. Adopt a system of bed management which will keep the leaves moist during the shortest length of time compatible with the production of good plants.

9. If the disease appears in certain spots in the bed, these spots, along with a broad margin of plants which appear healthy, should be killed by drenching with 1/10 formaldehyde.

10. Pull plants for setting only from disease-free beds.

11. Starting as soon as the plants have recovered and begun to grow in the field, make frequent inspections and remove every diseased plant from the field.

12. Do not work in a field where there is any wildfire while the leaves are wet.

13. Removal of diseased leaves at intervals of three or four days, where the infection when first found is light, will reduce the number of centers of spread and may materially reduce the percentage of wildfire in the crop when harvested.

14. Rotate tobacco with other crops if practicable.

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AGRICULTURAL EXPERIMENT STATION

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COMBATING APPLE SCAB

SPRAYING AND DUSTING EXPERIMENTS IN 1922

By WEBSTER S. KROUT

The scab fungus of the apple affects seriously the McIntosh Red, particularly as it is grown in the eastern apple region of the State. Nowhere in the State has scab yielded completely to the protective spraying and dusting methods commonly followed by apple growers. The Experiment Station started work on disease control in the fall of 1920. The outstanding fact to date is that of a high degree of control even in spite of adverse weather conditions. This bulletin gives the record of the 1922 operations, together with concise recommendations for protective treatment against the disease.

Publication of this Document approved by the Commission on Administration and Finance

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

BULLETIN No. 214.

DEPARTMENT OF BOTANY.

COMBATING APPLE SCAB.

SPRAYING AND DUSTING EXPERIMENTS IN 1922.[1]

BY WEBSTER S. KROUT.

Introduction.

The fact of control by both spraying and dusting is outstanding at the end of the second year's field study of this fungous disease. Weather conditions in both 1921 and 1922 were most adverse to successful spraying and dusting, and most favorable to scab infection, yet despite these handicaps almost perfect control was obtained.

These investigations were started in the fall of 1920. In the fall of 1921 a report of the results of the first year's work was published through the Extension Service of the College in a pamphlet entitled "Apple Scab and its Control." This bulletin presents to the practical orchardist a similar report for 1922.

The field work has been conducted in three orchards under the direct supervision of the writer. In three other orchards he was present whenever possible. The spraying experiments were in the orchards of Stephen Sabine of Groton and Harry L. Knights and H. L. Frost of Littleton. The dusting experiments were conducted in the orchards of Harry L. Knights and H. L. Frost of Littleton, A. N. Stowe of Hudson, George A. Marshall of Fitchburg and R. J. Fiske of Lunenburg. Especially helpful was the co-operation of J. W. Ames, superintendent of the Knights farm, Roy C. Wilbur, superintendent of the Frost farm, John J. Collins, superintendent of the Stowe farm, and the officers of the Nashoba Fruit Producers Association.

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[1] The writer is indebted to Prof. A. Vincent Osmun, head of the Department of Botany of the Massachusetts Agricultural Experiment Station, for many helpful suggestions during the progress of this study.

Apple Scab.

Apple scab presents one of the most serious problems of the commercial apple grower of Massachusetts. The disease is caused by a fungus which attacks the leaves, flowers, fruit, pedicels and twigs. It may attack any variety of apples, but is exceptionally severe on the McIntosh.

Every orchardist should endeavor to familiarize himself with the first symptoms of apple scab as they appear on the leaves, so that the disease may not reach the epidemic stage before he realizes the danger. Scab usually appears first on the lower side of the leaves as grayish or olive webby spots or blotches, darker than the normal surface of the leaf. The color deepens with age to dark brown or black. The spots on the upper surface of the leaves are first noticed as yellowish green discolorations, gradually deepening with age through olive brown to black. They are velvety, somewhat definite in outline, smaller than spots on the lower side, and have a tendency to become raised or convex.

The Causal Fungus.

The scab fungus passes the winter on the dead leaves, under the trees. In the autumn after the leaves fall the fungus continues growing, penetrating the interior of the leaf. Sometimes, in November, it begins to form the flask-shaped bodies (perithecia) in which mature winter spores (ascospores) are developed by the following spring. During the rainy periods of spring these spores are discharged, and, being extremely light, are carried upward by the air to the under surface of the leaves. The scab spots produced by this infection appear from eight to fifteen days later. These spots, almost as soon as they are noticeable, produce the summer spores in great quantities. These spores cause rapid spread of the disease.

Table I. — *Dates of Discharge of Winter Spores and of the First Appearance of Scab in 1921 and 1922.*

	1921.	1922.
First discharge of winter spores	April 26	May 2
First appearance of scab	May 12	May 18
Last discharge of winter spores	June 10	June 15

During both years the first spots were discovered on the lower side of the leaves at the time of the calyx spray. In other words, the first spots appeared as the petals were dropping.

Spraying Program for 1922.

A series of plots in triplicate were laid off in the three orchards previously mentioned. The sprays used were home-made Bordeaux mixture alone, home-made Bordeaux mixture and liquid lime-sulfur, home-made Bordeaux mixture and dry lime-sulfur, a 4–50 and a 3–50 dry lime-sulfur, liquid lime-sulfur, and liquid lime-sulfur plus lime.

Powdered arsenate of lead, at the rate of 2 pounds to 50 gallons of spray, and 40 per cent nicotine sulfate, at the rate of three-eighths pint to 50 gallons of spray, were used with all the different spray materials in the delayed-dormant, pink and calyx. In the fourth summer spray arsenate of lead was used but the nicotine was omitted.

In the Sabine and Knights orchards the plots were rectangular, 4 rows of 6 trees each, except the check at Sabine's which had 16 trees, and the Bordeaux–dry lime-sulfur plot at Knights' which had 20 trees. In the Frost orchard the plots consisted of single rows of 8 to 11 trees. The data were taken from 5 typical trees of the two middle rows of each plot in the Sabine and Knights orchards; and in the Frost orchard, from 5 typical trees of each row. The trees of each of the three sprayed orchards were approximately twelve years old.

Treatment of Plots.

All plots, except the checks, were given the delayed-dormant application. The plots in the Sabine and Knights orchards were sprayed with a 1–10 liquid lime-sulfur plus arsenate and nicotine. The plots in the Frost orchard were sprayed with a 15–50 dry lime-sulfur plus arsenate and nicotine. Plots 1 to 8 were conducted in each of the three orchards. Plots 9 to 11 were conducted only in the Frost orchard. The plots in the Sabine orchard were the only ones given the fifth summer spray. The detailed treatment of plots follows: —

Plot 1. — Check, unsprayed with fungicides. The same insecticides were used as on the other plots. A single check plot was used in each of the Sabine and Frost orchards. In the Knights orchard two check plots were necessary, because the Bordeaux plot was located in a separate block of trees.

Plot 2. — A 3–10–50 home-made Bordeaux mixture[1] for the pink spray, and a 1–50 liquid lime-sulfur for the calyx and following sprays.

Plot 3. — The same as plot 2, except that dry lime-sulfur was substituted for the liquid.

Plot 4. — 1–50 liquid lime-sulfur.

Plot 5. — 4–50 dry lime-sulfur.

Plot 6. — 1–50 liquid lime-sulfur plus 6 pounds of lump lime to 50 gallons of spray.

Plot 7. — A 3–10–50 home-made Bordeaux mixture for the pre-pink and pink, and liquid lime-sulfur for the calyx and succeeding sprays.

Plot 8. — A 3–10–50 home-made Bordeaux mixture only.

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[1] Directions for making Bordeaux mixture may be obtained by applying to the Extension Service, Massachusetts Agricultural College. Ask for Extension Leaflet No. 33.

Plot 9. — A 4–50 dry lime-sulfur for the pre-pink, pink and following sprays.

Plot 10. — A 3–50 dry lime-sulfur plus arsenate and nicotine.

Plot 11. — A 3–50 dry lime-sulfur plus nicotine sprayed on the trees, allowed to dry, and then the arsenate applied.

Time and Manner of Spray Applications.

TABLE II. — *Time of Application of Sprays for 1921 and 1922.*

Application.	1921.	1922.
Delayed-dormant	April 4– 6	April 13–19
Pre-pink	– –	April 28–May 3
Pink	April 25–27	May 3– 8
Calyx	May 10–12	May 16–20
Fourth summer	June 6– 8	June 9–22
Fifth summer	– –	June 25–31

As previously explained, two additional applications, the pre-pink and fifth summer, were made on some of the plots in 1922. Power sprayers which maintained approximately 200 pounds pressure were used, with spray rods equipped with the regular 45° Friend angle nozzles. By holding the rod close to the ground and in such a position as to shoot the sprays upward, the under surface of the lowest leaves was thoroughly covered. As these are the first leaves attacked by the scab fungus, it is exceedingly important that they be well covered at the pre-pink and pink applications.

DISCUSSION OF RESULTS OF SPRAYING.

Throughout most of the season weather conditions were exceedingly favorable for scab infection.

It will be noted in Tables IV, V and VI (pages 40 and 41) that all of the sprays gave exceptionally good control. In fact, many of the sprayed plots produced 100 per cent marketable fruit, whereas some of the checks produced fruit 100 per cent scabbed. There was not a single scab-free apple on the 16 check trees in the Sabine orchard, and 95 per cent were so badly scabbed that they were unmarketable. In the Knights orchard the situation was nearly as bad, 96 per cent of the fruit being scabbed and 69 per cent unmarketable. In the Frost orchard infection was not quite as severe, only 41 per cent of the fruit being scabbed.

Only small and probably insignificant differences were found in the results obtained from the different fungicides in so far as control of the scab fungus is concerned.

Importance of the First Spray Applications.

The dissemination of scab spores is most rapid about the time of the *pink* application. This is, therefore, the most important spray and should be so timed that it will be on the foliage, blossoms and pedicels of the blossoms before the winter spores are discharged. Observations of the writer *indicate that most growers who fail to control scab apply the pink spray too late in the season.*

In some places a *pre-pink* spray is used in order to make certain that the fungicide is on the leaves before the scab spores are discharged. Explained in the most simple terms, this means setting the pink spray ahead from seven to ten days. It is a spray applied approximately midway between the delayed-dormant and the pink. At that time most of the cluster buds are still closed, and a few only of the most advanced blossom buds show slight amounts of pink. Tables IV, V and VI, plots 7 and 9, show that the series of plots on which the pre-pink spray was applied yielded exceptionally high percentages of both clean and marketable fruit.

If the orchardist were positive that the pink application could be made before the discharge of the winter spores, it would be unnecessary to use a pre-pink spray. The pre-pink application is intended primarily to eliminate this uncertainty connected with the pink treatment. The cost of the spray material at this application is a small item, as the arsenate and nicotine are omitted. As this application has been tested one year only in this State, the writer hesitates to recommend it to the small orchardist. To any orchardist who has three or more days of spraying at the pink application, it is to be recommended without hesitation.

Home-made Bordeaux and Lime-Sulfur.

A 3–10–50 home-made Bordeaux mixture used alone for all applications russeted the fruit and burned the foliage so badly that its use in this way will be discontinued. Foliage burn due to the Bordeaux was not evident until the latter part of the season.

For two years, a 3–10–50 home-made Bordeaux mixture for the pink spray, followed by a 1–50 liquid lime-sulfur for the calyx and succeeding sprays, has given the most satisfactory results. From Tables IV, V and VI it will be seen that this combination in Sabine's orchard produced 98 per cent marketable fruit, but fell slightly lower than some of the other plots in clean fruit. In the Knights and Frost orchards it produced 100 per cent marketable fruit.

Some of the fruit sprayed with the Bordeaux–liquid lime-sulfur combination described above was russeted slightly. The writer questions whether this was caused by the Bordeaux at the pink spray or by natural conditions, as about the same amount of russeting occurred on some of the unsprayed trees. Also, no russeting occurred on similarly treated plots in 1921. The russeting was slight and did not injure the sale of the fruit except where the apples were sold to a fancy trade. In 1921 lime-sulfur burned the blossom buds badly.

A test was made to determine if dry lime-sulfur used with home-made Bordeaux mixture was as effective for the control of scab as the liquid form. Tables IV, V and VI, plots 2 and 3, show that the dry form was practically as good as the liquid, except in the Sabine orchard, where for some unexplained reason the Bordeaux–dry lime-sulfur plot yielded only 49 per cent clean fruit and 90 per cent marketable fruit. The fact that the total yield of this plot was exceptionally low may justify leaving it out of consideration.

Liquid Lime-Sulfur versus Dry Lime-Sulfur.

For two years dry lime-sulfur has given as good control of scab as the liquid form (Tables IV, V and VI). Four pounds of the dry form in 50 gallons of water have been used for all sprays except the delayed-dormant in most of the work, but judging from this year's results 3 pounds will give as good results. Some growers use only 2 pounds in 50 gallons, but in the opinion of the writer this is too dilute.

Dry lime-sulfur has the advantage of less bulk, and it is claimed that the fungicidal value is not injured by freezing. Both the dry and liquid forms of lime-sulfur used with lead will burn the foliage under certain conditions, but judging from the data at hand the liquid form seems to burn slightly more than the dry.

The Cost of Spraying.

In figuring the cost of spraying the writer has used the data from the experimental plots of 1922. It is assumed that there are 30 twelve-year-old McIntosh trees to the acre. Dry lime-sulfur and insecticides are used as indicated in the suggested spraying schedule for 1923: dry lime-sulfur, 15 pounds to 50 gallons of water for the delayed-dormant, and 4 pounds to 50 gallons of water for the four later applications; powdered lead arsenate, 2 pounds to 50 gallons of spray; and nicotine sulfate, three-eighths pint to 50 gallons of spray. Four gallons of spray are allowed for each tree. The cost of lime-sulfur is placed at 10½ cents per pound; powdered arsenate of lead at 14 cents per pound; and nicotine sulfate at $14 per gallon. Spraying with either liquid lime-sulfur or Bordeaux mixture costs slightly less than with dry lime-sulfur.

Table III. — *Cost of Spraying One Acre of Apple Trees.*

Applications.	Material.			Labor.		Total.
	Dry Lime-Sulfur.	Lead Arsenate.	Nicotine Sulfate.	Man.	Team.	
Delayed-dormant	$3 78	$0 67	$1 57	$0 70	$0 30	$7 02
Pre-pink	1 00	–	–	70	30	2 00
Pink	1 00	67	1 57	70	30	4 24
Calyx	1 00	67	1 57	70	30	4 24
Fourth summer	1 00	67	1 57	70	30	4 24
Total for five applications	$7 78	$2 68	$6 28	$3 50	$1 50	$21 74

Dusting Program for 1922.

The use of dusts for the control of apple scab is new in this State. Prior to 1921 the writer knew of only one dusting machine in the eastern part of the State, and that was used for dusting peaches. In 1921 dusting experiments were begun by the station in three orchards. The writer and growers who co-operated were inexperienced in the art of dusting, and consequently the dusts were not applied as well as they might have been. As a result, dusting compared very unfavorably with spraying.

In 1922 a number of growers bought dusting machines. With the experience of the previous year, and willingness on the part of growers to co-operate, extensive plans were made to test the efficacy of dusting materials for the control of apple scab. Accordingly, five orchards, previously mentioned, were chosen in which to locate the experiments. Two dusts, sulfur and a copper-lime-arsenate dust, were used in each orchard. Checks were used in all cases. The plots were all large, one of them containing 179 trees. Only McIntosh trees were used.

It will be noticed that there was no nicotine in any of our dusts. Nicotine makes a dust expensive, and the manufacturers state that it is difficult to manufacture a satisfactory sulfur dust high in sulfur with sufficient nicotine in it. As it happened, no nicotine was needed on any of the plots, but it was planned to spray with a nicotine solution or dust with a nicotine dust should infestation with sucking insects become serious.

Five representative trees of each dusted plot in the Marshall and Stowe orchards, 7 in the Knights orchard and 6 in the Frost orchard were chosen from which to take data. Also 3 representative trees of each undusted check in the Marshall and Knights orchards, 2 of one check in the Stowe orchard and 3 of the other (Table VII, plot 12) and 2 in the Frost orchard were chosen from which to take the data (Tables V, VI and VII, pages 40 and 41). The data of the Fiske orchard are not given as the trees were young and the yield exceptionally low.

Treatment of Plots.

Plots 13 and 14 in all the orchards were given the regular delayed-dormant spray with lime-sulfur. The plots in the Stowe orchard were given three dust applications, — the pre-pink, pink and fourth summer. The plots in the Frost and Fiske orchards had four applications, — the pre-pink, pink, calyx and fourth summer. The plots in the Knights orchard had five applications, — the pre-pink, pink, calyx, fourth and fifth summer. The plots in the Marshall orchard had nine applications, — the pre-pink, pink, calyx and six subsequent applications. The detailed treatment of plots follows: —

Plot 12. — Check untreated with fungicides, but sprayed with the usual insecticides.

Plot 13. — Sulfur dusts. The ordinary commercial dusting sulfur without insecticides was used for the pre-pink, fifth, sixth and seventh summer applications.

A sulfur dust, composed of 85 parts sulfur and 15 parts arsenate of lead, was used for the pink, calyx and fourth summer dusts.

Plot 14. — Copper-lime-arsenate dust for the pre-pink, pink and fourth summer applications only. An 85–15 sulfur dust was used at the calyx application, and dusting sulfur for treatments after the fourth summer application.

Time and Manner of Application.

The dusts were applied at approximately the same time as the sprays (Table II). Two different makes of power dusting machines were used. *The dusts were applied from two sides of the trees while the leaves were wet.* Dusting was started at 5 A.M. and continued until about 8 A.M. The best distribution of dust through the tree was accomplished by giving the hose a circular or a quick upward and downward movement. Care was taken to hit the lower leaves, especially at the pre-pink and the pink applications. The engine and duster should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dusts upward through the tree. Where rows of trees are too close together, this will hinder the operation of the duster.

Discussion of Results of Dusting.

In evaluating the results from dusting in 1922 it must be borne in mind that only a single year's work is represented, and that it is, therefore, decidedly unsafe and unsound to draw any conclusions whatever.

The data in Tables V, VI and VII show that the dusts gave excellent control of scab in a year most favorable for the development of the scab fungus. For example, in the Knights orchard the check for the dusts produced only 1 per cent marketable fruit, while the sulfur and copper-lime-arsenate dust plots produced 97 and 99 per cent marketable fruit. In the Frost orchard the check for the dusts produced 68 per cent marketable fruit; the sulfur dust plot, 96 per cent; and the copper-lime-arsenate plot, 97 per cent.

In the Stowe orchard the checks produced from 46 to 48 per cent marketable fruit; the dusted plots, 92 to 97 per cent. Table VII shows that in the Stowe orchard slightly better results were obtained on the younger trees than on the older. This, with the fact that practically all the scabby apples of the dusted plots were found in the tops of the trees, would indicate that the higher the tree the more difficult it is to apply the dust thoroughly. Although the results on the dusted plots were extremely good, it is evident that even better results might have been obtained had the dusts been more thoroughly applied to the topmost parts of the trees.

In several cases where late summer applications of lime-sulfur and dusts were made side by side in the same orchard, the lime-sulfur burned the foliage, while the sulfur dust caused no injury. Later observations showed that where the foliage was burned by the lime-sulfur, from 8 to 20 per cent of the fruit dropped prematurely; while where the sulfur dust was used, practically the entire crop remained on the trees.

It is quite evident that copper-lime-arsenate dust controlled scab more effectively than the sulfur dusts, as in three of four orchards it gave a higher percentage of clean and marketable fruit. *However, it cannot be recommended for apples on account of the russeting of the fruit and the burning of the foliage.* On the other hand, sulfur dusts neither injured the foliage nor russeted the fruit. If kept covered with the sulfur dust, the leaves grow normally and develop a dark green color. *Sulfur dust is cheap and is the only dust that has shown itself worthy of further trial.* It is possible that the copper-lime-arsenate dust may prove useful for the pre-pink and pink applications, to be followed with sulfur dust for the later applications. This combination will be tested another year.

In the Stowe and Marshall orchards there were no experimentally sprayed plots to compare with the dusted plots, but if we may judge from the results which these orchardists obtained on sprayed trees adjacent to the dusted plots, the sulfur dust was equal to the sprays.

The Effect of Apple Scab on the Vitality of the Tree.

The most striking example of what may be expected of an unsprayed McIntosh orchard may be seen on the check plot in Knights orchard (Table V, plot 1). The trees of this plot have not been sprayed with a fungicide since 1920, and in 1921 and 1922 they showed approximately 100 per cent infection of fruit and foliage. The heavy loss of foliage in 1921, in spite of the fact that the trees were fed heavily, caused a very light set of leaves and blossoms in the spring of 1922, and consequently a greatly reduced yield of fruit. Plots 1 and 2, Table V, are located side by side in the orchard. It is planned to shift the check plot in this orchard from its present location to some other part of the orchard in 1923, as permanent injury to the trees is feared.

The Relation of Weather to Spraying.

Spraying should always be done in advance of rain periods, since the fungicide must be on the leaves in advance of the germination of the spores. If allowed to dry thoroughly, efficient sprays do not wash off sufficiently to destroy their fungicidal value. By studying the low barometric areas of the daily weather reports, the grower should be able to predict, with some degree of accuracy, weather conditions two to three days in advance.[1]

Burning of Apple Foliage by Sprays and Dusts.

The foliage of some of the apple trees in the plots was badly burned with lime-sulfur during 1921, while in 1922 very little injury from this material was noticed. The writer believes that weather conditions were

[1] These daily reports may be obtained by addressing the United States Weather Bureau, Boston, Mass.

largely responsible for this difference. Temperature and humidity were quite high when many of the applications were made in 1921, while to a certain extent the opposite was true in 1922. *Apples should never be sprayed when temperature and humidity are both high, as burning of foliage is almost certain to result.*

The amount of spray applied does not seem to be as important a factor in burning the foliage as was formerly thought. In 1922 the writer selected trees in several plots in the Sabine and Knights orchards and thoroughly drenched them with the spray at the pink and calyx applications. At the end of the season the trees showed only slight injury.

Sulfur dusts have never burned the foliage, while burning from copper-lime dust is frequent.

Recommendations for 1923.

Spraying Program.

It should be borne in mind that the spray schedule which follows is based on only two years of experimental work, and therefore is subject to change. Where two or more spray materials are given, the first is preferable and should be used whenever possible.

Delayed-dormant. — Fifteen pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 9 gallons of water.

Pre-pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Calyx. — Three to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Fourth and Fifth Summer. — Same as the calyx. Unless the rainfall of June, July and August is above normal, the fifth summer spray may not be necessary for the control of scab. On the other hand, if these months are rainy and scab is bad, the fifth summer application will be found very profitable.

Three-eighths of a pint of 40 per cent nicotine sulfate to each 50 gallons of spray is used at the delayed-dormant, pink and calyx applications. Also, 2 pounds of powdered lead arsenate to each 50 gallons of spray are used at the delayed-dormant, pink, calyx and fourth summer applications.

Dusting Program.

If a dusting program is to be followed, the delayed-dormant spray should be applied. *Dusting sulfur* should be used for the *pre-pink* and for all applications after the fourth summer dust. A dust composed of 90 parts sulfur and 10 parts arsenate of lead should be used for the pink; an 85–15 dust for the calyx and fourth summer applications. In case sucking insects are bad, it will be necessary to spray the trees with three-eighths pint of 40 per cent nicotine sulfate in 50 gallons of water, or dust the trees with a commercial nicotine dust.

Miscellaneous.

Dry lime-sulfur passes through the spraying outfit better if it be allowed to stand in water about forty minutes before it is poured into the spray tank. Before going to the orchard with each tank of spray material, it is a good plan to weigh out the desired amount for the next tank in a 5 or 6 gallon pail, pour water over it and agitate with a wooden paddle for a few minutes. On returning, the spray tank is filled about two-thirds full of water, the agitator set in motion, the lime-sulfur from the pail poured into the tank, and the tank filled with water. Some growers consider soaking of the material unnecessary before putting it into the tank.

Lime-sulfur should be well agitated before it is applied to the trees as a too concentrated solution will burn the foliage.

Twelve-year-old trees with a height and spread of approximately 20 feet should receive about 4 gallons of spray material with each application.

Follow the spraying system outlined for 1921.[1] It is better to spray against the wind than with it, as less spray materials are wasted and a better covering is obtained.

The engine and duster of the dusting outfit should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dust upward through the tree. Special effort should be made to hit the extreme tops of the trees. Best results are obtained by giving the hose of the duster a quick circular or an up-and-down movement so as to hit all parts of the tree. Dusting should be done only when the surfaces of the leaves are moist. At least two sides of the trees should be dusted. On trees twelve to fifteen years old, approximately $1\frac{1}{2}$ pounds of dust should be used on each tree at each application.

[1] Extension Circular, "Apple Scab and its Control." This may be obtained by applying to Extension Service, Massachusetts Agricultural College.

Tabulated Results.

Tables IV to VII give briefly the results on the sprayed and dusted plots in each of the orchards during 1922.

Table IV. — *Results on the Sprayed Plots in Sabine Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check, arsenate and nicotine only	0	100	5	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	84	16	98	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	49	51	90	0
4	Liquid lime-sulfur	86	14	97	0
5	Dry lime-sulfur, 4–50	86	14	95	0
6	Liquid lime-sulfur plus lime	76	24	91	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	81	19	96	0
8	Home-made Bordeaux	87	13	97	52

Table V. — *Results on the Sprayed and Dusted Plots in Knights Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 7, arsenate only	4	96	31	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	98	2	100	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	97	3	99	0
4	Liquid lime-sulfur	96	4	99	0
5	Dry lime-sulfur, 4–50	92	8	97	0
6	Liquid lime-sulfur plus lime	93	7	99	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux	87	13	95	47
12	Check for Bordeaux and dusts only	0	100	1	0
13	Sulfur dust	84	16	97	0
14	Copper-lime-arsenate dust	93	7	99	22

Table VI. — *Results on the Sprayed and Dusted Plots in Frost Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 11, arsenate and nicotine only.	59	41	90	Negligible.
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	100	0	100	Negligible.
3	Home-made Bordeaux (pink) and dry lime-sulfur.	99	1	100	Negligible.
4	Liquid lime-sulfur	98	2	99	Negligible.
5	Dry lime-sulfur, 4-50	98	2	100	Negligible.
6	Liquid lime-sulfur plus lime . .	90	10	98	Negligible.
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux . . .	100	0	100	13
9	Dry lime-sulfur, 4-50, on pre-pink, pink, etc.	100	0	100	Negligible.
10	Dry lime-sulfur, 3-50	96	4	98	Negligible.
11	Dry lime-sulfur, 3-50 (lead and lime-sulfur put on separately).	96	4	100	Negligible.
12	Check for plots 13 and 14 . . .	34	66	68	Negligible.
13	Sulfur dust	89	11	96	0
14	Copper-lime-arsenate dust . .	86	14	97	13

Table VII. — *Results on the Dusted Plots in Stowe and Marshall Orchards.*

Stowe Orchard.

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check for 25-year-old trees, sprayed with lead and nicotine only.	15	85	48	0
13	Sulfur dust, 25-year-old trees . .	74	26	92	0
14	Copper-lime-arsenate dust, 25-year-old trees.	87	13	97	21
12	Check for 12-year-old trees, sprayed with lead and nicotine only.	16	84	46	0
13	Sulfur dust, 12-year-old trees . .	83	17	96	0

Marshall Orchard.

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check, sprayed with lead and nicotine only.	56	44	96	0
13	Sulfur dust	84	16	99	0
14	Copper-lime-arsenate dust . . .	93	7	100	26

MASSACHUSETTS

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PEDIGREE

THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

In this bulletin the records of ten years' poultry breeding investigations at the Massachusetts Agricultural Experiment Station are analyzed, specifically from the standpoint of the effect of the female ancestry on the transmitting power of the male. It is shown that the pedigree record basis of selection of the male has given marked results. On the other hand, there is nothing in the work done to date which in any way indicates superiority of this method over that of measuring transmitting power by means of the progeny test.

Available records, however, do indicate that the selection of females on the basis of those specific characters which together are believed to make up the group character of fecundity may be even more important in its results than the particular basis on which the male is selected.

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BULLETIN No. 215.

DEPARTMENT OF POULTRY HUSBANDRY.

PEDIGREE, THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION.[1]

BY F. A. HAYS AND RUBY SANBORN.

Introduction.

The practical importance of the selection of breeding males in flocks bred for egg production is much appreciated by poultrymen. Some believe that the ability of hens to make good egg records is more largely traceable to their male ancestors than to their female ancestors. At any rate, the fact is well recognized that the male breeders must be carefully considered in developing a flock uniform for high production. Since actual egg production can be measured only by the females of the flock, other criteria must be employed in choosing the males. Some breeders prefer to use cockerels, while others make use of yearling or older cocks for breeding; but the merits or demerits of these practices will not be discussed in this paper. The following discussion of data available at the Massachusetts Experiment Station has a bearing on methods of selection that may be applied to both cockerels and cocks (Inherited Production), and other methods that apply only to cocks (Potential Production). Experimental evidence on the transmission of egg-producing ability through the male is in a confused state at present.

Pearl, '12, concludes, after studying the inheritance of egg production with several thousand Barred Plymouth Rocks representing thirteen generations: (p. 284) "That the record of egg production or fecundity of a hen is not of itself a criterion of any value whatsoever from which to predict the probable egg production of her female progeny. An analysis of the records of production of large numbers of birds shows beyond any possibility of doubt that, in general, there is no correlation between the egg production of individuals and either their ancestors or their progeny." Pearl draws the above conclusions because he found no significant biometric correlation between mothers and daughters or between daughters and their female ancestry in egg production. Pearl states, on the other hand, (p. 379), "High fecundity may be inherited by daughters from their sire, independent of the dam."

Goodale, '19, believes that egg production is transmitted equally through males and females in Rhode Island Reds. He further crossed Cornish males on Rhode Island Red females and secured winter egg production corresponding with that of his Rhode Island Red flock.

Lippincott, '20, in discussing the grading up of mongrel flocks by the use of standard-bred cockerels of three breeds, (p. 45), states that a pullet's egg produc-

[1] The data included in this bulletin were collected by Dr. H. D. Goodale, until recently in charge of poultry investigations at this Station. All Rhode Island Red fowls bred by the Experiment Station from 1912 to 1921 are included, with the following exceptions: a small number of birds in an experiment in studying the behavior of broodiness, and a small number of birds in an inbreeding experiment during the year 1921. The flock included in this report differs from that reported on in Bulletin No. 211 of this Station in that only fowls in the experiment entitled *Breeding for Egg Production* are reported in Bulletin No. 211.

tion seems to bear a closer relation to the breeding of her sire than to the production of her dam.

Dryden, '21, reporting on eight generations of Barred Rocks, eight generations of Leghorns and eight generations of Cross-breds, states that some hens and some males have the power of transmitting high fecundity; others have not this power. He advises the progeny test as the most reliable method of selecting breeders.

Hurst, '21, in his work in breeding White Leghorns and Wyandottes, found no sex linkage in the inheritance of factors for egg production. In other words, he agrees with Goodale and Dryden in his assumption that both parents contribute equally in factors for egg production.

Other authorities rather generally agree with one or the other of the above schools, so that it seems safe to assume that egg production is transmitted in Mendelian fashion from parent to offspring. A discussion of the several proposed genetic theories is not within the province of this report. Whether or not factors for egg production are transmitted in the same fashion in all breeds requires further study. This report is intended to throw some light on the expected progress in mass breeding without considering definite Mendelian factors as operating to control the egg production of the flock.

Review of Progress in the Flock.

The data upon which this report is based cover ten years' work at the Massachusetts Agricultural Experiment Station in breeding Rhode Island Red fowls primarily for egg production. The foundation flock of 100 pullets and eggs from which 50 more were hatched were purchased in the fall of 1912 from a Massachusetts breeder. These were good representatives of the breed, judged by the breed standards of that time. This foundation female stock was placed in the laying houses December, 1912, and all females in the experiment have since been trapnested at all times unless physically incapacitated. All annual records cover 365 days and were made during the pullet year. Complete pedigrees of all breeding stock have been maintained throughout the period. The foundation males used consisted of twelve birds brought in in the spring of 1913, four from different breeders brought in in 1914, and ten from other outside sources brought in in 1915. Since 1915 no outside stock has been used in the flock.

Dr. Goodale has already given the question of egg production much study and made several reports on the egg-laying flock up to the end of the laying year 1921. His reports include a rather complete study on early maturity, rate and winter pause (Goodale, '18, '19). He has also carefully investigated the question of broodiness (Goodale, '20). This paper deals only with the application of methods for selecting breeding males, from data secured up to the end of 1922.

The average production of the flock by years is presented graphically in Chart I. All pullets that had an opportunity to lay for 364 days after their first egg are included. The birds are divided into six classes for study, and the percentage in each class is presented by years to show the general trend of the flock.

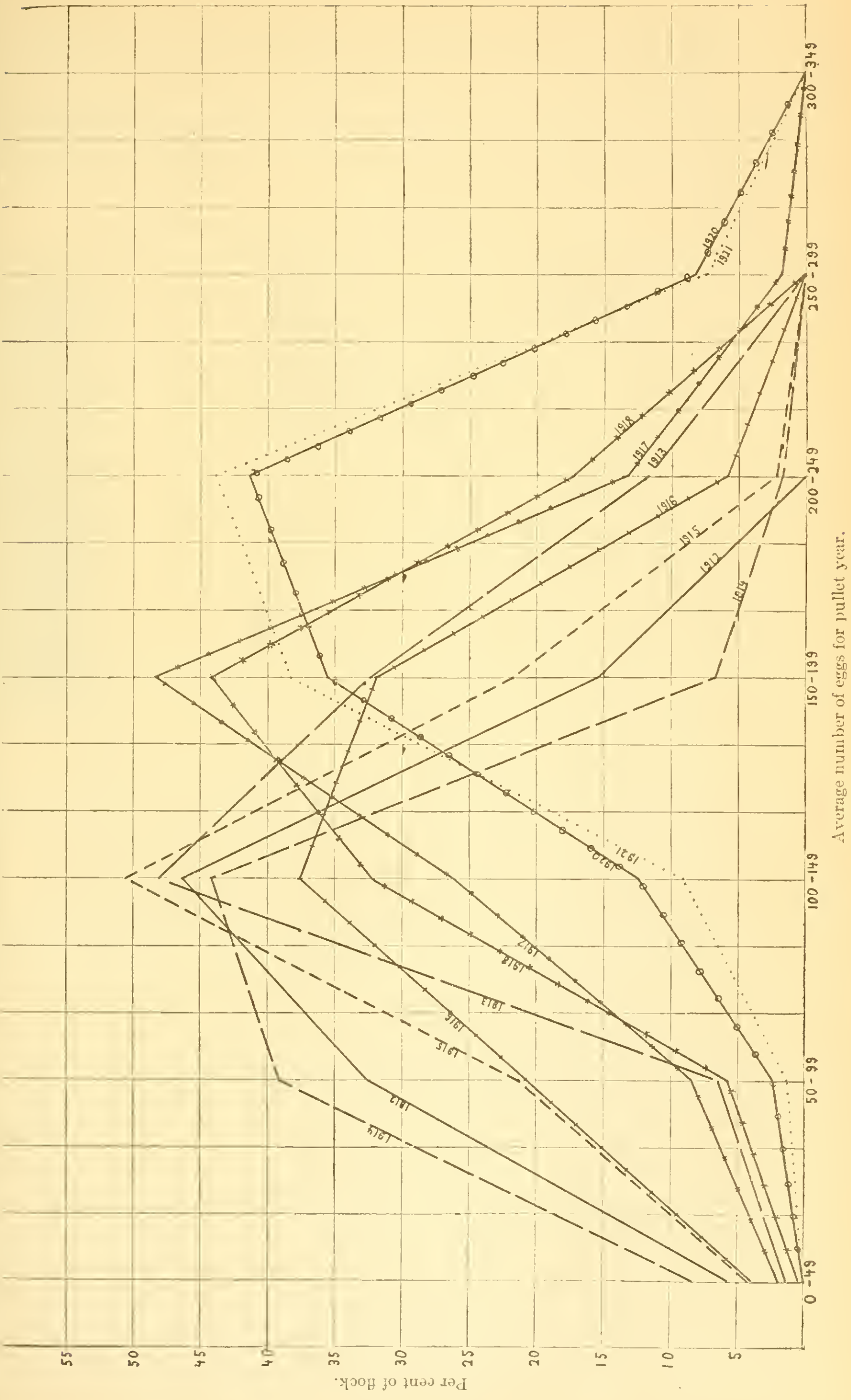
The total number of annual records at the close of 1922 was 1,945. The observation may be made that the mode (most common class) of the foundation stock lies between 100 and 149. Chart I further shows that the mode of the flock remained between 100 and 149 eggs until the 1917 pullets finished their year in the fall of 1918. This fact does not signify a lack of progress in increasing the egg production of the flock between 1913 and 1918. There was a total increase during this period up to the end of the laying year ending in 1918 amounting to an average of 12.97 eggs per hen. The graph for the hatching year 1913 would seem to indicate a higher degree of production in the flock as a whole than could be maintained in the flocks hatched in 1914 and 1915. This is only an apparent discrepancy, however, as explained by the fact that only about half the available flock hatched in 1913 could be trap-nested to the end of their laying year. The half selected represented those having the highest record for the first half of their year and consequently are a select group.

The distribution of the flock will be seen to remain almost the same for the birds

CHART 1.

FREQUENCY DISTRIBUTION IN EGG PRODUCTION.

Flock denoted by the year in which its annual egg-laying record commenced.

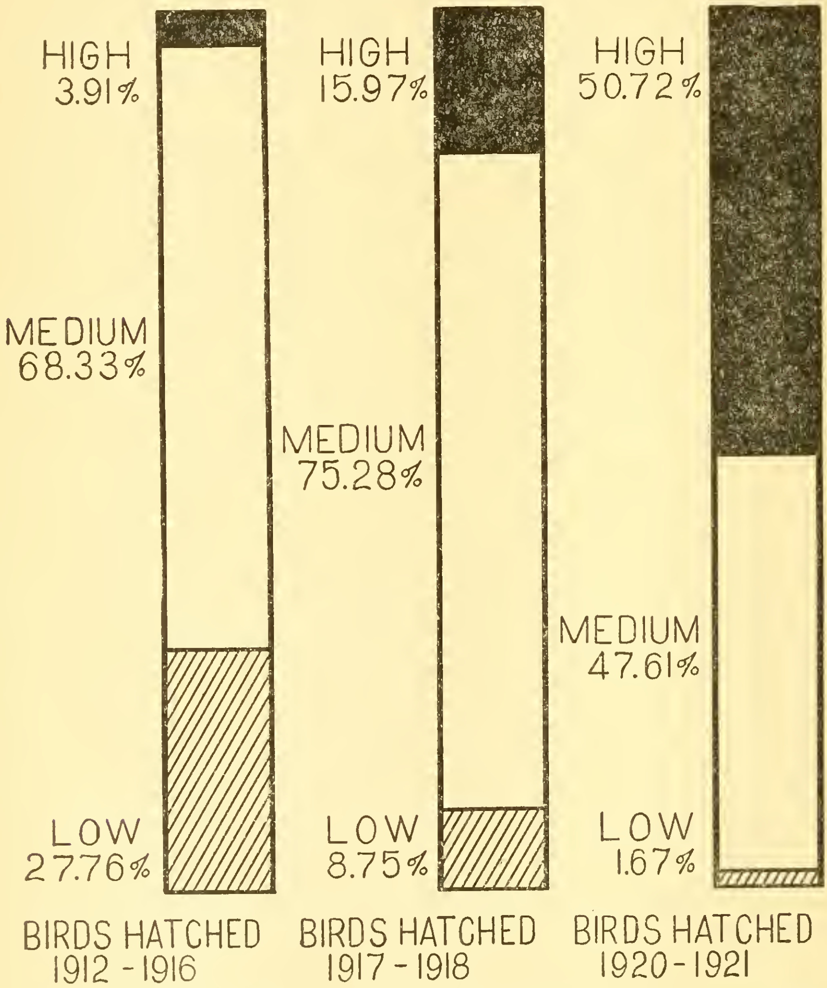


hatched in 1917 and 1918. Records for the flock hatched in 1919 were cut short by disease outbreaks. It was found necessary to dispose of most of the stock and exercise rigid quarantine measures. This prevented the completion of any annual records during 1920.

Referring again to Chart I, the mode of the flock will be observed to have advanced in 1920 to the 200 to 249 egg class, with a skewness indicating that the mode of the flock lies considerably above the average. In other words, a bimodal condition begins to present itself.

CHART II.

General Classification of Birds on the Basis of Production.



The results of the season ending in 1922 indicate that the general distribution of the 1921 flock conforms closely with that of 1920. The graph for 1921 also shows a bimodal condition of the flock, lying in the 150 to 199 class and in the 200 to 249 class.

Chart II is presented as supplementary to Chart I. Chart I shows that the most common group of producers falls in the 100 to 149 egg class in the years 1912 to

1916 inclusive; in the 150 to 199 egg class in the years 1917 and 1918; and in the 200 to 249 egg class in the years 1920 and 1921. Hence in the preparation of Chart II the birds hatched during the first five years have been grouped into one polygon, those hatched in the next two years into a second polygon, and those hatched in the last two years into a third polygon. Low producers laid from 0 to 99 eggs in their pullet year; medium producers laid from 100 to 199 eggs in their pullet year, high producers laid over 200 eggs in their pullet year.

Chart II shows that in the first five years there were 27.76 per cent low producers, 68.33 per cent medium producers and 3.91 per cent high producers. During the two-year period following, the percentage of low producers fell to 8.75, the medium class increased to 75.28 per cent, and the high producers increased to 15.97 per cent. During the last two years, the low class fell to 1.67 per cent, the medium class fell to 47.61 per cent, and the high class increased to 50.72 per cent.

Table 1, presented below, gives the number of sires used, the number of dams used, the number of pullets completing yearly records, and the average of all annual records by breeding years. The last column includes pullets hatched in the respective mating years.

TABLE 1.

Mating Year.	Number of Sires used.	Number of Dams used.	Number of Pullets with Yearly Records from Mating.	Average Annual Production of Pullets.
1913	12	42	77	146.22
1914	20	55	120	102.33
1915	21	99	378	122.93
1916	18	59	426	131.87
1917	14	52	318	159.19
1918	14	71	208	160.24
1919	12	29	None	None
1920	16	36	121	196.95
1921	9	43	297	197.89

Referring to the first column of the table, it will be observed that during the first four years of the experiment the average number of males was about 18, while during the past five years the number was cut down to an average of about 13. This policy has given a greater opportunity to determine the breeding ability of the sires and to regulate future mating with a greater degree of certainty, because the breeding ability of the sires can be ascertained with a higher degree of accuracy when their progeny are trap-nested in large numbers. This fact made it possible to regulate matings more carefully along specific blood lines.

The number of dams used was greater during the first four years of the experiment than during the last five. The range in number of dams for the nine-year period is from 29 to 99. The use of fewer dams makes possible more rigid selection standards and probably is of value in reducing variability in the flock.

The average number of completed records per year is 243. In general, the mean annual production of the flock shows progress from year to year. The first results of breeding at the Station are shown opposite the mating year 1913. Seventy-seven pullets averaged 146 eggs. These 77 pullets represent a selected group from a larger number, and consequently show a higher average than the 120 pullets hatched in 1914. The offspring of 1915 brings the average of the flock up to 123 eggs, and from that time to the present there has been uninterrupted progress, except for the disease outbreak of 1920. The 121 pullets hatched in 1920 averaged 197 eggs. The 297 hatched in 1921 averaged approximately 198 eggs. There is no noticeable tendency in the flock to produce a few phenomenal records, but rather a general homogeneity in production. This tendency to uniformity is probably traceable to the methods of mating for specific characteristics, and to a certain degree of relationship within the flock.

Selecting Breeding Males on Production Pedigree.

Before proceeding further with this question, it is necessary to define a few terms that are used in this report. *Sire's inherited production* is calculated from the average annual egg records of the 31 dams in five ancestral generations of each sire. *Dam's inherited production* is calculated from the average annual egg production of the 31 dams in five ancestral generations of each dam. *Sire's potential production* is the average of the annual records of all his daughters made during their first laying year. It is the same as daughter's annual production, save in those cases where a sire was used for more than one year.

It is a common practice to select males for breeding that come from dams with high annual egg records. In some flocks the practice is to emphasize the egg records of as many of the dams back of the sire as possible. In such cases the annual egg record is used as the guide for selection in a large measure, rather than any specific characters that the individual and his relatives may possess.

Table 2.

Mating Year.	Sires' Inherited Production.	Sires' Potential Production.	Dams' Inherited Production.	Daughters' Average Production.
1913	Unknown	136.55	Unknown	146.22
1914	138.00	107.29	117.07	102.33
1915	152.35	123.05	125.49	122.93
1916	149.93	133.23	144.63	131.87
1917	156.49	160.31	153.16	159.19
1918	156.77	161.23	151.78	160.24
1919	167.13	Not recorded	158.02	Not recorded
1920	168.79	196.95	163.02	196.95
1921	174.47	197.89	173.67	197.89

The inherited production of the sires used for the mating years included in this report is given in Table 2. This inherited production amounted to an average of 138 eggs in 1914, 152.35 in 1915, 149.93 in 1916, and so on up to an average of 174.47 in 1921, showing that although untested males from the progeny standpoint were used, those in charge were able to select a superior class of males each year, based on average annual records and pedigree. The progress that has been made in the flock as a whole would seem to indicate that this is a commendable practice. Such a method can be followed by breeders who keep complete pedigree and trap-nest records of their flock. Breeding sires from such flocks should command a high figure and should be very much appreciated by all smaller breeders who are seeking to improve their flocks without the use of the trap-nest or pedigree system. This method would be especially useful for selecting the more desirable cockerels to be retained. Mature sires can be selected with a greater degree of certainty from their progeny test.

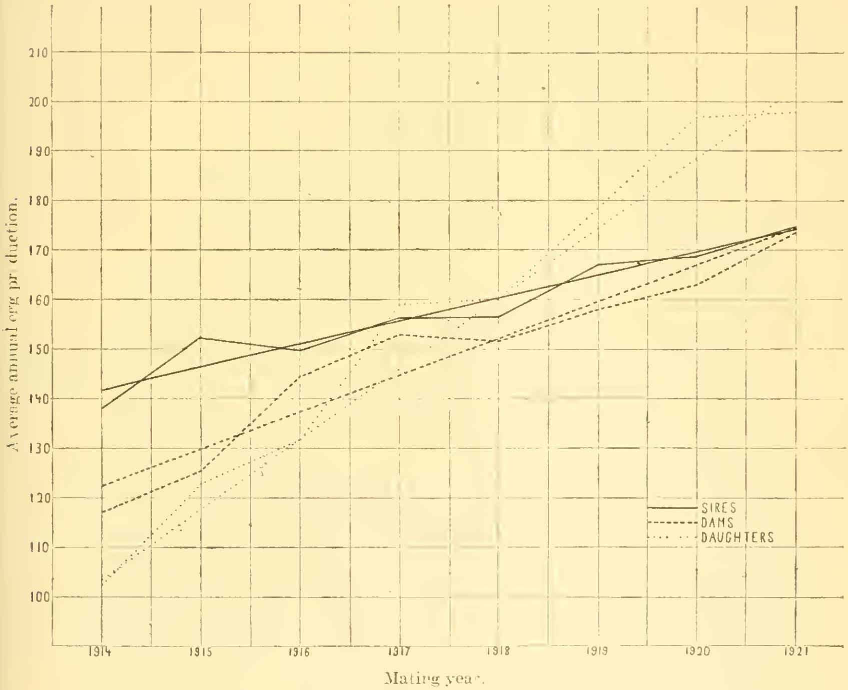
Relative Importance of Sire's and Dam's Pedigree.

A great deal of discussion and difference of opinion exists as to the relative importance of the sire and the dam in breeding for egg production. Poultry investigators differ in their opinion on this point, some holding that sex linkage makes the sire of greater importance than the dam, while others hold that sire and dam are of equal importance. In Chart III the average inherited production of the dams for each year is given as a dash line. A similar figure for the sire is given as a solid line. The actual annual production of the daughters coming from the mating of these sires and dams on their respective years is given as a dotted line. It should be understood that the egg record of the daughters was finished the year following the hatching year. These graphs are fitted to a straight line by the ordinary method of least squares.

Chart III very clearly indicates that selection on a mass basis from egg records alone will not be an insurance as to what the daughters will do during their first egg-laying year. Reference to the chart shows that the annual production of the daughters crossed the path of the inherited annual production of the dams during the year 1916, and the path of the inherited production of the sires during 1917. *The average annual record of the daughters has far outstripped their inherited production from sires and dams.* These facts are unmistakable evidence of the operation of many factors to influence annual egg production. From the year 1916 this flock was bred for specific characteristics, such as early maturity, lack of broodiness and lack of winter pause. Those hens which showed later maturity, broodiness, and a tendency to stop laying during the winter season were discrim-

CHART III.

Relation between Parents' Inherited and Daughters' Average Production.



inated against as breeders, even though they had made good annual records. Another characteristic which was sought was intensity of production. Those females that showed intense winter production were favored as breeders over others in which the degree of intensity was less marked.

Chart III does not furnish any conclusive indication of the relative importance of sire and dam in transmitting annual egg production. This may be due to the fact that the chart is based on mass data. A similar chart based on specific families or blood lines would be more enlightening on this point. Data are available and will be published later. The one outstanding item to be emphasized on the chart is the advisability of selecting for specific characteristics as affecting annual egg yield.

The Sire's Potential Production as a Guide in Selecting Males.

The average annual egg production of the daughters of a sire we have called his potential production. In other words, in order to know the potential breeding ability of a sire, there must be a trap-nest record of his daughters. This fact greatly reduces the usefulness of the method with many poultrymen. Records at this Station indicate very clearly, however, that males vary widely in their ability to sire daughters that make high annual records. If it were possible to recognize such sires in advance, their usefulness in the flock could be made many fold greater. Referring back to Table 2: the column giving the sires' potential production is very similar to the average egg yield of the daughters for the respective years. It differs only in those cases where some of the sires were used for more than one breeding year. A comparison of this column with the one headed *Sires' Inherited Production* shows that in the early years the inherited production was higher than the potential production, but beginning in 1917 the reverse is the case; clearly indicating that the flock had been developed by the method of breeding to a higher degree of prepotency. This greater prepotency in the last four or five years is due to the fact that the flock has increased in the percentage of early maturing birds, in the percentage of birds that do not show the winter pause, in the percentage that are free from broodiness, and in the annual rate of production. As evidence of this fact, there are now families (all the daughters of a hen) that are non-broody. Other families show no winter pause, others show a uniformly higher rate, etc. There is still a wide range in the annual egg production of the females in the flock. This range may be explained on the Mendelian basis as we have shown elsewhere. The statement still holds good that there is no guide in selecting the sire that is as certain and reliable as the progeny test or the potential production.

How to Select Cockerels.

A great many poultrymen use cockerels to a considerable extent in their breeding operations; and even where cockerels are used only to a minor degree for breeding purposes the first year, it is necessary to select and reserve considerable numbers for future sires. Any guide in the selection of cockerels, then, has a double value to poultrymen.

We have previously shown that the average annual records of the hens in the dam's pedigree is of about the same value as the average annual record of the hens in the sire's pedigree, so far as determining what the daughters from such matings will produce is concerned. Selection of cockerels on their mothers' annual records alone is a very inefficient and inaccurate method, compared with the five-generation pedigree method we have used here. In our opinion, therefore, there is no other method of choosing the cockerels to be used in breeding for egg production that is as satisfactory as the combined sires' inherited production and dams' inherited production behind such cockerels.

How to Select Cocks.

Too much stress cannot be laid upon the importance of making full use of breeding males that have a demonstrated ability to sire heavy egg layers. The history of a good many flocks shows that the great producing hens from the flock trace directly to a very few outstanding males. The same principle holds here as in breeding the higher domestic animals. Sires of proven ability are invaluable.

The cock may be selected both on the pedigree basis and on the progeny test. The yearling cock will have daughters that have a winter record rather well along by his second mating season, if he has been used as a cockerel. Winter records are known to be of great value as guides to annual records. Therefore, the yearling cock can be selected with a good deal of certainty as to what contribution he will make to the flock. As a two-year-old, he will be a strictly tested individual; and if possessing the proper amount of vigor, and if properly handled, can be used very successfully for two or more mating seasons. The items which are the guides to follow in selecting the cock may be summed up as follows:

1. Select those with a high inherited production, both on the sire and the dam side, for as many generations as possible.
2. Select those that have the best progeny performance.
3. Select those whose family are early maturers, free from broodiness, free from a tendency to winter pause, and show a high rate of production.

Summary.

1. In the space of nine years selection of breeding males, largely on an inherited production basis, has assisted in raising the average annual egg production during the pullet year from 146 eggs to 198 eggs per hen.
2. Evidence as presented in this report has no bearing on the value of the progeny test as a guide in the selection of breeding males.
3. Selection of males for production of daughters possessing specific characteristics, such as early maturity, lack of winter pause, high rate of production and freedom from broodiness, is necessary to attain high egg yields.

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DIGESTION EXPERIMENTS WITH CATTLE FEEDS

By J. B. LINDSEY, C. L. BEALS, P. H. SMITH, and J. G. ARCHIBALD

This bulletin reports results of digestibility studies on fourteen different materials, of real or claimed value as cattle feeds. The work of which this is a part was commenced thirty years ago. Results have been published in a number of reports and bulletins, and most of them summarized very briefly in a "Compilation of Analyses" published in November, 1919. Nearly all of the feed products available to Massachusetts dairymen have now been studied, and the digestibility of the nutrients contained measured. The publication of this bulletin, therefore, completes this phase of the service of the Massachusetts Experiment Station.

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AGRICULTURAL EXPERIMENT STATION

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DEPARTMENT OF CHEMISTRY.

DIGESTION EXPERIMENTS WITH CATTLE FEEDS.

BY J. B. LINDSEY, C. L. BEALS, P. H. SMITH AND J. G. ARCHIBALD.[1]

Introduction.

The digestion experiments here reported cover a period of four years, the work commencing annually about November 1 and extending through to mid-April or thereabouts. Methods followed in conducting the tests are given elsewhere.[2]

Each digestion period extended over sixteen days, nine of which were preliminary (five in ordinary pens and four in the digestion stall), the last seven constituting the actual trial during which the feces were collected. The animals were grade sheep, as nearly as possible of the same age and weight. The basal ration was either English hay, or English hay and gluten feed. Ten grams of salt were fed daily and water *ad libitum.*

Discussion of Results.

A summary of the coefficients of digestibility is here presented, together with a brief discussion of the same.

English Hay.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
1[3]	XXIII	1	9	57.90	45.16	47.35	61.90	59.67	43.90
1	XXIII	1	11	58.89	45.57	48.27	63.43	60.29	46.98
Average				58.40	45.37	47.81	62.67	59.98	45.44
2	XXIII	10	9	57.83	35.84	47.56	66.16	56.61	36.45
2	XXIII	10	11	60.59	41.43	53.47	67.73	59.40	40.35
2	XXIII	11	15	57.22	47.88	46.89	64.05	55.78	30.54
2	XXIII	11	17	56.76	46.81	45.44	64.38	55.15	24.83
2	XXIII	13	12	58.78	43.20	46.66	64.42	59.77	20.28
2	XXIII	13	13	60.68	28.11	49.25	67.97	61.43	23.22
2	XXIV	10	15	50.71	32.05	43.48	59.24	48.08	33.91
2	XXIV	10	16	53.30	20.57	39.43	63.65	51.12	38.53
Average				56.98	36.99	46.52	64.70	55.92	31.01

[1] Mr. Beals had immediate supervision of the experiments and did some of the analytical work. Mr. Smith, assisted by Miss E. M. Bradley, did the larger part of the analytical work. The tabulations were made by Mr. Archibald. The work at the feeding barn was done by Mr. J. R. Alcock.

[2] Mass. Agr. Expt. Sta., 11th Ann. Rpt., pp. 146-149, 1893.

[3] This lot of hay is the same as was fed in Series XXII, periods 8-17, coefficients of which are published in Mass. Agr. Expt. Sta. Bul. 181, p. 307.

English Hay — Concluded.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3	XXV	2	12	59.20	24.26	55.74	64.33	61.22	46.83
3	XXV	2	13	56.77	20.53	49.81	64.67	57.75	43.65
3	XXV	3	9	64.07	39.80	57.06	69.98	65.04	44.97
3	XXV	3	11	61.42	34.17	57.13	67.29	62.48	38.96
3	XXV	9	15	59.41	39.01	58.85	63.21	59.97	50.67
3	XXV	9	16	60.03	37.19	55.28	65.37	60.83	47.57
3	XXVI	1	17	59.95	29.40	54.92	65.68	61.19	46.97
3	XXVI	1	18	64.17	40.54	61.14	68.41	65.29	50.83
3	XXVI	1	19	59.89	34.96	55.22	63.78	61.73	45.76
Average				60.55	33.32	56.13	65.86	61.72	46.25
General average of above				58.82	36.13	51.21	65.03	59.09	39.75
General average, 5 earlier lots . . .				59.47	36.31	49.78	64.10	62.35	46.34
Timothy hay, for comparison . . .				55.00	39.00	47.00	51.00	62.00	50.00

Note. — Each series represents one winter's work, commencing about November 1 of each year and extending through to mid-April or thereabouts.

Three separate lots of hay were used in these experiments. It was of quite uniform quality and composition and consisted of mixed grasses, largely Kentucky blue grass, sweet vernal grass and some clover. It averaged in percentage of dry matter, 6.07 ash, 7.95 protein, 33.81 fiber, 49.52 nitrogen-free extract, and 2.65 fat. Such hay is rather richer in protein and has a higher degree of digestibility than has average timothy hay. The digestion results are on the whole quite uniform. It is interesting in this connection to compare the general average of the present results with the average of five earlier lots here cited and originally reported in Bulletin 181 of this Station. The close agreement of the two sets of coefficients in all items except fat emphasizes the fact that, when any considerable number of results are averaged, the resultant average is a pretty close approximation to accuracy and an accepted standard, even though there be considerable variation among the individual data.

English Hay and Gluten Feed — Basal.

Lot.		Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Hay.	Gluten Feed.									
2	1	XXIV	1	9	63.70	32.02	62.98	65.43	66.74	48.22
2	1	XXIV	1	11	67.31	40.75	69.24	68.37	69.51	54.82
2	1	XXIV	14	12	65.09	46.22	66.29	66.95	66.58	41.34
2	1	XXIV	14	13	65.56	45.61	67.57	66.77	67.28	43.39
3	2	XXV	1	9	64.81	29.53	69.27	66.40	67.34	54.79
3	2	XXV	1	11	67.89	30.57	71.20	70.67	70.42	56.32
3	2	XXV	4	12	66.72	27.44	71.59	67.20	69.63	55.02
3	2	XXV	4	13	66.62	20.55	73.19	67.66	69.48	54.30
3	2	XXV	6	15	67.68	27.40	72.71	67.58	70.88	55.92
3	2	XXV	6	16	65.92	20.94	70.34	66.14	69.44	55.55
3	2	XXVI	3	17	64.88	23.73	68.85	66.81	68.21	44.94
3	2	XXVI	3	18	65.46	23.16	65.11	72.39	67.01	46.96
3	2	XXVI	3	19	64.79	28.18	70.91	66.69	66.92	48.48

Note. — In all of these trials with the exception of period 3, Series XXVI, the ration fed was *500* grams of hay and 150 grams of gluten feed. In the exception noted, the ration was *550* grams of hay and 150 grams of gluten feed. Because of this difference in the ration fed, these results are not averaged.

Experience has proved that gluten feed is a satisfactory supplement to hay for use in basal rations. The necessity for such a supplement is greatest when the material under test is deficient in protein or is of a coarse, fibrous, unpalatable nature.

Gluten Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	1	9[1]	79.37	negative	73.56	37.80	89.76	70.95
XXIV	1	11	94.97	54.09	85.35	92.46	99.83	92.21
XXIV	14	12	82.09	123.50	82.51	83.85	83.86	77.25
XXIV	14	13	84.12	118.34	84.93	80.66	86.40	83.11
XXV	1	9[1]	70.86	negative	81.24	26.30	77.02	87.85
XXV	1	11	84.26	negative	85.05	96.50	89.06	93.31
XXV	4	12	95.72	56.84	89.86	102.10	100.55	84.34
XXV	4	13	95.28	12.76	93.03	109.94	99.95	81.53
XXV	6	15[1]	93.23	negative	88.09	125.06	101.97	76.91
XXV	6	16	85.60	negative	83.41	100.55	96.40	75.42
XXVI	3	17	79.23	negative	81.70	82.49	84.62	29.55
XXVI	3	18[1]	93.37	negative	79.99	281.89	88.37	38.32
XXVI	3	19	78.83	negative	86.21	80.19	79.27	50.86
Average			86.68	–	85.78	92.08	91.10	74.18
Average all previous trials			91.08	–	86.11	124.21	93.56	72.38

[1] Not included in the average.

The average composition and limits of variation of the two lots of gluten feed used in these experiments were as follows: dry matter 90 per cent (87.80–91.22), made up of ash 3.35 (2.52–4.74), protein 27.56 (24.53–29.50), fiber 6.83 (6.31–7.31), nitrogen-free extract 59.16 (56.44–62.52), fat 3.11 (2.08–4.31). The digestion coefficients for gluten feed were secured by applying the coefficients obtained for hay to the amount of hay fed, and deducting the product from the total digestible matter of the basal ration.

The negative results for ash in a majority of the trials are almost always noticed in work with gluten feed. No satisfactory explanation for such results can be given although they may be attributed in part to experimental error due to the small amount of ash present, and in part to the excretion of digested mineral matter from the intestines. In the case of fiber, it will be noticed that occasionally the coefficients were above 100 per cent, due probably to improvement in digestibility of the fiber in the hay as the result of adding a protein concentrate.

Incidentally it may be remarked that as a result of five separate trials with corn bran, the fiber was found to have an average digestibility of 75.12 per cent. This, together with the results secured for the fiber in gluten feed, shows that the fiber in corn is quite well utilized.

The present data, as well as those obtained as a result of many previous trials, show gluten feed to be a highly digestible protein concentrate.

Dried Apple Pomace.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	4	9	63.48	negative	negative	71.41	73.88	28.35
XXVI	4	11	68.11	56.25	negative	72.93	75.78	40.33
XXVI	5	17	71.41	2.53	negative	87.08	79.01	43.85
XXVI	5	19	59.45	14.01	negative	60.98	71.03	36.10
Average			65.61	–	–	73.10	74.93	37.16
XXVI	6	9	77.02	94.03	negative	80.21	83.87	37.14
XXVI	6	11	65.49	53.84	negative	58.61	75.45	25.22
XXVI	8	19	71.82	107.14	negative	52.13	73.39	41.38
Average			71.44	84.67	–	63.65	77.57	34.58
Average present trials			68.11	–	–	69.05	76.06	36.05
Average previous trials (6)			71.50	48.70	–	64.40	84.40	45.30
Dried beet pulp, for comparison			75.00	26.00	52.00	83.00	83.00	–

Note. — In periods 4 and 5 the pomace was fed unground. In periods 6 and 8 it was fed in the finely ground state. Two sheep were started in period 8, but one became sick and had to be rejected. The previous trials, averages of which are reported here for comparison, were with wet pomace.

This material was studied quite extensively during the winter of 1920–21, with respect to chemical composition, digestibility and value for milk production, and the results published in Bulletin 205. It is a carbohydrate feed, having a negligible amount of ash and relatively little protein. An average of the analyses of six samples shows a dry matter content of 94.70 per cent, composed of ash 1.55, protein 5.88, fiber 19.22, nitrogen-free extract 68.64, and fat 4.71.

The results of seven single digestion trials show a fairly high degree of digestibility as regards total dry matter, ash, fiber and nitrogen-free extract. The fat is rather poorly digested, due doubtless to the fact that it is not true fat but waxy material; and the protein is apparently not digested at all, or because of the small amount present the coefficients are of uncertain value. Dried beet pulp, a somewhat similar type of feed, has a slightly higher digestibility.

Barley Screenings.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	12	9	54.31	15.22	65.12	34.25	60.29	9.96
XXIII	12	11	60.59	29.79	82.72	42.65	63.99	8.99
Average			57.45	22.51	73.92	38.45	62.14	9.48
Oat feed, for comparison			52.00	47.00	86.00	49.00	47.00	58.00

Barley screenings is the residue from barley flour, which was prepared in considerable amounts during the war period. It contained dry matter 89.73 per cent, which was composed of ash 6.30, protein 9.98, fiber 19.51, nitrogen-free extract 61.08, fat 3.13.

Except for its lower fiber content, it resembled both oat feed and hay in chemical composition. Its total dry matter is a little better digested than oat feed because of a less complete separation of the starchy matter, and it has approximately 5 per cent greater feeding value.

Carrots.

(*a*) *Carrots fed with Hay.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII . . .	4	12[1]	97.56	28.42	80.22	165.87	103.91	106.48
XXIII . . .	4	13	74.34	10.15	65.19	54.28	89.23	75.14
XXIII . . .	5	12	76.95	6.21	67.84	72.24	92.86	60.91
XXIII . . .	5	13	80.65	18.88	83.16	67.97	94.38	66.82
Average present trials			77.31	11.75	72.06	64.83	92.16	67.62
Average 5 previous trials			85.90	47.75	75.90	102.14	93.51	41.33

(*b*) *Carrots fed with Hay and Gluten Feed.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	9	9	78.50	49.64	56.78	80.27	87.82	6.06
XXIV	9	11	82.27	41.27	62.18	91.95	91.94	18.79
XXIV	11	9	85.88	50.17	55.80	140.63	93.31	36.58
XXIV	11	11	74.59	30.68	50.85	108.23	85.31	5.69
Average present trials			80.31	42.94	56.40	105.27	89.60	16.78
Average all trials (7 present, 5 previous) .			81.89	37.15	68.44	93.86	91.87	39.72

[1] Not included in the average.

The digestion work with carrots is a continuation of earlier work reported in Bulletin 181. In the present trials, two lots of carrots were fed, averaging 88.02 per cent water, with dry matter composed of ash 9.91, protein 8.92, fiber 8.33, nitrogen-free extract 71.61, fat 1.23. In common with most other roots, they are relatively low in protein, fiber and fat, and high in ash and nitrogen-free extract.

The first lot (periods 4 and 5, Series XXIII) was fed with hay only; the second lot (periods 9 and 11, Series XXIV) was fed with hay and gluten feed; and in both cases constituted about 20 per cent of the dry matter of the ration.

The digestibility of the dry matter of the carrots in the present hay-carrot ration was 77 per cent as against 86 per cent in five previous trials. In both experiments quite wide variations are observed for which a satisfactory explanation cannot be given. It is quite possible that bacterial activity in the intestinal tract was more pronounced in some cases than in others.

When the carrots were fed in combination with hay and gluten feed, their digestibility appeared to be slightly more — 80 per cent as against 77 per cent when fed with hay only.

The fiber in carrots as well as in most roots appears to be quite completely digested, former experiments with mangels and turnips showing a dry matter digestibility of 87 to 89 per cent. The carrots seem to fall slightly below these figures.

Coffee Refuse.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	14	15	26.95	97.18	11.48	12.76	32.03	75.36

This material was the residue from the coffee bean, and was being used as a component of a low-grade feed mixture. It contained 93.77 per cent of dry matter, which was composed of ash 5.29, protein 13.29, fiber 33.86, nitrogen-free extract 40.98 and fat 6.58. It was fed in combination with hay and gluten feed to the extent of about 16 per cent of the dry matter of the ration. One sheep refused the mixture, while the other ate it but digested only a small portion. It evidently had very little nutritive value.

Cottonseed Meal.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	15	12	75.03	95.44	82.57	33.43	82.67	102.75
XXV	15	13	69.54	72.45	81.80	13.35	78.75	93.31
Average			72.29	83.95	82.19	23.39	80.71	98.03
Average all previous trials (14)			79.00	65.00	84.00	32.00	77.00	95.00

The sample contained 92.90 per cent of dry matter, which had 7.40 per cent of ash, 39.35 per cent of protein, and 20.05 per cent of fiber, the latter ingredient being some 8 per cent above the average. It is evident that considerable ground hulls had been added, and the above coefficients show that such an admixture caused the digestibility to be below that for the better grades. As is well known, cottonseed meal is sold on a basis of from 43 to 36 per cent protein; the latter grade results from the addition of ground hulls, which naturally reduces both its feeding and fertilizing value.

Feterita.

Series.	Period.	Sheep.	Dry. Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	10	17	86.71	188.88	86.77	negative	89.73	90.57
XXVI	10	19	86.59	123.08	98.55	negative	89.63	88.61
Average			86.65	155.98	92.66	–	89.68	89.59
Average previous trials (2)			74.65	–	46.55	–	87.94	56.69
Texas Station results[1]			88.99	–	90.03	50.00	96.60	74.52
Corn, for comparison			90.00	–	74.00	57.00	94.00	93.00

[1] Texas Agr. Expt. Sta. Bul. No. 203, p. 32.

Feterita or sudan durra is one of the grain sorghums which include also milo, durra and kaoliang. Two digestion trials were made on another sample a number of years since and reported in Bulletin 181. The present sample analyzed 89.22 per cent of dry matter, which contained ash 1.75, protein 14.46, fiber 1.63, nitrogen-free extract 78.37, and fat 3.8 per cent. In chemical composition it resembles Indian corn, except for its higher protein and lower fat percentage. The present digestion coefficients are quite uniform, and conform fairly well to those secured at the Texas Station. It is evident that feterita is about equal to corn in digestibility. The results secured by us in the former trial, showing 75 per cent of dry matter, 51 per cent of protein and 61 per cent of fat digested, were evidently too low, although they were obtained under satisfactory experimental conditions.

Oat Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	12	12	51.30	92.67	81.48	39.03	44.88	118.62
XXIV	12	13[1]	18.94	52.47	4.85	0.83	19.47	101.80
XXV	11	9[1]	28.71	negative	18.28	22.57	30.74	184.69
XXV	11	11[1]	26.88	negative	22.23	20.93	32.20	99.69
XXV	13	9	54.89	25.70	85.57	55.59	49.38	43.28
XXV	13	11	51.46	25.70	89.90	42.79	49.04	46.23
XXV	18	12	56.68	68.79	89.63	57.12	52.37	15.96
XXV	18	13	46.51	23.07	85.95	52.55	39.61	66.57
Average			52.17	47.19	86.51	49.42	47.06	58.13
Timothy hay, for comparison			55.00	39.00	47.00	51.00	62.00	50.00

[1] Not included in the average.

Note. — The average coefficients for ash, fiber, nitrogen-free extract and fat in oat feed, published in Table II (e), p. 120 of Bulletin No. 200, are incorrect. The correct figures are given here.

The value of this material as a food for farm stock was studied by us some two years ago, and the results of the work have been published as Bulletin 200 of this Station. Oat feed, as the term is generally understood by the trade, is a by-product of oatmeal manufacture, and consists of the reground hulls plus the middlings and dust from the first milling of the grain. At some mills the residue from the second milling is also incorporated, but this is not the usual practice.

An average of the analyses of four samples shows the following percentage composition in dry matter: ash 6.48, protein 6.20, fiber 29.18, nitrogen-free extract 55.82, and fat 2.31. It resembles ordinary English hay in composition, except that it contains rather less fiber.

Eight single digestion trials were made with the sheep on this material, four in combination with hay (500 grams hay, 150 grams oat feed), and four with hay and gluten feed (500 grams hay, 150 grams gluten feed, 150 grams oat feed). The results of three of the trials were so much below the others in almost all respects that they are not included in the average. The average of the other five shows a digestibility comparable with timothy hay.

Oat Hulls.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	13	9	31.30	15.74	negative	49.64	28.94	negative
XXIV	13	11	36.23	9.46	12.10	51.45	36.13	14.38
Average			33.77	12.60	–	50.55	32.54	–

These coefficients have also been published in Bulletin 200.

The oat hulls contained the following percentages in dry matter: ash 6.37, protein 2.52, fiber 32.66, nitrogen-free extract 57.44, and fat 1.01. Fiber and nitrogen-free extract constitute the larger part of the hulls. The total dry matter is about one-third digestible, which places them among the lowest grades of cereal by-products.

Peanut By-Products.

A study has been made of three peanut by-products, viz., peanut meal, peanut shells and peanut skins. Peanut meal is the ground residue from the extraction of edible oil or soap oil stock. In the former instance it consists of the ground residue from the kernels only, and is specifically known as peanut oil meal. In the manufacture of soap-stock oil the whole peanut is extracted, and the ground residue should be known as peanut feed, a product much inferior to the peanut oil meal, due to the admixture of shell and skin. Peanut shells are the ground or unground outer hull of the nut; while peanut skins are the thin, waxy inner coat of the endosperm or kernel.

Analysis.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Peanut meal	92.33	5.27	39.74	5.09	33.67	16.21
Peanut shells	96.70	3.28	8.91	63.16	18.88	5.77
Peanut skins	94.59	3.46	18.75	8.48	40.01	29.29

Peanut meal, as indicated by the analysis, is a high-grade protein feed with considerably more fat than is contained in most concentrates. The shells are composed of nearly two-thirds fibrous material. The skins contain a reasonable amount of protein and nitrogen-free extract, comparatively little fiber, and a very high percentage of fat.

Coefficients of Digestibility.

(*a*) *Peanut Meal.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	19	9	74.62	negative	80.81	59.43	77.59	87.84
XXV	19	11	80.53	5.34	85.47	47.52	84.02	93.94
Average			77.58	–	83.14	53.48	80.81	90.89
German data[1]			83.00	–	90.00	(9)	84.00	90.00

(*b*) *Peanut Skins.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	8	11	38.48	negative	49.49	negative	28.80	90.16
XXV	12	15	8.43	34.93	negative	negative	2.70	93.47

(*c*) *Peanut Shells.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	16	9	32.83	34.24	69.35	8.63	29.25	83.32
XXV	16	11	25.19	12.61	67.72	.69	55.68	84.83
Average			29.01	23.43	68.54	–	42.47	83.58

[1] Mentzel & Lengerke Landw. Kalender 1922, results of seven single trials with four samples.

While the digestion results with peanut meal are not as high as the average results secured by German observers, the utilization of the protein, nitrogen-free extract and fat, of which it is largely composed, shows that the meal should be placed among the best of the protein feedstuffs.

The digestion results secured with the peanut skins are neither concordant nor very satisfactory. However, in each case they show that the fat, which comprises nearly 30 per cent of the skins, was quite fully utilized. When the skins were fed with hay (period 8), the digestion of the fiber of the ration seemed to be noticeably depressed or interfered with; and when fed with hay and gluten feed (period 12), none of the organic ingredients except the fat was digested. One might therefore conclude that the fat interfered with the utilization of the protein, fiber and nitrogen-free extract. On the basis of the above results, their value as a cattle feed is questionable. In order to utilize them economically, it may be possible to extract the oil and use the residue for litter or for packing purposes.

Peanut shells are shown to have a low digestibility, inferior even to oat hulls. While the small percentage of protein and fat which they contain seems to be well utilized, the fiber which comprises over 60 per cent of the dry matter apparently is little if any digested. The shells, therefore, are of little value as a feed.

Velvet Bean Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	8	12	82.06	41.48	76.64	81.07	89.71	86.69
XXIII	8	13	71.48	28.52	73.96	51.09	81.82	74.41
XXIII	9	9	70.96	22.97	68.56	46.60	80.35	72.79
XXIII	9	11	81.16	33.24	78.02	71.06	86.83	85.63
Average			76.42	31.55	74.29	62.46	84.68	79.88
Wheat bran, for comparison			66.00	–	77.00	39.00	71.00	63.00

Velvet bean feed consists of the ground seed and pod of the velvet bean, a rank-growing tropical legume which is cultivated extensively in Florida, Alabama and Mississippi. It has appeared at different times in Massachusetts, and a full report on its merits may be found in Bulletin 197.

Its composition on a dry matter basis is as follows: dry matter 88.16, ash 5.79, protein 18.94, fiber 14.50, nitrogen-free extract 56.16, fat 4.62. It resembles wheat bran in composition, but has slightly more protein and considerably more fiber, due to the presence of the pods. The average of the four trials shows about the same amount of digestible protein as is found in wheat bran. The fiber, nitrogen-free extract and fat are, however, somewhat more digestible, and on the basis of total digestible nutrients the velvet bean feed has about 11.5 per cent greater feeding value than bran.

Summary.

In the table following, the average composition of each feeding stuff is given, together with the average coefficients of digestibility and the limits of error, calculated by Bessel's formula. The error limit is large in some cases, the cause therefor being explained in the discussion of results on pages 53-61. In case of oat hulls and peanut shells the results vary so widely that the limits of error are not stated. The coefficients indicate that much difficulty was experienced in digesting these materials and that they possessed comparatively little nutritive value. The coefficients for the ash in all cases are of uncertain value because it is now recognized that a considerable portion of the digested mineral matter is excreted through the feces, whereas in case of organic nutrients the end products of digestion are eliminated through the lungs, skin and urine. Where the percentage of fat in the feed is small — 1 per cent or less — the coefficients have little meaning.

Composition and Coefficients of Digestibility of Feeding Stuffs.

Feedstuff.	Number of Tests.	Number of Animals.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
English Hay, composition	–	–	89.67	6.07	7.95	33.81	49.52	2.65
Coefficients, lot 1	2	2	58.40±0.33	45.37± 0.14	47.81±0.31	62.67±0.52	59.98±0.21	45.44
Coefficients, lot 2	8	7	56.98±0.82	36.99± 2.29	46.52±0.98	64.70±0.66	55.92±1.08	31.01± 1.79
Coefficients, lot 3	9	9	60.55±0.53	33.32± 1.60	56.13±0.70	65.86±0.51	61.72±0.53	46.25± 0.81
Average coefficients	19	9	58.82±0.49	36.13± 1.32	51.21±0.90	65.03±0.39	59.09±0.66	39.75± 1.42
Gluten Feed, composition	–	–	90.00	3.35	27.56	6.83	59.16	3.11
Coefficients	9	6	86.68±1.54	–	85.78±0.81	92.08±2.44	91.10±1.83	74.18± 4.68
Dried Apple Pomace, composition	–	–	94.70	1.55	5.88	19.22	68.64	4.71
Unground, coefficients	4	4	65.61±1.77	–	–	73.10±3.62	74.93±1.13	37.16±2.25
Ground, coefficients	3	3	71.44±2.25	–	–	63.65±5.73	77.57±2.16	34.58± 3.26
Both lots, coefficients	7	4	68.11±1.50	–	–	69.05±3.18	76.06±1.08	36.05± 1.76
Barley Screenings, composition	–	–	89.73	6.30	9.98	19.51	61.08	3.13
Coefficients	2	2	57.45±2.12	22.51± 4.91	73.92±5.94	38.45±2.83	62.14±1.25	9.48± 0.33
Carrots, composition	–	–	12.00	9.91	8.92	8.33	71.61	1.23
With hay, coefficients	3	2	77.31±1.23	11.75± 2.52	72.06±3.78	64.83±3.66	92.16±1.03	67.62± 2.79
With hay and gluten feed, coefficients	4	2	80.31±1.64	42.94± 3.08	56.40±1.57	105.27±8.84	89.60±1.24	16.78± 4.90
Coffee Refuse, composition	–	–	93.77	5.29	13.29	33.86	40.98	6.58
Coefficients	1	1	26.95	97.18	11.48	12.76	32.03	75.36
Cottonseed Meal, composition	–	–	92.90	7.40	39.35	20.05	25.33	7.87
Coefficients	2	2	72.29±1.85	83.95± 7.75	82.19±0.26	23.29±6.77	80.71±1.32	98.03± 3.18
Feterita, composition	–	–	89.22	1.75	14.46	1.63	78.37	3.80
Coefficients	2	2	86.65±0.04	155.98±22.19	92.66±3.97	–	89.63±0.03	89.59± 0.66
Oat Feed, composition	–	–	93.11	6.48	6.20	29.18	55.82	2.31
Coefficients	5	4	52.17±1.18	47.19± 9.59	86.51±1.04	49.42±2.43	47.06±1.49	58.13±11.56
Oat Hulls, composition	–	–	91.75	6.37	2.52	32.66	57.44	1.01
Coefficients	2	2	33.77	12.60	–	50.55	32.54	–
Peanut Meal, composition	–	–	92.33	5.27	39.74	5.09	33.67	16.21
Coefficients	2	2	77.58±1.99	–	83.14±1.57	53.48±4.02	80.81±2.17	90.89±2.06
Peanut Shells, composition	–	–	96.70	3.28	8.91	63.16	18.88	5.77
Coefficients	2	2	29.01	23.43	68.54	–	42.47	83.58
Velvet Bean Feed, composition	–	–	88.16	5.79	18.94	14.50	56.16	4.62
Coefficients	4	4	76.42±2.03	31.55± 2.64	74.29±1.41	62.46±5.51	84.68±1.47	79.88± 2.46

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THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING

By J. B. LINDSEY and C. L. BEALS

Condensed (semi-solid) and dried buttermilk are by-products of the creamery industry, now widely advertised for use in pig feeding. An experiment with twelve growing pigs showed that condensed (semi-solid) and dried buttermilk when fed in limited amounts proved altogether too expensive to warrant their use for economical pork production. The semi-solid milk cost six cents and the dried article twelve cents a pound, and they were fed in the diluted form to the extent of from two to four quarts daily per pig.

Two experiments with lactic acid added to the grain slop in the amounts usually found in ordinary buttermilk showed no pronounced effect in promoting appetite or in causing an increase of growth.

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BULLETIN No. 217.

DEPARTMENT OF CHEMISTRY.

THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING.

BY J. B. LINDSEY AND C. L. BEALS.

Condensed and Dried Buttermilk as a Food for Pigs.

Buttermilk, as it comes from the creamery, has long been recognized as a valuable food for growing pigs and poultry. Some thirty-five years ago, the late Professor Goessmann of this Station showed that on the basis of total solid ingredients (dry matter), buttermilk and skim milk when fed to growing pigs possessed substantially equal values.

At the present time neither by-product is obtainable in regular supply in most sections of Massachusetts at prices which warrant its use, especially for pigs. In recent years buttermilk, from which a portion of the water has been removed by the use of a partial vacuum and which is of a pasty consistency, has been placed upon the market under the trade name of semi-solid buttermilk,[1] and offered at from five and one-half to six cents per pound in barrel lots. It is also put up in fifty-pound wooden pails, intended particularly for poultry. A completely dried buttermilk, of a creamy color and of a powdered or flaky appearance, is also to be had, costing from ten to twelve cents a pound.

Inasmuch as the condensed or "semi-solid" material is freely advertised and its use recommended and urged, it seemed worth while to test its economy by feeding it in limited amounts to two groups of pigs. The dried buttermilk was also similarly tried.[2]

Chemical Composition.

Material.	Water.	Ash.	Protein.	Lactic Acid.	Milk Sugar.	Fat.
"Semi-solid" buttermilk	67.63	3.25	12.43	7.02	8.77	.90
"Semi-solid" buttermilk	67.06	–	–	–	–	–
Dried buttermilk	6.64	8.29	32.71	–	51.91[3]	.75
Liquid buttermilk	91.60	0.70	3.60	–	5.00[3]	.10–.27
Skim milk,[4] for comparison	90.10	0.70	3.80	–	5.20	.20

[1] The Universal Products Sales Co., 165 Liberty St., New York, are wholesale distributors.

[2] Sample secured from the Merrell-Soule Co., Syracuse, N. Y. The Collis Products Co., of Clinton, Iowa, claim to be large manufacturers of dried buttermilk and offer it in paper-lined sax at $9.50 a cwt. delivered, or $10 a cwt. in barrels. The price, naturally, is subject to change.

[3] Including lactic acid.

[4] Centrifugal process of separation.

The first two analyses represent the composition of the "semi-solid" material as it was received in barrels. It was about two-thirds water, whereas ordinary liquid buttermilk as it comes from the creamery contains about nine-tenths water. Naturally, the semi-solid milk contains more protein, ash, lactic acid, milk sugar and fat because of the evaporation of a part of the water. The dried buttermilk contained scarcely 7 per cent of water. On the basis of dry matter, 300 pounds of "semi-solid" buttermilk would be equal in feeding value to about 100 pounds of dried buttermilk; and on this basis should sell for four cents a pound when a like amount of the dried article was costing twelve cents. Actually, however, the cost of the "semi-solid" buttermilk was six cents a pound as compared to twelve for the dried buttermilk. Freight and cartage also favor the latter article, if either is to be bought.

Plan of Experiment.

Twelve pigs, weighing from 33 to 50 pounds each, were divided into six lots of two each (sow and barrow), and *each lot* was fed on a definite ration. An ash mixture was kept continuously before each lot, composed of:

20 per cent Salt.
40 per cent Rock phosphate.
20 per cent Ground limestone.
20 per cent Wood ashes.

The several lots were fed as follows:

Lot I. — Nine ounces of grain mixture I to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture I.

20 pounds Ground oats.
40 pounds Flour middlings.
40 pounds Corn meal.

This was considered a check ration, and as good as could be made from purchased grain.

Lot II. — Nine ounces of grain mixture II to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture II.

90 pounds Grain Mixture I.
10 pounds Digester or pig tankage.

This was an improvement over the ration fed to Lot I in that it contained 10 per cent of high grade tankage testing 19.9 per cent of ash and 63 per cent of protein. It also could be considered a check ration.

Lot III. — Four quarts of diluted "semi-solid" buttermilk daily, plus nine ounces of grain mixture I to each quart of warm water in amounts to satisfy appetites. The buttermilk in all cases was diluted to the consistency of ordinary buttermilk.

Lot IV. — Eight quarts of diluted "semi-solid" buttermilk daily, plus the same grain ration fed to Lot III.

Lot V. — Twelve ounces of dried buttermilk stirred into four quarts of warm water daily, plus the same grain ration fed to Lot III.[1]

Lot VI. — Twenty-four ounces of dried buttermilk stirred into eight quarts of warm water daily, plus the same grain ration as fed to Lot III.

After the animals had reached about 100 pounds each in weight, the grain mixture received by Lot II was changed by reducing the tankage to 5 per cent, and correspondingly increasing the grain. Otherwise the experiment was continued to completion, covering 126 days.

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[1] Owing to the fact that one of the pigs in this lot proved inferior, the results were discarded.

Results of the Experiment.

Rations, Food Consumption, Daily Gain, Dry Food Required to Produce Gain, and Cost of Gain.

Lot.	Ration.	Dry Food consumed (Pounds).	Daily Gain (Pounds).	Dry Food required to Produce 100-pound Gain.	Cost of 100-pound Gain.
I	Grain only	702.92	.95 .96	293	$7 22
II	Grain+tankage	758.18	1.10 .87	311	8 55
III	Grain+"semi-solid" buttermilk	812.96	1.07 .92	327	14 47
IV	Grain+"semi-solid" buttermilk	924.46	1.22 1.09	319	18 91
VI	Grain+dried buttermilk	899.40	1.27 1.43	264	13 16

It is evident from the above data that, while the buttermilk products as a component of the ration aided in growth, their cost is too great to render their use financially advisable.[1] Pigs on the grain plus ash mixture made a very good growth, and must have found at least a fair amount of growth accessories (vitamins) in the ration fed.

Note. — Considerable quantities of evaporated buttermilk and skim milk are used in growing poultry. It is undoubtedly very efficient, furnishing mineral matter, desirable proteins and vitamins; and probably its use in reasonable amounts is economical in forcing pullets to early egg production. The writer, however, has no data on this subject. Other things being equal, the dried product should prove more economical than that which has only a portion of the water removed.

Lactic Acid — Its Value in Promoting Growth in Pigs.

The claim has been made that the addition of dilute lactic acid — the acid of sour milk — to the grain slop fed to pigs will improve the appetite and digestion and promote an increase in growth. Two trials were made to demonstrate the truth or fallacy of the claim.

Trial I, May 19–September 8.

Two lots of two pigs each (averaging 30 pounds each in weight) were placed in two separate pens and fed as follows:

Lot I. — Six ounces of corn meal to each quart of skim milk, in sufficient amounts to satisfy the appetite. When the lot reached a daily consumption of 72 ounces of meal and 12 quarts of skim milk, the ration was increased by the addition of the following mixture, in the proportion of 9 ounces to each quart of water:

28 pounds Corn meal.
28 pounds Wheat middlings.
28 pounds Ground oats.
16 pounds Digester tankage.

After the animals had reached a weight of about 100 pounds each, the skim milk was reduced to 8 quarts daily for the lot, and was supplemented with a grain

[1] The use of small amounts of "semi-solid" or dried buttermilk, or of dried skim milk may be worth while from the time young pigs are weaned until they attain a weight of 25 to 30 pounds, when the natural product is not available.

mixture of one-third each of corn meal, wheat middlings and ground oats to satisfy appetites. This was continued until the end of the trial. This ration, with its variations, was considered a standard or check ration suitable for promoting normal growth.

Lot II. — The same corn meal, middlings, oats and tankage mixture fed to Lot I. This was fed throughout the trial in the proportion of 9 ounces to each quart of water containing .7 per cent of lactic acid. Milk was omitted from the ration.

Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.
Number of days in trial	116	116
	Pounds.	Pounds.
Dry Matter in food consumed:		
Skim milk[1]	199.0	none
Corn meal	336.4	164.0
Wheat middlings	140.2	167.0
Ground oats	140.2	167.0
Digester tankage	4.8	76.0
Lactic Acid[2]	none	18.0
Total	820.6	592.0
Growth Produced:		
Weight at beginning	35 26	28 29
Weight at end	165 175	122 120
Total gain	130 149	94 91
Daily gain	1.12 1.28	.81 .78
Dry Matter per 100 pounds Gain	294.1	320.0

[1] Pigs 1 and 2 received 1,028 quarts of skim milk averaging 9 per cent solids. One quart was taken to equal 2.15 pounds.

[2] Pigs 3 and 4 received 1,224 quarts of water containing .7 per cent lactic acid. One quart was taken to equal 2.1 pounds.

A glance at the above table shows that Lot I, which received considerable skim milk in addition to the grain mixture, made a satisfactory growth. This may be attributed, in part at least, to the ease of digestion and assimilation of the milk, to the extra dry matter consumed, to the favorable proteins and also to the vitamin content of the milk. Lot II grew fairly well, but the pigs were not equal to Lot I because of the absence of the skim milk. The lactic acid did not seem to be helpful in growth production.

Trial II, September 22–December 1.

Six grade Chester White pigs were procured in September and fed upon skim milk and corn meal until each weighed between 20 and 30 pounds. They were then divided into three lots of two each and fed as follows:

Lot I. — Eight ounces of the following mixture to each quart of water, in amounts to satisfy the appetite:

30 pounds Corn meal.
30 pounds Wheat middlings.
30 pounds Ground Oats.
10 pounds Digester tankage.

Lot II. — The same grain mixture as Lot I, with sufficient lactic acid added to the water so that it tested .4 per cent of that ingredient.

Lot III. — The same grain mixture as Lots I and II, with sufficient lactic acid to make the solution test .8 per cent of that ingredient.

The experiment began September 22 and ended December 1, proceeding without any disturbances. The weighing, housing and general care of the pigs were the same as in the preceding experiments. For the first two weeks of the experiment, after the change was made from the corn meal and skim milk to the experimental diet, none of the pigs made much growth; but as soon as they adapted themselves to the new diet a reasonable growth was noted from week to week.

Dry Matter in Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.	Lot III. Pigs 5 and 6.
Number of days in trial	70	70	70
	Pounds.	Pounds.	Pounds.
Dry Matter in food consumed:			
Corn meal	79.4	77.8	79.4
Wheat middlings	80.2	78.6	80.2
Ground oats	80.8	79.2	80.8
Digester tankage	27.2	26.8	27.2
Lactic acid	none	5.0[1]	10.4[2]
Total	267.6	266.2	278.0
Growth Produced:			
Weight at beginning	29 28	21 21	25 23
Weight at end	67 66	62 57	60 65
Total gain	38 38	41 36	35 42
Average daily gain	.54 .54	.59 .51	.50 .60
Dry Matter per 100 pounds Gain	351.3	345.7	361.0

[1] Pigs 3 and 4 received a total of 604 quarts each of water containing .4 per cent lactic acid, 2.1 pounds per quart.
[2] Pigs 5 and 6 received a total of 616 quarts each of water containing .8 per cent lactic acid, 2.1 pounds per quart.

From the general appearance of the pigs, and from the above data, one is justified in concluding, in case of both trials, that the lactic acid was without any pronounced effect in promoting growth. It is possible that lactic acid may have some therapeutic effect in case of animals undergoing digestive disturbances, but under normal conditions its use is not advised.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 218 OCTOBER, 1923

THE

CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS

By HARLAN N. WORTHLEY

The squash vine borer is a widely distributed and very serious enemy of squashes and related plants. Because of the protected life of the larva, which burrows within the squash stem, insecticides have been considered useless in the control of this pest. The best direct remedy has been to cut the borers from infested vines, a tedious and impractical treatment in commercial plantings.

This bulletin reports the discovery and application of a spraying program for squash vine borer control which has given satisfactory results under Massachusetts conditions, and which kills the insect in the egg stage, thus protecting the plants against the slightest injury from borers.

Publication of this Document approved by the Commission on Administration and Finance

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS.

BY HARLAN N. WORTHLEY.

Distribution and Importance.

The squash vine borer[1] is a native of the New World, and apparently is of tropical origin. It has spread northward over that portion of the United States east of the Rocky Mountains, and into Southern Canada. It is found as far south as Argentina.

In many localities the squash vine borer is the most serious enemy of winter squashes. Pumpkins and summer squashes are also affected, and more rarely melons and cucumbers.

Description.

Egg. — The egg of the squash vine borer is shown in Plate I, figure 1 and Plate II, figure 2. It is about one-twenty-fifth of an inch in length, and is of a dark reddish brown color. As may be seen in Figure 1, the eggs are not laid in clusters, as in the case of the squash bug eggs, but singly. Magnification, as in Plate II, figure 2, shows the chorion to be finely reticulated into tiny hexagonal figures.

Larva. — The larva, or "borer" (Plate I, figure 1 & Plate II, figure 3) as it is commonly called, is a fleshy, white, nearly hairless caterpillar with a black head and a dark brown to black thoracic shield. When full grown it measures about an inch in length. Newly-hatched larvae, which are commonly not detected in the field, are about one-sixteenth of an inch long, sparsely covered with hairs, and with a broad black head, from which the white body tapers away to the anal extremity. In appearance the borer is quite distinct from the larva of the striped cucumber beetle, with which, however, it is often confused. The latter is but three-tenths of an inch long and is very slender, with the head and anal plate dark brown.

Pupa. — The pupa (Plate I, figure 1) is contained in an earth-covered cocoon of very tough, black silk about three-fourths of an inch long. The pupa itself is about five-eighths of an inch long, and is of a dark shining brown color. The head bears a horn-like process between the eyes, and the abdomen bears circles of hook-like spines.

Adult. — The adult moth (Plate I, figure 1) is five-eighths of an inch or more in length, with a wing spread of an inch to an inch and a half. It is strikingly beautiful, with long narrow olive green fore wings, bearing a fringe of blackish hairs at the tips. The hind wings are transparent, bearing scales only along the veins. The abdomen is covered with red or orange scales, and is marked with transverse white lines and a longitudinal row of black or bronze-colored spots. The tarsi are banded with white, and the hind legs are covered with long black, white, and orange-colored hairs. The sexes are quite similar, the male being more brilliantly marked than the female, and with a narrower abdomen.

Life History and Habits.

The squash vine borer passes the winter as a full-grown larva. It is enclosed in the tough silken cocoon which it spins in the soil of squash fields, at a depth of from one to six inches below the surface of the ground. Pupation occurs within this cocoon in the spring, and lasts about three weeks. At the end of this time the pupa cuts through one end of the cocoon by means of the horn-like process on its head, and wriggles to the surface of the ground, being aided in this endeavor by the circles of spines around its abdomen. When it projects above the ground about three-fourths its length, motion ceases, and very shortly the pupal skin splits back from the head and the adult moth slowly drags itself forth. The emergence occupies in the neighborhood of five minutes, when the freed moth climbs upon some nearby object to expand and dry its wings in readiness for flight, which can be accomplished in a matter of fifteen minutes following emergence.

Plate I, figure 1, is a record of continuous observations from 1920 to 1923,

[1] *Melitta satyriniformis* Hübner (Lepidoptera, Ægeriidæ).

PLATE I.

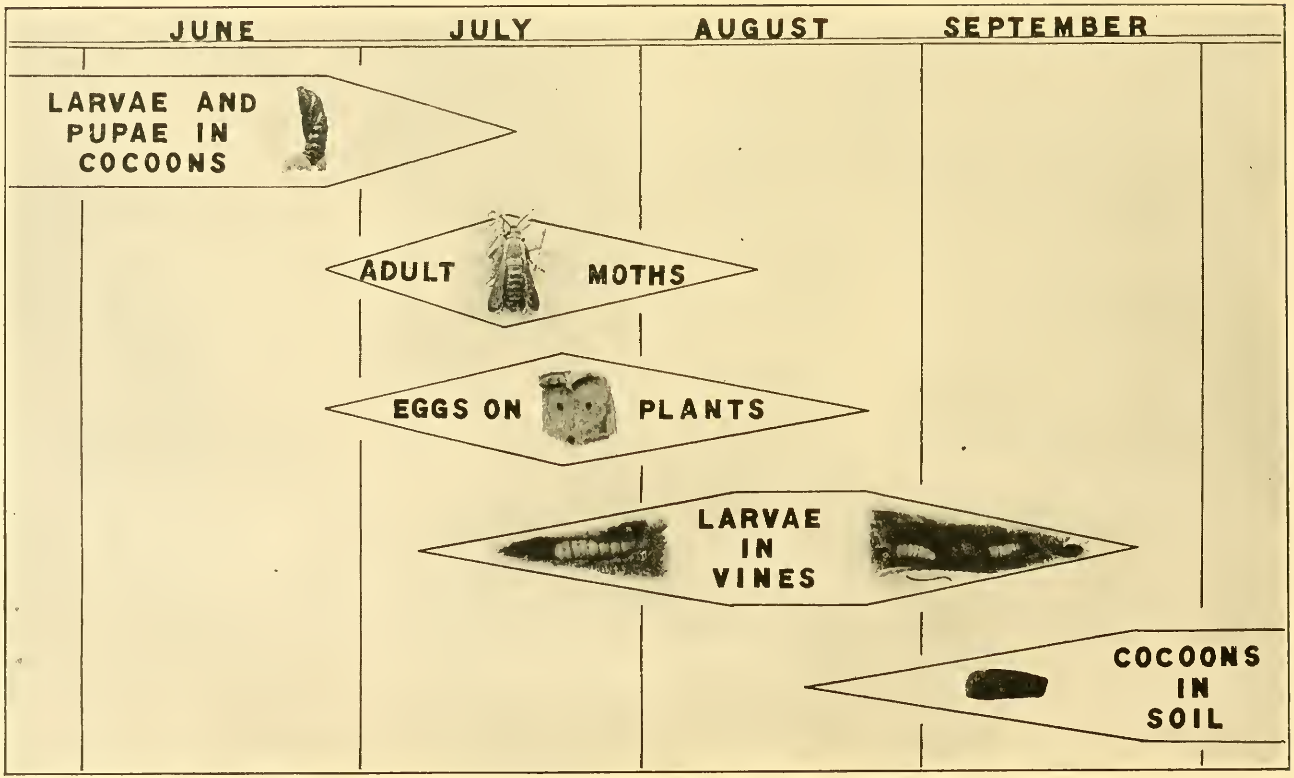

FIG. 1. Seasonal History of the Squash Vine Borer at Amherst.

and indicates an average seasonal occurrence of the different life stages of the insect at Amherst, and the average period of greatest abundance. The moths are present in numbers from the last of June until the first week in August. They dart from plant to plant in the heat of the day, and their rapidly vibrating wings and brilliant coloration cause them to be easily mistaken for wasps. They are fairly strong flyers, and the writer has known them to locate squash fields removed one-half mile from where cucurbits were grown the previous year.

The female moths lay their eggs singly, going from hill to hill, depositing one to several eggs on each plant. The eggs are attached by the flattened base, and are held in place by a cement-like secretion. Individual moths seem to have different tastes regarding the location selected for the eggs. In following moths from hill to hill, some are observed to seek the junction of the stem and the ground, some oviposit upon the leaf-stalks, and some even tuck the eggs down between the squash stem and the surrounding soil. Other moths lay their eggs indiscriminately upon main stem, leaves, leaf-stalks, and even upon tendrils and blossoms. The favorite location, however, appears to be the main stem near the base. Several counts have been made to determine the percentage of the total number of eggs laid on the different parts of the plant. The data are presented in Table I.

Table I. — *Location of Squash Vine Borer Eggs.*

	On Stem.	On Leaf-stalks.	On Leaves.	Total.
Lexington, 1922 .	377	299	10	686
Amherst, 1922 .	168	48	0	216
Littleton, 1923 .	48	5	7	60
Amherst, 1923 .	426	36	23	485
Total . .	1,019	388	40	1,447
Per cent of total .	70.4	26.8	2.8	

Individual moths may lay as many as one hundred fifty to two hundred eggs. Theoretically, therefore, ten moths only, flying from plant to plant and each laying a total of one hundred fifty eggs, are necessary to cause a one hundred per cent infestation of fifteen hundred plants, which is perhaps the average number of plants per acre.

Eggs are to be found from late June or early July until mid-August, and even later in some seasons. The period spent in the egg stage has been placed by various investigators at from six to fifteen days. Breeding records at Amherst show a variation of from nine to thirteen days, but they are not extensive and may not represent the extremes for this climate.

Table II. — *Length of Egg Stage, Amherst.*

Number of Eggs.	Eggs laid.	Eggs hatched.	Number of Days.
10 . .	July 29, 1920	Aug. 11, 1920	13
4 . .	Aug. 4, 1923	Aug. 13, 1923	9
1 . .	Aug. 5, 1923	Aug. 14, 1923	9

The records are those obtained from eggs laid by confined moths. Eggs collected in the field showed a high percentage of parasitism, which is discussed in another section of this paper, and were quite unsatisfactory for rearing.

When emerging from the egg, the young larva chews a ragged hole in one end and crawls forth upon the surface of the squash plant. Its subsequent action shows considerable variation in habit. In many cases it burrows directly into the host tissue. In other instances newly-hatched larvae have been seen to crawl to distances of eight to ten inches from the egg-shell, feeding here and there on the leaf or stalk before finally tunneling out of sight. Those which invade the leaf-stalks and main leaf veins gradually work their way toward the main stem. Since the average squash plant has not put forth runners when the majority of the eggs have been laid, the result of this movement is a concentration of injury in the main stem near the base.

The burrow made by the squash vine borer larva is a twisting one, and is frequently obstructed by a webbing of silk mixed with yellowish grains of excrement, called "frass". The greater part of the frass is pushed out through holes in the stem, where it clings in moist masses, serving to indicate the position of the borer within. The popular opinion seems to be that borers penetrate directly to the central cavity of the main stem along which they work, feeding at the walls of this cavity. This is not strictly the case. The larvae usually work in the tissue surrounding the central cavity of the stem, and often do not break through into this cavity until they are about half grown.

One borer can usually find food for its complete development at the base of the stem. When more borers are present, however, the mining is extended along the main stem and runners, into the bases of the leaf-stalks and, in rare instances, even into the fruit itself. Upon the death of one plant, the larvae are able to transfer their activities to one nearby.

Growth is completed in a month to six weeks, at the end of which time the full-grown caterpillar deserts its burrow in the squash plant and enters the soil nearby. After penetrating to a depth of from one to six inches it hollows out a cell, spins its cocoon of tough black silk and, gradually shrinking within its last larval skin, settles down to pass the winter.

There is but one generation of the squash vine borer each year in New England. It is partially double-brooded, however, in the latitude of New Jersey and Southern Ohio and two full generations occur in Georgia and further south.

Nature of Injury.

In late July in Massachusetts, squash growers begin to notice plants with wilted, drooping leaves. This condition may be the result of excessive feeding in the root by larvae of the striped cucumber beetle. It is also a symptom of the disease known as bacterial wilt. The chief cause of this wilting, however, is found in the gradual destruction of the main stem of the squash plant near its base by the tunneling of squash vine borer larvae, which may be detected by the yellowish masses of frass which they push from their burrows.

The base of the main stem frequently fails to support all the borers present, and becomes a filthy, rotting mass, invaded by various sap-feeding beetles and filth-loving insects. See Plate II, figure 4. It is finally reduced to a few dried shreds, separated from the root by a light pull. See Plate II, figure 5.

The effect of squash vine borer infestation varies from a slight check in the growth and productiveness of the infested vine, to its death outright, and the loss of its partly-formed fruit. In the same field one may see a well-grown, thrifty vine which shows some borer injury, and nearby a dried, withered remnant of a vine, the shredded and distorted base and hardened masses of frass testifying to the cause of its death. A combination of factors is involved in this difference in the effect of infestation. First, a thrifty vine can often support one or two borers, while a less vigorous plant will be completely girdled. Second, plants which have been girdled do not always die. If the runners have developed far enough to "strike" numerous secondary roots from the nodes, and if these roots can find sufficient moisture and food, the vine may yet produce a fair crop. The crop is materially reduced, however, if not lost entirely in dry portions of the field or in dry years, or when fertilization of a naturally poor soil has been confined to the hill, as is so often the case. In the case of squashes planted late, or having a slow early growth, in which the runners have failed to root before the borers become half grown, the crop is very often a failure.

Natural Enemies.

No parasitic enemies of the adult moth have yet been recorded. It is the chance prey, however, of certain large robber flies (Asilidae) which have been observed to pounce upon the moths in the fields. The larvae in their tunnels in the squash stem appear to have escaped parasites, but are sometimes attacked by the larvae and adults of ground beetles (Carabidae). These agencies are of little economic importance.

The eggs of the squash vine borer are subject to a high degree of parasitism by a tiny wasp of the family Scelionidae, the members of which are exclusively egg parasites. The species has been identified by Mr. A. B. Gahan, of the

PLATE II.

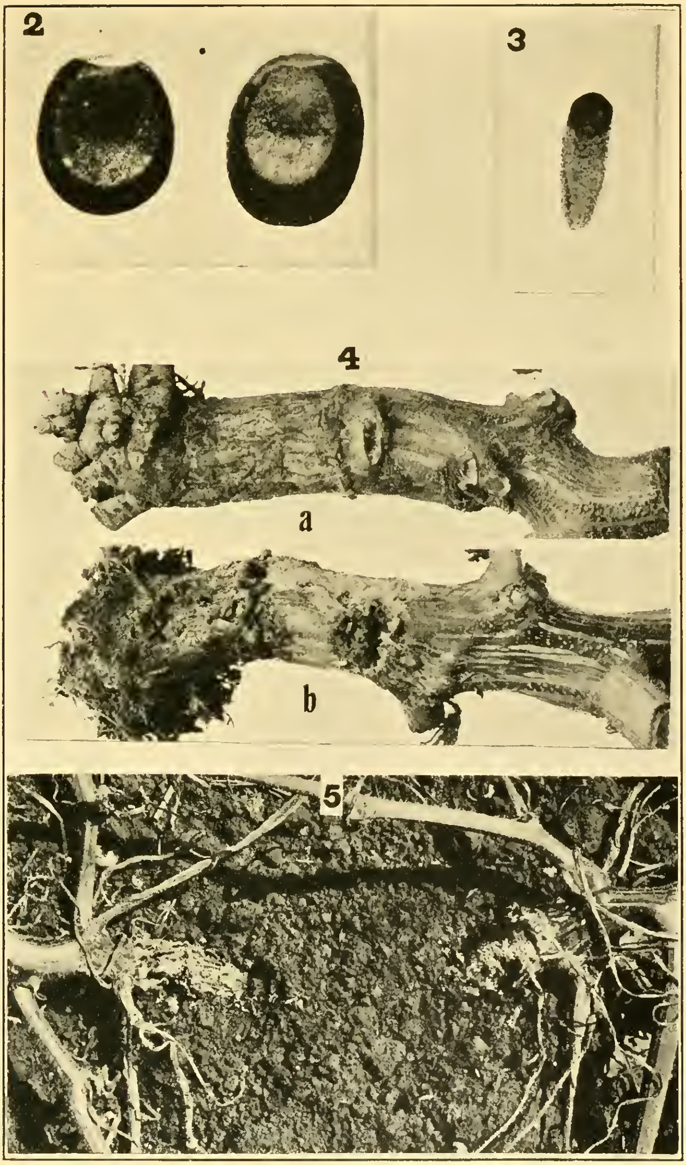

Fig. 2. Photomicrograph of squash vine borer eggs, x 24 (original).
Fig. 3. Newly hatched squash vine borer larva. Photomicrograph, x 13 (original).
Fig. 4. *a*. Healthy squash stem. *b*. Badly infested squash stem. Note burrows at "X." (Photo by R. L. Coffin.)
Fig. 5. Center of badly infested hill of squash. Note shredded condition of the bases of the stems. (Photo by R. L. Coffin.)

United States National Museum, as *Telenomus* (*Prophanurus*) sp. The extent of the work of this tiny benefactor is evident from the following records of rearings.

TABLE III. — *Parasitism of Squash Vine Borer Eggs.*

Date.	Eggs.	Parasites.	Per Cent of Parasitism.
1920			
July 24	11	11	100
July 31	20	9	45
1922			
July 7	6	2	33.3
July 28	8	1	12.5
1923			
July 16	52	40	77

CONTROL.

Cultural and Hand Methods.

Insecticides have heretofore been considered useless in the control of the squash vine borer, and consequently many cultural practises and hand methods have been advanced for the purpose of lessening the severity of the attack. A few of these are applicable under Massachusetts conditions, and are here discussed.

Trap Crops. — Winter squash, summer squash, pumpkins, melons, and cucumbers seem to be visited in the above order of preference by the egg-laying moths. Plantings of winter squash or summer crooknecks may draw the moths away from other cucurbits, and when used for this purpose should then be destroyed before the borers in them become full grown.

Fall Plowing. — Although many larvae doubtless penetrate below the plow line before spinning their cocoons, others are turned up, crushed, or exposed to the winter weather when squash fields are plowed in the fall following the removal of the crop.

Fertilization. — Many farmers seek to grow squashes on poor land with no application of fertilizer except in the hill. Borer damage is sometimes greatly enhanced by this practice. A note made by the writer in 1920 shows the effect of adequate fertilization, and is here quoted:

The history of the squash crop this year is a good illustration of the effect of proper preparation of the land and care of the crop during early growth in offsetting the attack of the squash vine borer. The experimental plot was a sandy loam. In the spring a thirty-inch stand of rye had been plowed under. Lime was applied at the rate of three thousand pounds per acre, and a 4–8–4 fertilizer at the rate of fifteen hundred pounds per acre. At planting, double furrows were opened up ten feet apart, and a good big forkful of manure was dropped every eight feet in the furrows. Over this manure, the seeds were planted. From the time the plants appeared until the runners closed the spaces between the rows, the ground was kept mellow by frequent cultivation. Before the plants started to run they were thinned to two plants in each hill. High fertilization and mellowness of soil promoted vigorous growth and the formation of secondary roots from the nodes of the runners. This formation of secondary roots was favored also by the unusually even distribution of rainfall throughout the summer. The importance of these secondary roots can be judged by the fact that every plant in the field was infested with borers, and the great majority suffered a complete rotting off of the main stem as a result. In spite of this, the harvest of squashes was declared to be satisfactory.

Covering the Runners. — Some growers make it a practise to insure the "striking" of secondary roots by covering the runners with earth at about a foot from the base of the plant. Fertilizer is sometimes added at these points. This practise is a useful one, and often serves to reduce materially the amount of damage done by the borers.

Cutting out the Borers. — The practises mentioned above, while they often aid in mitigating the severity of the squash vine borer attack, have no direct effect upon the borer itself. The best method heretofore practised for actually killing the borers has been the custom of cutting them from the vines. Slitting the stem lengthwise in both directions from the frass-clogged hole and bending back the cut portion will usually reveal the borer, which can then be removed and killed. If the stem is subsequently covered with earth, the operation will have little injurious effect upon the plant. By constant watchfulness from the middle of July to the first of September, a few plants in a home garden can be protected from excessive borer injury by this means.

The Use of Insecticides.

Certain insecticides have been tried in the past against the squash vine borer, and have been declared valueless. Among these were arsenate of lead painted thickly on the squash stems, and wrappings of tarred paper. Injections of various toxic substances have been tried at this station, but without success, both because of the nature of the burrows and of the webbing of silk and frass which obstructs them. Studies of the life history and habits of the species in 1920 led to spraying experiments in 1921 with the following materials: —

Material.	*Possible Action.*
Arsenate of lead powder, 3 pounds in 50 gals. water.	Poisoning of newly-hatched larvae.
Nicotine sulfate (Black-leaf "40"), 1 part in 100 parts of water.	Penetration and killing of the eggs — repelling of adult moths.
Bordeaux mixture, 4–4–50 formula.	Repelling of adults.

Preliminary experiments with these materials were conducted in 1921 and 1922 leading up to the successful field applications of 1923. On the basis of this work, the following sprays were applied in 1923: —

Material.	*Action of Spray.*
Black-leaf "40", 1–100, 1–250, and 1–500.	Toxic to eggs.
Arsenate of lead powder, 2 pounds in 50 gals. water; 3 pounds in 50 gals. water, plus "Kayso" sticker.	Poisons newly-hatched larvae as they chew at surface of squash plant.

The work was done on a commercial scale at Littleton, in coöperation with a squash grower, and at the Agricultural Experiment Station at Amherst. It is here reported in some detail.

The Littleton Experiment. — Mr. Homer Richards, a truck gardener and orchardist living in Littleton, offered the use of a one-acre field of winter squashes and, in addition, his assistance in the application of the sprays. The field contained twenty rows planted fifteen feet apart, and twenty-five hills six feet apart in each row. Plots were marked off as follows: —

Rows.	Treatment.	Rows.	Treatment.
1–2	Check	13–14	Check
3–6	Black Leaf "40", 1–500	15–18	Black Leaf "40", 1–100
7–8	Check	19–20	Check
9–12	Lead Arsenate, 2.5–50		

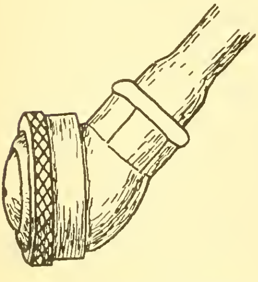

Fig. 1. — 45° Angle-disc Nozzle Used in the Experiments.

Four applications were made: on July 5, July 12, July 19, and July 26. Compressed air sprayers of three gallon capacity were used for the first three applications. Each was fitted with a short spray rod and a 45° angle disc nozzle, pictured in figure 1. All portions of the plants were thoroughly sprayed, particular attention being paid to the base of the stem. The fourth application was made with a power sprayer and one lead of hose bearing the short spray rod and angle nozzle. A pressure of 100 to 125 pounds per square inch was maintained.

Examinations to check the progress of the infestation and the effect of the treatment were made by the writer on each trip to Littleton. On July 13, a count of eggs on about twenty-five plants in each treatment gave the following results: —

TABLE IV. — *Squash Vine Eggs at Littleton, July 13, 1923.*

TREATMENT.	Eggs per Plant.
Check	1.04
Black Leaf "40", 1–500	.77
Lead Arsenate, 2.5–50	.94
Black Leaf "40", 1–100	.80

The difference in number of eggs exhibited by the check and treated plots is attributed to the mechanical effect of the spray in knocking some eggs from the plants. The writer has noticed frequently that while some eggs are firmly attached to the plants, others may be dislodged at a touch. The difference exhibited between the lead arsenate treatment and the Black-leaf "40" is attributed to a possible slight repellent effect of the nicotine sprays, the odor of which can be detected on the vines for about twenty-four hours following their application.

The effectiveness of the treatments was determined by counts of the number of borers and number of plants in treated and check plots. The final count was made on August 13 and 14, at which time the oldest larvae were ready to leave the vines, and the youngest ones were large enough to make their presence known. Every plant in the experimental field was carefully examined for borer injury, and the number of plants and number of borers in each hill recorded. The detailed results of this count are given in Table V. A summary of these counts, translated into borers per thousand plants, is also given.

TABLE V. — *Effectiveness of Treatments, Littleton, 1923.*

TREATMENT.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1–2	221	50	50	326
Black-leaf "40" 1–500	3–6	387	100	81	162
Check	7–8	187	50	50	148
Lead arsenate, 2.5–50	9_12	335	100	69	130
Check	13–14	132	50	46	134
Black-leaf "40", 1–100	15–18	375	100	18	18
Check	19–20	159	50	47	126

Summary.

MATERIAL.	BORERS PER THOUSAND PLANTS. Check.	Treated.	Per Cent of Control.
B. L. "40", 1–100	910	48	94.8
B. L. "40", 1–500	1,138	420	63.1
Lead arsenate, 2.5–50	909	388	57.4

The Amherst Experiment. — The experimental field at the Massachusetts Agricultural Experiment Station contained twenty-eight rows, twelve feet apart, with nine hills, eight feet apart in each row. Each treatment was applied to each of three separate plots, and each treated plot was flanked by a check plot with which its infestation was compared. The plan was as follows: —

Rows.	Treatment.	Rows.	Treatment.
1–2	Check	15–16	Black Leaf "40", 1–250
3–4	Black Leaf "40", 1–100	17–18	Lead Arsenate, 3–50
5–6	Black Leaf "40", 1–250	19–20	Check
7–8	Check	21–22	Black Leaf "40", 1–100
9–10	Lead Arsenate, 3–50	23–24	Black Leaf "40", 1–250
11–12	Black Leaf "40", 1–100	25–26	Check
13–14	Check	27–28	Lead Arsenate, 3–50

Four applications were made: — on July 7, July 17, July 23, and August 2. The first application was made with a compressed air sprayer, and the other three with a power outfit. Before the last application it was found necessary to move some runners from the path of the spray rig as it passed between the rows.

On July 24, a count of eggs and larvae present in the different plots gave the following results: —

Table VI. — *Status of Infestation, Amherst, July 24, 1923.*

Treatment.	Eggs per 100 Plants.	Eggs already Hatched.
Check	41	17+
Black Leaf "40", 1–100	16	0
Black Leaf "40", 1–250	19	0
Lead Arsenate, 3–50	16	3+

The difference in the number of eggs found in the checks and in the treated plots is greater here than at Littleton (see Table IV). This difference is doubtless due to the greater force with which the spray stream is applied with a power sprayer than with a compressed air sprayer. It seems clear that the difference is due to the mechanical action of the spray stream in knocking eggs from the plants rather than to any marked repellent qualities of the spray materials themselves. Lead arsenate has not been demonstrated to be repellent to insects, and yet no more eggs were found in the plot sprayed with this material than in the plots treated with the nicotine sprays. In view of this fact, it is impossible to attribute definite repellent qualities to the Black-leaf "40", in this connection.

The number of larvae found compared with the number of eggs present, as expressed in the last column of the table, indicates the toxic effect of the spray materials. The counts in the check plots may be taken as a normal progression of development of the eggs. The counts in the plot treated with lead arsenate indicate a kill of about 50 per cent, while those in the plots treated with both strengths of Black-leaf "40" indicate 100 per cent control.

The final count was made on August 20 and 21. The detailed results are recorded in Table VII, and are summarized below.

Table VII. — *Effectiveness of Treatments, Amherst, 1923.*

Treatment.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1–2	65	16	13	33
Black-leaf "40", 1–100	3–4	61	18	2	2
Black-leaf "40", 1–250	5–6	69	18	7	9
Check	7–8	82	18	18	82
Lead arsenate, 3–50	9–10	70	18	10	19
Black-leaf "40", 1–100	11–12	55	18	0	0
Check	13–14	39	17	16	32
Black-leaf "40", 1–250	15–16	69	18	3	3
Lead arsenate, 3–50	17–18	63	18	7	10
Check	19–20	61	18	17	58
Black-leaf "40", 1–100	21–22	69	18	0	0
Black-leaf "40", 1–250	23–24	76	18	7	8
Check	25–26	66	17	14	36
Lead arsenate, 3–50	27–28	54	18	7	12

Summary.

	Borers per Thousand Plants. Check.	Treated.	Per Cent of Control.
Black-leaf "40", 1–100.			
Rows 3–4	481	33	93.2
Rows 11–12	837	0	100.0
Rows 21–22	953	0	100.0
Average	757	11	97.7
Black-leaf "40", 1–250.	Check.	Treated.	Control.
Rows 5–6	995	131	86.9
Rows 15–16	837	43	94.9
Rows 23–24	547	53	90.4
Average	793	76	90.5
Lead Arsenate, 3–50.	Check.	Treated.	Control.
Rows 9–10	995	280	71.9
Rows 17–18	953	159	83.4
Rows 27–28	547	223	59.3
Average	832	221	73.5

The high degree of effectiveness exhibited by Black-leaf "40" at the above dilutions is undoubtedly due to its ovicidal action, since, as shown in Tables VI and VII, eggs were found in the plots treated with these materials in great excess of the numbers of larvae found later in the same plots. Substantiation of these observations has been sought by laboratory tests.

In these tests Black-leaf "40" at the strengths of 1–100 and 1–250 killed all the eggs which were not parasitized. It is interesting to observe that Black-leaf "40" does not destroy the egg parasites. Parasitized eggs included in the experiments yielded the adult wasps even when sprayed with the greatest strength of Black-leaf "40".

Recommendations. — The experiments here recorded indicate that almost complete relief from squash vine borer attack can be gained by four applications in July of Black-leaf "40" at a strength of 1 part in 100 parts of water, where the applications are made with a power sprayer. At the same strength, the material is over 90 per cent effective applied with a low-pressure, small-capacity outfit such as the compressed air sprayer. Applied at a strength of 1 part in 250 parts of water with the aid of a power sprayer, the material is also over 90 per cent effective. Lead arsenate gives too small a percentage of control to warrant its use.

On the basis of the experimental evidence, the following recommendations are made for the use of nicotine sulfate against the squash vine borer.

1. If a compressed air sprayer, knapsack pump, or other small capacity, low-pressure outfit is to be used, apply Black-leaf "40" at the rate of 1 part in 100 parts of water (1.3 fluid ounces per gallon) making 4 applications, one week apart in July.
2. If a machine capable of maintaining a pressure of 100 to 150 pounds per square inch is to be used, such as a good barrel pump or a power outfit, apply Black-leaf "40" at the rate of 1 part in 250 parts of water (3.2 pints in 100 gallons), making 4 applications, one week apart in July.
3. In spraying, be sure to drench all sides of the stem at the base. See that the leaf-stalks, and the under and upper surfaces of the leaves are thoroughly sprayed. When the plants have started to run, it is hardly necessary to spray the runners beyond three or four feet from the center of the hill.
4. Thorough spraying will largely free the sprayed fields from borers. Extermination may then be made complete by an examination of the plants in mid-August, cutting out those borers that have escaped the spray.

Spraying may be begun during the first week in July. It would be better, however, to examine a few plants closely every day during the last week in June, in order to discover the first eggs. The first spray should be applied not later than a week after eggs are discovered.

Cost of Treatments Versus expected Profits.

Nicotine sulfate is a relatively expensive insecticide, and any spraying operation using this material at a strength of one part in one hundred parts of water, or one part in two hundred fifty parts of water, is a costly treatment, which will be quite likely to prove impractical under certain conditions of squash culture (*i.e.,* where the squash vine borer is not a serious pest).

The expense of treatment can be materially reduced by following the suggestions given below.

1. To facilitate spraying squashes, plant in wide rows with the hills close together in the row. This type of planting allows free passage of the spray rig between the rows, and little time is lost in stepping from hill to hill.
2. Thin to the desired number of plants in each hill as early as is compatible with good farm practise. In this way, no spray material is wasted on plants that are later to be destroyed.
3. Equip the four-foot spray rod with a 45° angle disc nozzle with a small hole in the disc. This breaks the spray up into a very fine mist which covers quickly and thoroughly with a minimum of waste. In addition, equip the base of the spray rod with an automatic shutoff of the spring-grip type, so that the stream can be stopped instantly, thus allowing no wastage when passing between hills. This type of equipment can be used as well with a compressed air

sprayer or one of the knapsack type as with a barrel pump or power outfit. With a power outfit, regulate the pressure at from 100 to 150 pounds per square inch.

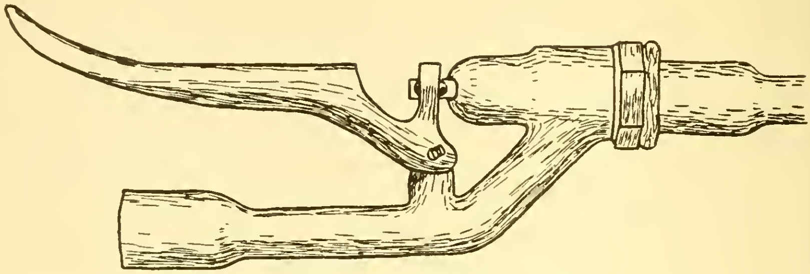

Fig. 2.— Automatic Shutoff Used in Experiments.

What may be called the average cost of spraying squashes has been figured from the records kept of the experimental work. The cost per acre can be seen to vary enormously, depending on the type of planting (hills per acre and plants per hill) and the stage of growth of the plants during the period of spraying. The figures given below are for four treatments, one week apart in July, applied to an acre containing one thousand squash plants of average growth.

1. Using compressed air or other small capacity, low-pressure outfit. Black-leaf "40", 1–100 recommended.

Dilute spray material, 150 gallons containing Black-leaf "40", 1.5 gallons at $12.50	$18 75
1 man, 24 hours at $.40	9 60
Total cost per acre of one thousand plants . . .	$26 55

2. Using a barrel pump or power outfit giving a fairly large delivery at 100 to 150 pounds pressure. Black-leaf "40", 1–250 recommended.

Dilute spray material, 275 gallons containing Black-leaf "40", 1.38 gallons at $12.50	$17 25
3 men — 1 horse, 6 hours at $1.55	9 30
Total cost per acre of one thousand plants . . .	$26 55

If the type of planting calls for more than 1,000 plants per acre, the cost of treatment is increased accordingly.

In an effort to discover the average increase in yield which might reasonably be expected from the use of the above treatment, and the relation of the value of this increase to the cost of treatment, letters were sent to prominent squash growers in various parts of the State. The replies received from those portions of the State where the borer is well established have been tabulated as follows:

Table VIII. — *Average Expected Increase in Yield of Winter Squashes.*

	Average Yield Per Acre (Tons).	Estimated Per Cent Increase from Borer-free Plants.
1 . .	–	100
2 . .	8.0	20
3 . .	12.0	5
4 . .	–	100
5 . .	8.5	10
6 . .	3.0	50
7 . .	8.5	30
8 . .	6.0	60
9 . .	10.0	10
10 . .	5.0	200
Average	7.6	59.5

The average increase thus estimated is 4.5 tons per acre. The average wholesale price of winter squashes during the sales-from-harvest period, September 1 to November 15, appears to be $.03 per pound or $60 per ton.[1] The value of the expected average increase of 4.5 tons per acre is therefore $270. Subtracting from this figure the cost of treatment leaves an estimated average net profit of from $241.65 to $243.45 per acre.

Summary.

The squash vine borer is a serious native enemy of winter squashes and related plants, for which no adequate remedy has previously been devised. The adult insect is on the wing during July, laying its tiny, reddish eggs upon the squash plants. The borers developing from these eggs cause the vines to droop and die by tunneling in the stem and girdling the plant, throwing masses of yellow frass out through holes in the stem, and causing the stem to rot. These larvae leave the vines in the fall, and spin cocoons in the soil. A number of cultural practises, such as fall plowing of infested fields, adequate fertilization to promote growth and to aid the secondary roots, and covering the runners with earth, have been recommended, as has the practise of cutting the borers from infested vines.

Experiments at this Station indicate that nicotine sulfate (Black-leaf "40"), at the strength of 1 part in 100 parts of water, kills over 97 per cent of the eggs, and, at the strength of 1 part in 250 parts of water, kills over 90 per cent of the eggs. Spraying should be done four times, at weekly intervals beginning the first week in July, using the stronger dosage with compressed air sprayers or similar machinery, and the weaker dosage with barrel pumps or power sprayers. When thoroughly done, spraying will largely eliminate borers from the fields. Complete extermination is then possible by cutting out the remaining borers during the middle of August.

The treatment is estimated to cost between $25. and $30. per thousand plants. Thus intensive methods of culture and careful, economical spraying must be the rule where the treatment is to be found practicable on a commercial scale. However, estimates of various squash growers regarding the expected increase in yield from borer-free plants indicate an average net profit of over $200. per acre from the use of this treatment. For the home gardener, to whom cost of production is a small item, it offers a ready means of successfully fighting this most troublesome enemy of squashes.

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[1] Computed from the Boston Produce Market Reports, 1920–1923.

INDEX.

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MASSACHUSETTS AGRICULTURAL COLLEGE

THIRTY-SEVENTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

REPORT OF THE DIRECTOR FOR THE FISCAL YEAR ENDING NOV. 30, 1924, PUBLISHED IN ACCORDANCE WITH THE PROVISIONS OF SECTION 32 OF CHAPTER 30 OF THE GENERAL LAWS

Being Parts III and IV of the Sixty-Second Annual Report of the Massachusetts Agricultural College

A Record of the Forty-Second Year from the Founding of the State Agricultural Experiment Station

DEPARTMENT OF EDUCATION
THE COMMONWEALTH OF MASSACHUSETTS

Publication of this Document approved by the Commission on Administration and Finance

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MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

Officers and Staff.

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REPORT OF THE DIRECTOR

Sidney B. Haskell.

SIGNIFICANT DEVELOPMENTS OF THE YEAR.

The best portrayal of the work of the year ending December 1, last, is in terms of service to the agricultural industries of the State, rather than in terms of the work of the several departments of the Experiment Station. In the following paragraphs, therefore, we have attempted to state the more important events of the year, classified as just indicated.

Animal Husbandry and Dairying.

The most important agricultural industry of the State is dairying, whether the basis of judgment be total value of product, area of land used in production, or numbers of men and women engaged in the industry. Contributions to this great industry are being rendered by four different departments of the Experiment Station. The Department of Plant and Animal Chemistry carries on studies in animal nutrition and on the properties of feeding stuffs. The Departments of

Agronomy and of Botany are associated in certain studies with reference to crops produced for feed for dairy animals; and the Department of Agricultural Economics is making a thoroughgoing study of our dairy market.

In the studies in animal nutrition two projects of great promise are: first, a study of substitutes for milk in the rearing of dairy calves; and second, the role of mineral constituents in the ration of dairy animals. In both cases the project bears on an economically significant problem. The relatively high price at which most milk produced in Massachusetts is sold makes its use for animals economically impracticable; whereas the poverty in lime of many Massachusetts soils makes the study of the role of mineral supplements essential. A progress report on the former project has been prepared for publication, and will shortly be printed as a Station bulletin.

In the agronomic field the most significant work now under way is study of the improvement of permanent pastures. The fact that such improvement is possible has been abundantly demonstrated. The next step must be to carry this work into the field to determine facts as they apply to different soil types and pasture conditions in the several geographical subdivisions of the State. This work is exceedingly important; for our New England dairymen, operating usually on rather poor pastures, often overgrown with brush and weeds, are finding increasing difficulty in competing with dairymen located where pastures are still in better condition.

Finally, the study recently completed on the New England dairy market, supported cooperatively by the College and the Bureau of Agricultural Economics of the United States Department of Agriculture, is of outstanding significance. For the first time facts relating to the marketing problem of the Massachusetts and New England dairy industry are brought together within the compass of a single volume. This work when published should be of immense value to the farmers of the State, as a basis for developing their marketing program.

Fruit Production.

Five different departments of the Experiment Station have cooperated this past year in furthering projects having to do with the production and marketing of Massachusetts fruit. These are the Departments of Pomology, Entomology, Botany, Plant and Animal Chemistry, and Agricultural Economics.

At the home station, results secured in experimental orchards show strikingly the superiority of the sod mulch with nitrate method of treatment over against cultivation of the producing orchard. As far as is known to us, the facts in this comparison have been established for the first time. The significance to our Massachusetts orchard industry lies in the fact that most of our orchards are located on hilly land, on which the advantage of the sod mulch system of management over against cultivation is obvious. The other work of the department, having to do particularly with methods of tree and soil management, is of increasing value with every passing year.

The work in nursery certification carried on under the supervision of the Station, but without cost to the State or drain on Experiment Station funds, and under the general auspices of the Massachusetts Fruit Growers' Association, has progressed rapidly during the year. The following table shows the progress of the work since it was initiated in 1921:

Year	Number of Trees Certified	Number of Trees Refused	Total	Number of Nurseries Examined
1921	2,580	267	2,847	1
1922	8,437	438	8,875	2
1923	65,910	905	66,815	3
1924	125,609	3,505	129,114	6

The success of the work thus far has abundantly justified the expense of the original research project.

In disease control studies the Department of Botany has brought to a successful close its investigation of apple scab control in the eastern part of the State. As a result of the work of the Station, apple scab is being controlled to a very large degree. The season's work also contributed to our knowledge of the relative values of dusts versus sprays in controlling apple diseases, and to the development of a treatment calendar for each general material. From Entomology also are several distinct contributions: first, in the study of the life history of the codling moth with particular reference to control other than that now secured through the calyx spray; secondly, through additions to our knowledge of the life history of scale insects; and finally, in a study of the possible injurious effect of Scalecide, a type of miscible oil. In the latter case, contrary to expectations, anticipated injury has not yet materialized.

Of significant service to the fruit growing interests of the State has been the work of the Department of Agricultural Economics in studies on the costs of marketing apples. A manuscript giving complete report on this subject was submitted just as the year was drawing to a close, and will be published in the fairly near future.

Vegetable Gardening.

The research work of the Market Garden Field Station was seriously disorganized during the year by the transfer of the plant from Lexington to Waltham. Little could be done in the way of following up regular projects from the Field Station. However, the work of the Department of Entomology on the control of the squash vine borer is a distinct and valuable contribution to the vegetable growing industry of the State. An insect causing serious economic loss, which formerly was practically uncontrollable, can now be controlled. By-products of this investigation were the discovery of the possible role of nicotine as an ovicide, and work initiated for the purpose of activating nicotine and in this way enabling our growers to secure better results at lower costs. The work of this same department on control of the destructive onion thrips, and of the Department of Botany on control of onion smut are both important contributions to our vegetable growing industry.

During the year a cooperative agreement was entered into with the Bureau of Plant Industry of the United States Department of Agriculture, having for its objective the determination of the relation between varieties of sweet corn and time of planting, to susceptibility to corn borer attack. The project contemplates at least three years of observation before the facts of the case may be considered as having been even indicated.

The Cranberry Industry.

The two outstanding services of the Cranberry Station have been its contribution to our scientific and practical knowledge regarding the control of injurious insects, and its work with reference to frost predicting. In the former activity the results of twelve years' work are being brought together in a single manuscript, which will probably be offered for publication during the coming year. In the latter, organization has been perfected through which frost warnings are distributed by telephone throughout the cranberry growing section, at the expense of the cranberry growers. It is also planned to get out a forecasting manual for the growers, through which, by the use of data taken on their own bogs, they may predict the probability of local frosts with at least a fair degree of accuracy.

Work was continued on the blueberry investigation started some years ago in cooperation with the United States Department of Agriculture. A system of pruning the bushes was inaugurated with gratifying results. The plantation is continually being improved and the crop of the past year was the largest which we have as yet secured.

Poultry Husbandry.

The main projects in poultry husbandry are continuing ones, and in no one year can results be said to be particularly outstanding. Gains already made in breeding for high production were maintained; there was a decrease in mortality in the laying flock; through the granting of additional clerical help, much of the material collected through the past eleven years has been analyzed and submitted for publication. The new equipment granted by the State has been of immense assistance in enabling the Station to carry on this work in an effective and thoroughgoing way.

The cooperation of the Department of Veterinary Science in carrying forward research projects with reference to diseases of our domestic poultry and in making diagnoses showing the cause of death have been of great assistance. Likewise the work being done by this department in the administration of the law to reduce or eliminate certain poultry diseases is of very definite service to the Massachusetts poultry industry. Through the work thus carried on it will shortly be possible for Massachusetts poultrymen to purchase hatching stock and day-old chicks from known sources practically disease free. The work done under this law has been increasing annually. The record of number of birds tested and percentage of infection found in the testing work of the last four seasons is as follows:

Year.	Number of Birds Tested.	Percentage of Infection Found.
1920-21	24,718	12.50
1921-22	29,875	12.65
1922-23	33,602	7.60
1923-24	59,635	6.53

The number of disease-free flocks found increased from 25 in 1920-21 to 38 in 1923-24.

Soil Fertility and Plant Growth.

Many different departments of the Experiment Station contribute to work on this subject. Basic studies are being made by the Departments of Plant and Animal Chemistry and of Microbiology; the Department of Botany is carrying on a study relative to effective control of light, particularly in greenhouse culture; and the Department of Agronomy is initiating field experiments on a large scale. The new work started during the year includes a study of crop effect and rotation problems with reference to the onion and tobacco industries of the Valley. Of necessity work such as this must be carried on in a long-time project.

Tobacco Growing.

The newly organized research work on tobacco is just completing its second season. An outstanding result is indication of the depressing effect of timothy cover crop on yield and quality of the tobacco crop. This result is contrary to prevalent ideas on the subject, but is confirmed by three years' work carried on on the Tillson Farm. It warrants further investigation. Most of this newly organized field work is under the supervision of the Department of Agronomy.

The Department of Botany completed its work on wildfire during the year. The seed-bed treatment developed at this Station in cooperation with the Connecticut Station has proven to be at least fairly effective in controlling this most destructive disease. The possibility of extensive field infestation depends mainly on weather conditions. No successful field control has yet been developed; and in view of the uncertainties as to its need would probably not be widely utilized by growers even if developed.

Continued work of the Department of Botany at Tillson Farm has shown the depressing effect of lime on tobacco, particularly in a field infested with black root-rot. The timothy cover crop failed to remedy this condition, despite the fact that it was supposed to be effective in this way.

The new equipment granted by the Legislature of 1923-24 has enabled the Station to carry on this comparatively new work much more efficiently than could otherwise have been possible.

CATALOG OF EXPERIMENT STATION PROJECTS.

The list of projects in force as of January 1, 1925, and the industries of the State to which these projects apply, together with names of project leaders, are shown in the following table:

CATALOG OF ACTIVE PROJECTS, JANUARY 1, 1925.

Project Number, Title and Leader	Fruit Production	Tobacco Growing	Vegetable Gardening	Crop Protection	Soil Fertility and Plant Growth	Animal Husbandry	Poultry Husbandry	Agricultural Economics	General Field Crops
	Service of Project								
Agricultural Economics									
7 Boston food supply study. Professor McFall	...	...	...	...	...	...	...	*	...
8 Study of the costs of marketing apples. Assistant Professor Jefferson	*	...	...	...	...	...	...	*	...
Agronomy									
1 Investigation of the value of Hubam or annual sweet clover as compared to the biennial clovers. Professor Michels	...	...	...	...	*	*	...	...	*
2 Tobacco cropping system investigation. Assistant Professor J. P. Jones and Professor Anderson	...	*	...	...	*	...	...	...	...
3 Soil fertility studies on the South Soil Test. Assistant Professor J. P. Jones	...	...	...	...	*	...	...	...	...
4 Study of residual effects of fertilizers. Assistant Professor J. P. Jones	...	...	...	...	*	...	...	...	...
5 A field study of tobacco production in Massachusetts. Professor Beaumont	...	*	...	...	...	...	...	...	...
Botany									
1 Optimum conditions of light for plant resposse. Assistant Professor Clark	...	...	*	...	*	...	...	...	...
3 Tobacco investigations. (A study of soil reactions as a means for control of root rots of tobacco; also study of effects of soil reaction alone on the growth and development of tobacco.) Professor Osmun and Professor Anderson	...	*	...	*	*	...	...	...	...
5 Experimental spraying for control of cucumber mildew under glass. Assistant Professor Doran	...	...	*	*	...	...	...	...	...
6 Investigation of onion diseases. Professor Osmun and Professor Anderson	...	...	*	*	...	...	...	...	...
9 Investigation of a carrot blight. Assistant Professor Doran	...	...	*	*	...	...	...	...	...
13 Ecological study of pasture vegetation. Professor Osmun and Director Haskell	...	...	...	...	*	*	...	...	...
14 Investigation on control of tobacco wildfire. Professor Anderson	...	*	...	*	...	...	...	...	...
16 Relation of soil character to occurrence of onion smut. Professor Anderson	...	...	*	*	*	...	...	...	...
17 Study of the apple black rot control and the dusting schedule. Assistant Professor Doran.	*	...	...	*	...	...	...	...	...
18 Control of diseases of greenhouse vegetables. Assistant Professor Doran	...	...	*	*	...	...	...	...	...
Plant and Animal Chemistry									
4 Record of the Station herd. Professor Lindsey	...	...	...	...	...	*	...	...	...
14 A study of the availability of soil potash, with the object of developing a system of diagnosis for soils of the State. Professor Morse	...	...	...	...	*	...	...	...	...
17 Investigation of the role of physical condition in artificial feeds for calves. Assistant Professor Archibald	...	...	...	...	...	*	...	...	...
19 The value of inorganic calcium phosphate in the promotion of growth and milk production. Professor Lindsey and Assistant Professor Archibald	...	...	...	...	...	*	...	...	...

CATALOG OF ACTIVE PROJECTS, JANUARY 1, 1925.—*Continued.*

Project Number, Title and Leader	Service of Project: Fruit Production	Tobacco Growing	Vegetable Gardening	Crop Protection	Soil Fertility and Plant Growth	Animal Husbandry	Poultry Husbandry	Agricultural Economics	General Field Crops
Plant and Animal Chemistry—Continued									
20 A study of the fundamental factors affecting the suspension, adhesiveness, toxicity and general efficiency of copper fungicides. Professor Holland and Mr. Gilligan	...	...	...	*	...	...	...	...	...
21 Study of nitrogen fixation in the presence of, or as the result of, growth of legumes versus non-legumes under certain defined agronomic conditions. Professor Morse	...	...	...	...	*	...	...	...	...
22 Determining the nutritive value of hydrolized sawdust. Professor Lindsey and Assistant Professor Archibald	...	...	...	...	...	*	...	...	...
23 Study of the coloring matter in cranberries. Professor Morse and Professor Chenoweth	*	...	...	...	...	...	...	...	...
Cranberry Station									
1 Injurious and beneficial insects affecting the cranberry. Professor Franklin	*	...	...	*	...	...	...	...	...
2 Cranberry disease work. (Co-operative, U. S. D. A.) Professor Franklin	*	...	...	*	...	...	...	...	...
3 Weather observations with reference to frost prediction. (Co-operative, U. S. D. A.) Professor Franklin	*	...	...	...	...	...	...	...	...
5 Blueberry investigations. (Co-operative, U. S. D. A.) Professor Franklin	*	...	...	...	...	...	...	...	...
6 Cranberry bud development investigation. Mr. Lacroix	*	...	...	...	...	...	...	...	...
Entomology									
4 Control of the squash vine borer. Assistant Professor Worthley	...	...	*	*	...	...	...	...	...
5 Control of the squash bug. Assistant Professor Worthley	...	...	*	*	...	...	...	...	...
9 Number of generations of codling moth in Massachusetts and whether spraying for a second generation is advisable. Assistant Professor Bourne	*	...	...	*	...	...	...	...	...
10 Dates of hatching of scale insects and when to spray for them. Assistant Professor Bourne	*	...	...	*	...	...	...	...	...
12 Determination of best strength of lime-sulfur. Assistant Professor Bourne	*	...	...	*	...	...	...	...	...
13 Study of possible injurious effects of Scalecide on trees. Assistant Professor Bourne	*	...	...	*	...	...	...	...	...
14 Does spraying orchards kill bees? Assistant Professor Worthley	*	...	...	...	...	...	...	...	...
15 A study of the factors influencing the efficiency of nicotine in dusts and spray mixtures. Assistant Professor Worthley	*	...	*	*	...	...	...	...	...
16 Investigation of materials which promise value in insect control. Assistant Professor Bourne	*	*	*	*	...	...	...	...	...
17 Control of onion thrips. Assistant Professor Bourne	...	...	*	*	...	...	...	...	...
Farm Management									
1 Investigation of farm organization and labor efficiency on Massachusetts farms. Professor Foord	...	...	...	...	...	*	...	*	*
2 A study to determine the competitive status of the more important agricultural enterprises of Massachusetts. Assistant Professor Abell	...	...	...	...	...	*	...	*	*

Market Garden Field Station									
7 Study of the factors influencing heading of greenhouse lettuce. Assistant Professor Tiedjens	...	...	*	...	...	...	...	...	...
8 Study of conditions affecting the production and vegetative propagation of Washington asparagus. Assistant Professor Tiedjens	...	...	*	...	...	...	...	...	...
9 Investigation of susceptibility to corn borer attack of varieties of sweet corn as influenced by time of planting. (Co-operative U. S. D. A.) Mr. Dempsey	...	...	*	*	...	...	...	...	...
10 Variety improvement through seed and root selection:									
a. The improvement of beets (*Beta vulgaris*) through selection of roots and seed production.									
b. The improvement of carrots (*Daucus carota*) through selection of roots and seed production.									
Assistant Professor Tiedjens	...	...	*	...	...	...	...	...	...
Microbiology									
2 Soil fertility as influenced by micro-organisms in their relation to the presence and disappearance of organic matter. Assistant Professor Werkman	...	...	...	...	*	...	...	...	...
Pomology									
1 Study of interrelation of stock and scion in apples. Professor Shaw and Mr. Bailey	*	...	...	...	...	...	...	...	...
2 Study of the tree characters of fruit varieties. Professor Shaw and Mr. A. P. French	*	...	...	...	...	...	...	...	...
3 The genetic composition of peaches. Professor Shaw and Mr. Bailey	*	...	...	...	...	...	...	...	...
5 Comparison of cultivation and sod mulch in a bearing orchard. Professor Shaw	*	...	...	...	*	...	...	...	...
6 Comparison of clover sod and grass in sod mulch orchard. Professor Shaw	*	...	...	...	*	...	...	...	...
7 Test of fertilizers in a sod mulch orchard. Professor Shaw	*	...	...	...	*	...	...	...	...
8 Test of cover crops for apple orchards. Professor Shaw	*	...	...	...	*	...	...	...	...
9 Testing methods of pruning:									
a. An experiment in pruning apples									
b. Test of pruning methods on the Northern Spy and other varieties. Professor Shaw	*	...	...	...	...	...	...	...	...
12 Apple variety fruit spur study. Professor Shaw, Assistant Professor Drain and Assistant Professor C. P. Jones	*	...	...	...	...	...	...	...	...
13 Study of varieties of tree fruits. Professor Shaw and Mr. Raleigh	*	...	...	...	...	...	...	...	...
14 Study of the relation of winter injury of brambles to differential fertilization with potash salts. Professor Shaw, Assistant Professor C. P. Jones and Assistant Professor Clark	*	...	...	...	*	...	...	...	...
15 Orchard fertilization. Professor Shaw	*	...	...	...	*	...	...	...	...
16 Test of different amounts of nitrate of soda. Professor Shaw and Assistant Professor Drain	*	...	...	...	*	...	...	...	...
17 A study of the cultivation of the high bush cranberry (*Viburnum opulus*). Professor Shaw	*	...	...	...	...	...	...	...	...
18 Comparison of cultivation and heavy mulching for apples and pears. Professor Shaw	*	...	...	...	*	...	...	...	...
19 A study of the effects of fertilizer limitation on fruit plants. Professor Shaw	*	...	...	...	*	...	...	...	...
20 Test of fertilizers for pears. Professor Shaw	*	...	...	...	*	...	...	...	...
21 Study of fruit harvesting and storage. Mr. Raleigh	*	...	...	...	...	...	...	...	...
Poultry Husbandry									
1 Broodiness in poultry. Professor Hays	...	...	...	...	...	...	*	...	...
2 Breeding poultry for egg production. Professor Hays	...	...	...	...	...	...	*	...	...
3 A genetic study of Rhode Island Red color. Professor Hays	...	...	...	...	...	...	*	...	...
4 Determination of genetic laws governing results in inbreeding of poultry. Professor Hays	...	...	...	...	...	...	*	...	...
5 The hatchability of eggs. Professor Hays	...	...	...	...	...	...	*	...	...

CONTROL SERVICE.

In addition to carrying on investigations, the Experiment Station is required to perform certain control and regulative functions, as follows:

1. Inspection of commercial fertilizers.
2. Inspection of commercial feed stuffs.
3. Inspection of machinery and glassware used in the testing of dairy products.
4. Elimination of white diarrhoea in poultry.

Reports on all except the third of these are published separately, respectively in control bulletins Nos. 29 and 30, 28, and 27 of the Experiment Station.

The work of the year under the law providing for the inspection of dairy glassware is summarized below:

Certificates of proficiency awarded	42
Machines and apparatus inspected by Mr. Howard, November and December, 1924	117 places
Machines condemned	3
Minor repairs ordered on machines	14
Necessary re-inspections	4
Glassware calibrated	5,092 pieces
Glassware condemned	11 pieces

GENERAL ANALYTICAL AND DIAGNOSTIC WORK.

Since its very beginning the Experiment Station has been called upon to perform a large amount of miscellaneous diagnostic and analytical work. Diseased plants, specimens of insect injury, dead birds, and other materials are sent in for diagnosis. Soils, feeds, fertilizers, insecticides and fungicides, samples of milk and cream, the alimentary tract of animals supposedly poisoned, and many other things are submitted for analysis. Formerly this work was done free of charge. There is no doubt that this policy of making free diagnosis and analysis had great educational value. In recent years, however, the burden on the research forces of the Experiment Station has been increasingly great. This, together with the significant fact that many samples are submitted out of mere curiosity rather than on the basis of definite need for service, led to the imposition of a fee for performing the greater part of this work, exceptions being diagnoses of plant disease and insect injury. As a result, there has been a significant decrease in the amount of service requested. There has been criticism of the practice of making charges for this miscellaneous work. Many farmers and farm organizations feel that the Experiment Station is not now giving the service which it formerly did. It should be remembered, however, that because of reducing its activities in this direction the Station is able to do more work in the study of problems of vital significance to Massachusetts agriculture. Other than as above mentioned, this phase of the year's work does not differ markedly from that of other years.

ADVANCED REGISTRY TESTING OF PURE BRED COWS.

This work was started in 1902 on a very small scale. The work is operated on the basis of a revolving fund, and has no financial support from the State. Up to three years ago, a rather general and consistent increase was shown year by year. Owing probably to the current depression in agriculture with consequent diminished demand for pure bred stock, tne work this past year was somewhat less than in the immediately preceding years. The following table shows the more important operations of the period in question:

SUMMARY OF TWO-DAY WORK, DECEMBER, 1923, THROUGH NOVEMBER, 1924.

Number of Cows Tested.

Month	Number of Supervisors Whole or Part Time	Guernsey	Jersey	Ayrshire	Shorthorn	Holstein	Totals
December	9	214	102	70	22	97	505
January	10	250	91	71	21	89	522
February	13	251	98	79	17	75	520
March	9	251	94	85	14	92	536
April	11	252	93	101	13	93	552
May	10	259	91	102	13	97	561
June	10	237	85	95	11	80	508
July	10	243	76	99	11	69	498
August	11	262	89	97	10	61	519
September	11	247	101	95	9	64	516
October	10	249	101	101	6	66	523
November	10	248	90	92	11	68	509
Totals	—	2963	1111	1087	157	951	6269

Number of Herds Visited.

Month	Number of Supervisors Whole or Part Time	Guernsey	Jersey	Ayrshire	Shorthorn	Holstein	Totals
December	9	35	15	7	2	10	69
January	10	38	13	8	2	11	72
February	13	40	13	9	2	13	77
March	9	41	12	7	2	10	72
April	11	39	11	10	1	11	72
May	10	42	11	8	1	13	75
June	10	41	12	9	1	13	76
July	10	41	13	8	1	11	74
August	11	43	12	7	1	11	74
September	11	40	13	8	1	11	73
October	10	38	14	7	1	11	71
November	10	38	13	7	1	12	71
Totals	—	476	152	95	16	137	876

The above compares with a total of 6270 tests for the year ending December 1, 1923. The number of cows on yearly test decreased in one year from 520 to 509; the number of farms visited remained practically the same.

HOLSTEINS. There were 10 men employed for seven-day work, 19 farms visited, and 86 reports turned in.

CHANGES IN STAFF

The changes in staff during the year are shown in the following table:

	Resignations	*Position*	*Appointments*	
		Analyst, Feed and Fertilizer Control	George B. Dalrymple	Jan. 1.
Jan. 15.	Harold F. Tompson	In Charge, Market Garden Field Station		
Mar. 31.	Charles O. Dunbar	Investigator in Chemistry	Gerald M. Gilligan	July 1.
June 30.	Robert L. Coffin	Investigator in Agriculture		
Aug. 1.	Anna M. Wallace	Curator in Botany	Gladys I. Miner (transfer)	Aug. 1.
		Technical Assistant, Department of Veterinary Science	James J. McDermott	Aug. 1
Sept. 1.	Arao Itano	Assistant Professor in Microbiology	Chester H. Werkman	Sept. 1.
Oct. 31.	Hazel Parker	Analyst, Poultry Disease Elimination	Alice Norcross	Oct. 27.
Nov. 1.	O. S. Flint	Analyst Poultry Disease Elimination (new title, Specialist)	Patrick E. Bransfield	Nov. 1.
Nov. 12.	Henry S. Green (retired)	Librarian	Basil B. Wood	Nov. 12.
Nov. 30.	Harold E. Wilson	Laboratory Assistant in Pomology		
		Investigator in Botany	Theodore T. Ayers	Nov. 16.
		Microscopist, Feed Control	F. A. McLaughlin	

PUBLICATIONS OF THE YEAR.

Annual Report.

Thirty-sixth annual report with index.

Bulletins.

No. 219. Combating Apple Scab, by William L. Doran and A. Vincent Osmun.
No. 220. Correlation Studies on Winter Fecundity, by F. A. Hays, Ruby Sanborn and L. L. James.

Bulletins, Technical Series.

No. 6. The Inheritance of Fertility and Hatchability in Poultry, by F. A. Hays and Ruby Sanborn.

Bulletins, Popular Edition.

No. 6. The Inheritance of Fertility and Hatchability in Poultry, by F. A. Hays and Ruby Sanborn.

Bulletins, Control Series.

No. 27. Control of Bacillary White Diarrhoea, 1923-24, by G. E. Gage and O. S. Flint.
No. 28. Inspection of Commercial Feedstuffs, by Philip H. Smith and Frank J. Kokoski.
No. 29. Inspection of Commercial Fertilizers, by H. D. Haskins, L. S. Walker and G. B. Dalrymple.
No. 30. Inspection of Lime Products used in Agriculture, by H. D. Haskins, L. S. Walker and G. B. Dalrymple.

Meteorological Reports.

Nos. 421-432, inclusive.

Scientific Contributions.

No. 19. The Biology of Trichopoda Pennipes Fab., a Parasite of the Common Squash Bug, by Harlan N. Worthley. In Psyche, Vol. 31, Nos. 1 and 2, February and April, 1924.
No. 22. Oxidase Activity in Varieties of Apples, by Brooks D. Drain. In Proceedings of the American Society for Horticultural Science, 1923.
No. 23. The Effect of Sodium Hydroxide on the Composition, Digestibility and Feeding Value of Grain Hulls and Other Fibrous Material, by J. G. Archibald. In Jour. Agr. Research, Vol. XXVII, No. 5, February 2, 1924.
No. 25. The Loss of Calcium Carbonate in Drainage Waters as Affected by Different Chemical Fertilizers, by F. W. Morse. In Soil Science, Vol. XVII, No. 3, March, 1924.
No. 26. The Problem of Pastures in Semi-Waste Lands of New England, by S. B. Haskell. In Jour. Amer. Soc. Agron., Vol. 16, No. 3, March, 1924.
No. 27. Overwintering of Tobacco Wildfire in New England, by P. J. Anderson. In Phytopathology, Vol. XIV, No. 3, March, 1924.
No. 28. Adsorption and Absorption of Bases by Soils, by C. P. Jones. In Soil Science, Vol. XVII, No. 3, March, 1924.
No. 29. The Higher Cost of Food in Massachusetts, by R. J. McFall. In Quarterly Publication, American Statistical Association, Sept., 1924.
No. 31. Stimulation of Plant Growth by Means of Electric Lighting, by Victor A. Tiedjens. A paper presented before the Eighteenth Annual Convention of the Illuminating Engineering Society, October, 1924.

METEOROLOGICAL OBSERVATION.

Department of Meteorology.

PROF. J. E. OSTRANDER, HEAD

ANNUAL SUMMARY FOR 1925.

PRESSURE (IN INCHES)

Maximum reduced to freezing	30.44 Jan. 2nd, 9 A.
Minimum reduced to freezing	28.88, Dec. 13th, 7 P.
Maximum reduced to freezing and sea-level	30.77, Jan. 2nd, 9 A.
Minimum reduced to freezing and sea-level	29.19, Dec. 13th, 7 P.
Mean semi-daily reduced to freezing and sea-level	30.010
Annual range	1.58

*AIR TEMPERATURE (IN DEGREES FAHR.)

Highest ....97.0, Aug. 7th, 1 :00 P.
Lowest ....-8.0, Jan. 27th 6 :00 A. Jan. 28th, 6 :00 A.
Mean hourly 46.6
Mean of means of max. and min 46.7
Mean sensible (wet bulb) 41.0
Annual range 105.0
Highest mean daily ....78.8, Aug. 7th
Lowest mean daily ....-0.3, Jan. 27th.
Mean maximum 57.8
Mean minimum 35.7
Mean daily range 22.1
Greatest daily range..43.5, Oct. 23rd., 24th.
Least daily range ....3.0, Feb. 5th.

HUMIDITY

Mean dew point 36.4
Mean force of vapor 362
Mean relative humidity 73.9

WIND

Prevailing direction ....West

Summary

North ....10 per cent
North Northeast .... 9 per cent
South .... 9 per cent
South Southwest ....19 per cent
Northwest .... 9 per cent
Other directions ....41 per cent
Total movement ....53.855 m
Greatest daily movement..553m., Mar. 12th
Least daily movement.....22 m., Dec. 12th
Mean daily movement..............147 m
Mean hourly velocity ....6.1 m
Maximum pressure per square foot, 23.5 lbs., =69 m. per hour, Apr. 14th, 3 P., N. W.
Maximum velocity for 5 minutes, 42 m. per hour, July 13th, 1 P., S. W.

*Temperature in ground shelter.

PRECIPITATION (IN INCHES)

Total precipitation, rain or melted snow 30.96
Snow total in inches 45.0
Number of days on which .01 or more rain or melted snow fell 96

WEATHER

Mean cloudiness observed ......41 per cent
Total cloudiness recorded by Sun Thermometer ......1637 hrs.=37 per cent.
Number of clear days 141
Number of fair days 145
Number of cloudy days 80

BRIGHT SUNSHINE

Number of hours recorded, 2838 hrs.=63 per cent.

DATES OF FROSTS

Last ....May 2d
First ....Sept. 24th

DATES OF SNOW

Last ....April 8th
First ....Nov. 9th
Total days of sleighing 54

GALES OF 50 OR MORE MILES PER HOUR

Jan. 1st, 58m, N. W.; 11th, 67m, S.S.E.; 21st, 63m, N.W.; 26th, 56m, N.W.

Mar. 11th, 57m, N.E.; 12th, 63m, N.N.E.; 28th, 59m, W.N.W.

Apr. 14th, 69m, N.W.; 51m, 24th, N.N.W.

May 18th, 52m, S.

July 13th, 56m, S.W.

Nov. 17th, 55m, N.N.W.

REPORT OF THE TREASURER

F. C. KENNEY

United States Appropriation, 1923-24.

Dr.	Hatch Fund.	Adams Fund.
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1924, under acts of Congress approved March 2, 1887 and March 16, 1906	$15,000.00	$15,000.00

Cr.

Adams:		
By salaries	$15,000.00	
Hatch:		
By salaries	$15,000.00	

State Appropriations, 1923-24.

Cash balance brought forward from last fiscal year	$119,790.75
Cash received from State Treasurer	40,733.93
fees	9,710.88
sales	393.54
miscellaneous	
	$170,629.10

Cash paid for salaries	$73,870.99
labor	19,015.27
stationery and office supplies	666.31
scientific supplies	2,770.72
feed	1,254.71
seeds, plants and sundry supplies	3,151.64
fertilizers	1,502.08
communication service	1,021.94
traveling expenses	5,929.08
transportation of things	862.98
publications	2,262.23
heat, light, water and power	1,240.26
furniture and fixtures	767.36
library	1,163.99
scientific equipment	633.49
livestock	—1,606.16
tools and machinery	2,264.09
buildings and land	3,001.98
contingent	17.79
remitted to State Treasurer	50,838.35
	$170,629.10

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 219 JANUARY, 1924

COMBATING APPLE SCAB

Spraying and Dusting Experiments in 1923 with Summary of Three Years' Results

By WILLIAM L. DORAN and A. VINCENT OSMUN

Recently completed studies on apple scab and its control show that development of this disease may be prevented through the use of a number of different materials — lime-sulfur, dry lime-sulfur, or copper sprays followed by lime-sulfur, may be effectively used, as also dusts of various kinds. Scab development is governed largely by weather conditions; possibility of successful control, by the proper timing of protective treatment and efficiency in the actual spraying and dusting work. These facts are brought out in this bulletin, which is the final report of a three-year investigation. Tabulated results of the work carried on in 1923 are presented, likewise a summarization of all data collected during the course of the study.

Publication of this Document approved by the Commission on Administration and Finance

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

COMBATING APPLE SCAB.

SPRAYING AND DUSTING EXPERIMENTS IN 1923[1] WITH SUMMARY OF THREE YEARS' RESULTS.

By William L. Doran and A. Vincent Osmun.

Introduction.

Scab has long been a disease to reckon with in the apple orchards of Massachusetts, but not until the advent and extensive planting of the McIntosh, a variety particularly susceptible to attack by the scab fungus, did it become a menace of large proportions. As more and more of the McIntosh orchards came into bearing, an increasing number of growers experienced difficulty in controlling the disease and losses became so large as to seriously threaten the orchard industry. Finally, in 1920, appeal was made to the Station by the growers, and in the fall of that year the Station entered into a cooperative agreement with the Nashoba Fruit Producers' Association under which experiments on the control of scab were planned and undertaken by the Department of Botany.

The results of the spraying and dusting experiments of the first two seasons already have been reported by Krout (1) (2).[2] The present report is on the work of 1923, together with such references to the work in Massachusetts in 1922 and 1921 as will assist in making points clear. The results of the three years' experiments are summarized in Table III (page 17). Other references in this report are for the most part to spraying and dusting experiments conducted within the last two years, especially in the northeastern states.

The general objectives of the investigations in 1923 were to secure more light on the following questions in regard to the control of apple scab:

1. What is the effect of the addition to the spray schedule of a prepink application?
2. How does dry lime-sulfur compare with liquid lime-sulfur in fungicidal efficiency?
3. What is the ratio of dry lime-sulfur to water, at which this fungicide is dependable?
4. What is the effect of the addition of calcium caseinate spreader to the fungicide when applied as a dust and as a spray?
5. How does a spray schedule consisting of lime-sulfur throughout the season compare with a schedule in which Bordeaux mixture is substituted for the application or applications before flowering?
6. How does Atomic Sulphur compare with dry and liquid lime-sulfur for the control of scab?
7. Does the addition of lime or of calcium caseinate to the combination lime-sulfur-lead arsenate spray improve the mixture?
8. For the control of apple scab, what is the fungicidal efficiency of sulfur dust? What is the effect of substituting a copper-lime-arsenic dust for the prepink and pink applications?

The rainy summer of 1922 was especially suitable for the experimental work, because of the abundant infection on unsprayed trees. The summer of 1923 was much drier; there was a rainfall of only 7.29 inches in May, June and July, as compared with 20.14 inches in the same period in 1922. This naturally resulted in less infection, but there was sufficient infection on unsprayed trees in every case but one to justify the drawing of conclusions as to the relative values of the several treatments applied.

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[1] The experiments here described were conducted in the orchards of Harry L. Knights of Littleton, H. L. Frost of Littleton, Stephen W. Sabine of Groton, and A. N. Stowe of Hudson. The superintendents of these orchards are Roy C. Wilbur of the Frost Farm, John J. Collins of the Stowe Farm, and J. W. Ames of the Knights Farm. Acknowledgment is due these men for placing their orchards at the disposal of the Experiment Station, and for cooperating in the investigations. Acknowledgment is also due to the Nashoba Fruit Producers' Association for their cooperation.

[2] Numbers in parenthesis refer to literature cited, see page 13.

The results, as given in tables I and II, and in the text, are expressed in percentage of scabby apples present in the check and in each sprayed or dusted plot. In interpreting the results of any spraying or dusting experiments, the percentage of infection in the check is of primary importance. If this is low, the data are correspondingly of less value, since it cannot be said that the fungicidal treatment was put to a real test. The percentage of infection on the unsprayed trees in the Sabine orchard where some of the spraying experiments were conducted was so low that the results in that orchard are not considered in this report.

Methods and Materials Used.

The trees used for these experiments were of the McIntosh variety. Each orchard was divided in such a way that the check plot was as nearly as possible like the treated plots in every way except fungicidal treatment received. The check plots received no treatment for scab control, but did receive a calyx application with insecticides only. All check plots were surrounded by or contiguous to the treated plots. In dividing an orchard for a dusting experiment, it is difficult to so locate the check plot that it will not receive some dust as the dust drifts through the orchard. If it were possible to prevent this entirely, the percentage of scabby fruits on the dust checks would probably be larger.

The following treatments were tested or compared:

1. Dry lime-sulfur 3–50 for the pink, calyx and one later application.
2. Dry lime-sulfur 3–50 with calcium caseinate added for the pink, calyx, and one later application.
3. Dry lime-sulfur 2–50 for the pink, calyx and one later application.
4. Dry lime-sulfur 4–50 for the pink, calyx and one later application.
5. Dry lime-sulfur 3–50 for the prepink, pink, calyx and one later application.
6. Bordeaux mixture 3–10–50 for the prepink and pink applications followed by liquid lime-sulfur 1–50 for the calyx and one later application.
7. Bordeaux mixture 3–10–50 for the pink application followed by liquid lime-sulfur 1–50 for the calyx and one later application.
8. Atomic Sulphur for the pink, calyx and one later application.
9. Liquid lime-sulfur for the pink, calyx and one later application.
10. Bordeaux mixture 3–10–50 for the pink application followed by dry lime-sulfur 4–50 for the calyx, and one later application.
11. Liquid lime-sulfur with lime added for the pink, calyx and one later application.
12. Copper dust for the prepink and pink applications followed by sulfur dust for the calyx and two later applications.
13. Sulfur dust for the prepink, pink, calyx and two later applications.
14. Sulfur dust with calcium caseinate added for the prepink, pink, calyx and two later applications.

In one orchard, the dusting schedule began with the pink instead of the prepink application.

An examination of Tables I and II will show which treatment each of the thirty-five plots received, including the fungicide and its dilution used at each application, together with the date of each application.

Rates of Application.

About four gallons of spray per tree per application were used for trees twelve to fifteen years old. About one and one-half pounds of dust per tree of this size were used at each application.

Liquid lime-sulfur was used at the rate of one gallon in fifty gallons of water. Dry lime-sulfur was used at the rate of two, three or four pounds in fifty gallons; this is expressed in abbreviated form in the text as dry lime-sulfur 2–50, 3–50, etc. It was not found necessary to add water to this material before placing it in the spray tank; in fact, to do so resulted in increased lumpiness. A more satisfactory method is to sift this material into the nearly filled spray tank with the agitator running.

Calcium caseinate spreader (which is sold under various trade names, such as Kayso, Spracein, etc.) was used at the rate of 1 pound in 100 gallons, or it was added to sulfur dust so that the dust mixture would contain 5 per cent calcium caseinate.

The copper dust (used only before the flower buds opened) contained 11 per cent dehydrated copper sulfate. The sulfur dust contained 92 per cent sulfur and 8 per cent inert ingredients. When it was desired to apply an arsenical also to dusted trees, a dust containing sulfur and lead arsenate in the ratio 90:10 or 85:15 was used.

Arsenate of lead and nicotine sulfate (Black Leaf 40) in the usual proportions were added to the sprays for each application, except for the fourth summer spray when nicotine sulfate was omitted.

The spraying was done with power sprayers with about 200 pounds pressure, using Pilot rods or regular spray rods.

The dusting was done with power dusters, either Perfect or Niagara. The duster was driven along both sides of each row of trees, so that dust was applied to each tree from opposite sides. Dusting is not a pleasant operation, because of the pain caused by the sulfur getting into the eyes. Goggles, although somewhat of a nuisance, appear to be a necessity when much dusting is to be done. Some difficulty was experienced in thoroughly dusting the tops of tall trees. Krout (2) and Childs (3) both mention this. The tops of taller trees cannot be thoroughly coated with dust when any wind is blowing. The dusting was done early in the morning, beginning about five o'clock in most cases. The foliage was not always wet, however. There is no experimental evidence of the necessity of dusting only when the foliage is wet.

Friez hygro-thermographs and rain gauges were maintained in the Frost and Sabine orchards. The data on rainfall secured in the orchards is not considered complete, and the precipitation data given in this report are from the Concord observer for the United States Weather Bureau as recorded in Climatological Data for New England.

Because of the large yield of fruit, it was manifestly impossible to examine every apple in a plot at picking time. For this reason, four representative trees were selected from each plot for examination of the fruit. About 150,000 apples were examined. Since much of the infection was late, most of the scabby apples even on the check plots were marketable. Apples designated as scabby in the data include both marketable-scabby, and unmarketable scabby.

Effect of the Addition of a Prepink Application to the Schedule.

The delayed dormant application is made just as the buds are breaking or when the first tips of green show. The pink application is usually understood to mean that which is applied as soon as the blossom buds separate in the clusters, while they show pink, but before they begin to open. Any application of a summer-strength fungicide made between the delayed dormant and the pink applications may be spoken of as a prepink application. The interval between the prepink and pink applications, which will depend upon the weather and consequent rapidity of growth, is bound to be short. In the case of large orchards, there is likely to be no interval, so that an application begun as a prepink will end as a pink, as regards the development of the flower buds. The first summer application, either prepink or pink, should be made when the tree is first in danger of infection, that is, before the first discharge of winter spores from the dead leaves beneath the tree. It is probable that many of the failures to control apple scab in Massachusetts have occurred because this first summer spray was too long delayed. The prepink cannot be regarded as a substitute for the pink application. If a prepink application is necessary, a pink is none the less so, because new growth has exposed new and unprotected leaf surface to the danger of infection.

The beginning of the period when the tree is in danger of infection can be determined only by "trapping" the winter spores on adhesive-coated glass slides inverted over the dead leaves and microscopic examination of the slides, after the method described by Wallace (4) and Childs (5). In some years, winter spores are mature and ready to be discharged, if the dead leaves containing them are wet, while the apple buds are only beginning to swell. In such years, it is evident that if the first application is deferred until the flower buds show pink, some infection is likely to occur before that time. Because a prepink application is proved necessary or unnecessary one year, it does not follow that the reverse may not be true the next year. A prepink application made in the absence of information as to the development and condition of the winter spores is to be regarded as insurance.

Krout (2) in 1922 tested the addition of a prepink application to the spray schedule. In the first orchard, the addition of the prepink application was not followed by a decrease in the percentage of scab but rather by an increase of 3 per cent. In each of two other orchards the prepink spray apparently reduced the scab 1 per cent. It is evident, therefore, that in 1922 no real benefit from the use of the prepink spray was shown, as compared with a schedule which included only a pink application before the flowers opened.

In 1923, spray schedules with and without a prepink application were tested in two orchards. In the Frost orchard trees sprayed with lime-sulfur beginning with the pink application yielded 7.06 per cent scabby fruit and when this material was used beginning with the prepink application, there was only 1.2 per cent scab, a significant reduction. Where Bordeaux mixture was used for the pink application, followed by lime-sulfur for the later applications, there was 1.7 per cent scabby fruit, and on the plot where this schedule was modified by the addition of a prepink application of Bordeaux mixture, only 0.6 per cent scabby fruit was produced. Here again there was a reduction in the percentage of scab, although such a small one as to be probably without significance.

In the Knights orchard, trees sprayed with dry lime-sulfur 4–50 beginning with the pink application, yielded 1.7 per cent scabby fruit, and where dry lime-sulfur 3–50 was applied beginning with the prepink spray, there was 4.8 per cent scabby fruit. Since the strength of the material was different the addition of a prepink application was not the only changed factor affecting the control of the disease. When the cost of the material and the cost of the labor for each application are considered, however, it is evident that three applications of dry lime-sulfur 4–50 beginning with the pink were a more profitable treatment than four applications of dry lime-sulfur 3–50 beginning with the prepink. There was 1.06 per cent scabby fruit on the trees sprayed with Bordeaux mixture beginning with the pink application and dry lime-sulfur 4–50 for the later applications. As compared with this there was 4.9 per cent scabby fruit on trees sprayed with Bordeaux mixture for the prepink and pink applications followed by liquid lime-sulfur for the later applications. Since, as is shown elsewhere in this report, we may regard liquid lime-sulfur as of equal fungicidal efficiency with dry lime-sulfur 4–50, it is evident that the addition of a prepink application did not reduce the percentage of scab; instead, it was followed by an increase of 3.84 per cent. The need of a prepink application is not shown by the data of either 1922 or 1923.

When we consider dusting, however, the case may be entirely different. In the two orchards where the dusting schedule began with a prepink application, a good control of scab was secured. In the orchard where only one application, the pink, was made before the flower buds opened a much poorer control resulted. Satisfactory experimental evidence on this point, however, would necessitate that the two schedules, with and without a prepink application, be used in adjoining parts of the same orchard with one check for the two.

The Use of Dry Lime-Sulfur.

Arguments for and against the use of dry lime-sulfur as compared with the liquid form include, of course, considerations of the relative costs, convenience in handling, and effect on the pump. But the first question to consider is, does it control scab? For if it does not, further consideration is needless. In the experiments here described, trees sprayed with dry lime-sulfur 4–50, beginning with the pink application, produced an average of 1.3 per cent scabby apples as compared with 60.7 per cent on the unsprayed trees. In the same orchards, on trees sprayed with liquid lime-sulfur, the percentage of scabby apples was 2.7. The conclusion from this is that dry lime-sulfur is fully as dependable for the control of apple scab as is liquid lime-sulfur.

In two successive years, Krout (2) secured as good control of apple scab with dry lime-sulfur as with the liquid. Gardner (6) found dry lime-sulfur as effective as liquid lime-sulfur against apple scab. In most of the experiments of Keitt and Jones (7), the results with dry lime-sulfur in controlling apple scab were similar to those obtained with liquid lime-sulfur. Massey and Fitch (8) had practically the same results with dry as with liquid lime-sulfur.

Dry lime-sulfur is less bulky to transport. But the material necessary to make 100 gallons of spray costs about twice as much in the dry form as in the liquid. The so-called free sulfur in dry lime-sulfur does not redissolve in water, and this, according to Sears (9), wears out pumps and nozzles more rapidly than does liquid lime-sulfur. It may be added that if this objection is valid, it will hold none the less for dry-mix sulfur-lime, or any sulfur fungicide other than a solution. It seems that the orchardist must decide for himself whether to use dry or liquid lime-sulfur, but he may be sure that the fungicide in either form is efficient for the prevention of infection by the apple scab fungus.

Concentration at Which to Use Dry Lime-Sulfur.

Trees sprayed with dry lime-sulfur 4–50 yielded on the average 1.3 per cent scabby apples as compared to 60.7 per cent on unsprayed trees; while trees sprayed with dry lime-sulfur 2–50 and dry lime-sulfur 3–50 yielded 3.9 and 5.8 per cent scabby apples respectively, as compared to 67.6 per cent on unsprayed trees. The indications are that the use of less than 4 pounds of dry lime-sulfur in 50 gallons will be followed by a slight increase in the percentage of scabby apples.

Krout (2) secured similar results. The check plot yielded 41 per cent scabby fruit, the dry lime-sulfur 4–50 plot yielded 2 per cent, and the dry lime-sulfur 3–50 plot yielded 4 per cent scabby fruit. The difference was slight in 1922 as it is in 1923, but the variation is in the same direction.

Whether liquid or dry lime-sulfur is used, the protection afforded is dependent upon the amount of sulfur present in the diluted spray. The percentage of sulfur is of course not always the same in all dry lime-sulfurs. But in general it may be said that not less than 4 pounds of dry lime-sulfur in 50 gallons are required to supply the same number of pounds of sulfur as are present when 1 gallon of commercial concentrated lime-sulfur, of the usual strength tested in degrees Baumé, is diluted to 50 gallons. According to Dutton (10) the amount of dry lime-sulfur necessary to furnish the equivalent amount of sulfur in 50 gallons is 4.4 pounds, and according to Eustace and Pettit (11), it is 4.8 pounds.

The evidence submitted indicates that reducing the amount of dry lime-sulfur below 4 pounds to 50 gallons is a practice of doubtful economy.

Effect of a Calcium Caseinate Spreader on Control of Scab.

The percentage of scabby fruit was reduced slightly by the addition of calcium caseinate spreader to lime-sulfur. At Frost's, this reduction was from 7.06 to 5.08 per cent scabby fruit; and at Knights', the reduction was from 4.6 to 0.68 per cent. It is a question whether these reductions are in themselves large enough to be significant, but the results are consistently in favor of the use of the calcium caseinate.

The addition of calcium caseinate to sulfur dust did not result in a reduction in the percentage of scabby apples, as compared with the plots dusted with sulfur alone, in either the Frost or the Sabine orchard; and in the Stowe orchard the results were practically the same. In the Frost orchard, the addition of calcium caseinate spreader to sulfur dust was followed by a considerable increase in the percentage of scabby apples.

In the spreader tests of Stearns and Hough (12) the addition of calcium caseinate did not increase the effectiveness of the spray in protecting fruit and foliage from disease and insects. Keitt and Jones (7) secured slightly better control of scab when calcium caseinate was added to lime-sulfur than when the latter was used alone, but it was not considered that the commercial value of its addition was determined. Trees sprayed with lime-sulfur by Parrott, Stewart, and Glasgow (13) yielded 2.1 per cent scabby apples, while trees sprayed with lime-sulfur with calcium caseinate added yielded 4.8 per cent scabby apples. In the experiments of Massey and Fitch (8) trees sprayed with lime-sulfur yielded 1.2 per cent scabby apples, and those trees which were sprayed with lime-sulfur with calcium caseinate added yielded 1.1 per cent scabby apples. In their dusting experiments, trees which received sulfur yielded 2.6 per cent scabby apples and those which were dusted with sulfur with calcium cascinate added yielded 2.4 per cent scabby apples.

The claim is made that calcium caseinate spreaders improve the adhesiveness of sprays, but it should be noted that Butler and Smith (14) found that the adhesiveness of Bordeaux mixture is not affected by the addition of calcium caseinate. Whatever may be said in favor of the use of calcium caseinate, and there are sound arguments in its favor, it cannot be said that there is sufficient or satisfactory evidence as to its increasing the fungicidal efficiency of lime-sulfur against apple scab to a point of commercial importance. It is probable, however, that the more imperfect the spraying, the greater the benefit to be derived from the use of a calcium caseinate spreader.

Calcium caseinate is further considered in connection with its effect on compatibility of ingredients in combination sprays.

Bordeaux Mixture as Compared with Lime-Sulfur for Applications Before Flower Buds Open.

The Bordeaux mixture used in these experiments was an excess-lime Bordeaux mixture containing 3 pounds of copper sulfate and 10 pounds of lime in 50 gallons of water. This is referred to in the abbreviated language of practice as 3–10–50 Bordeaux mixture. It was used, rather than a Bordeaux mixture containing copper sulfate and lime in the ratio 1:1, because it has been found to be somewhat safer to the sprayed tree.

In the preparation of Bordeaux mixture, the diluted copper sulfate solution and the diluted milk-of-lime may be poured together into a third barrel or into a spray tank, and this is a method quite generally followed. But it requires some special equipment and involves unnecessary labor. It is important that at least one of the stock solutions, either copper sulfate or lime, be diluted before the other and concentrated one is added to it, but as Butler (15) has shown, it is not necessary that both be diluted before mixing. In practice, it is sufficient to place the copper sulfate stock solution in the spray tank when it is about three-fourths full of water; then, with the agitator running, add the undiluted stock solution of the lime, and fill the tank with water. The Bordeaux mixture used in these experiments was prepared in this way.

In many experiments where Bordeaux mixture and lime-sulfur have been compared, it has been found that the former has a somewhat greater fungicidal efficiency than the latter against apple scab. Unfortunately, Bordeaux mixture usually burns the fruit and foliage of the apple. The results of many experiments are well illustrated by those of Krout (2) who found that even an excess-lime Bordeaux mixture of 3–10–50 formula, when used for all applications, russeted the fruit and burned the foliage severely. For this reason, the use of Bordeaux mixture throughout the spraying season was not attempted in 1923. It was, however, used on certain plots for the pink, or the prepink and pink applications, followed by lime-sulfur for later applications.

The plot in the Frost orchard which received three applications of liquid lime-sulfur yielded 2.1 per cent scabby apples, while the plot which received Bordeaux mixture for the pink application and liquid lime-sulfur for the calyx and last applications yielded 1.7 per cent scabby apples. This is too small a difference to have any significance. The plot which received the prepink and pink applications of Bordeaux mixture followed by liquid lime-sulfur for the later applications yielded 0.6 per cent scabby fruit. This reduction in the amount of scabby fruit cannot be attributed entirely to the substitution of Bordeaux mixture for lime-sulfur since this plot received one extra application; namely, the prepink. The results in Frost's orchard do not show that any benefit is to be derived from the substitution of Bordeaux mixture for lime-sulfur for the early application.

At the Knights orchard, Bordeaux mixture was substituted for dry lime-sulfur in one case and for liquid lime-sulfur in another for the pink or prepink and pink applications. The plot sprayed with dry lime-sulfur throughout the season yielded 1.7 per cent scabby fruit, and the plot on which Bordeaux mixture was substituted for dry lime-sulfur at the time of the pink application yielded practically the same; namely, 1.06 per cent scabby fruit. No benefit from the substitution of Bordeaux was proved in this case. The plot sprayed with liquid lime-sulfur throughout the spraying season beginning with the pink application produced a slightly smaller percentage of scabby apples than did the plot which received Bordeaux mixture at the prepink and pink applications followed by liquid lime-sulfur for the calyx and fourth summer spray.

We have no evidence at either of these orchards that Bordeaux mixture is preferable to lime-sulfur for the prepink and pink applications. The labor involved in preparing Bordeaux mixture is sufficient to swing the scale against it in the absence of more evidence in its favor.

Dr. O. R. Butler states (in correspondence) that in his experiments in New Hampshire in 1922 where a spray schedule of lime-sulfur alone was followed, there was 67.5 per cent scabby fruit; while the substitution of Bordeaux mixture for the pink application reduced the amount to 49.2 per cent. Krout (2) reports that in the Sabine orchard in 1922 the substitution of Bordeaux mixture for lime-sulfur at the pink application did not reduce the percentage of scabby fruit, as compared with results following the use of lime-sulfur alone; in fact, in the case of both dry and liquid lime-sulfur, when Bordeaux mixture was substituted there was a larger percentage of scab. At the Knights and the Frost orchards, however, there was a slight decrease in the amount of scab when Bordeaux mixture was substituted for the pink application; in the case of liquid lime-sulfur this decrease was from 4 to 2 per cent in one orchard and 2 to 0 per cent in another, and in the case of dry lime-sulfur the decrease was from 8 to 3 per cent in one orchard and 2 to 1 per cent in another. We may conclude that although Bordeaux mixture under some conditions may prove slightly superior to lime-sulfur for the pink spray, there is, nevertheless, abundant evidence of the completely satisfactory control of apple scab by lime-sulfur throughout the spraying season; and it does not appear, therefore, that we have sufficient reason to devote extra labor to the preparation of Bordeaux mixture.

Atomic Sulphur.

The proprietary sulfur fungicide, Atomic Sulphur, was used in two orchards with a view to comparing it with lime-sulfur for its fungicidal efficiency and its toxicity to the sprayed tree. Enough of this material to make 100 gallons costs more than three times as much as the liquid lime-sulfur necessary to make an equal amount. Atomic Sulphur, therefore, needs to show very decided advantages over lime-sulfur if it is to compete with it in the spraying of apples.

There was this year no injury to fruit or foliage on trees sprayed with lime-sulfur or with Atomic Sulphur. It was, therefore, impossible to compare them as regards toxicity to the sprayed tree.

Mason (16) found that when apple trees were sprayed with a combination Atomic Sulphur-lime-lead arsenate spray, the foliage was uninjured, while under the same climatic conditions, foliage and fruit were burned by the lime-sulfur-lead arsenate combination.

Atomic Sulphur was used by the writer at the rate of 7 pounds to 50 gallons of water, and when it was used in combination with arsenate of lead, 4 pounds of lime slaked into a milk were added to each 50 gallons, as directed by the manufacturers. At one of the orchards, the results were as follows: Atomic Sulphur, 4.2 per cent scabby fruit; liquid lime-sulfur 2.1 per cent scabby fruit; dry lime-sulfur 4–50, 1.03 per cent scabby fruit. At this orchard, the control secured by Atomic Sulphur was somewhat surpassed by both dry lime-sulfur and liquid lime-sulfur. At the other orchard, the percentages of scabby fruit were as follows: Atomic Sulphur, 3.9 per cent; dry lime-sulfur 3–50, 4.6 per cent. At this orchard also, the results with the two materials are very nearly alike.

If Atomic Sulphur has any advantages over lime-sulfur, they are not to be found in relative efficiency in scab control, but rather in degrees of difference in toxicity to the sprayed plant. Apple orchards in which peaches are planted as fillers are sometimes sprayed with Atomic Sulphur because of the known danger to peaches in leaf from the use of commercial lime-sulfur. When this is done, we may be sure that the apples have received treatment with a fungicide which can protect them against scab infection.

Compatibility of the Ingredients in the Combination Spray as Affected by Addition of Lime, Calcium Caseinate, and Order of Mixing.

Apples are not often sprayed with lime-sulfur alone. They are now more often sprayed with a mixture of lime-sulfur, lead arsenate, nicotine sulfate, and calcium caseinate. The reaction between lead arsenate and lime-sulfur has been studied by Ruth (17) and others, and it is known that both of these materials are somewhat decomposed, one of the results being the formation of the black sludge, lead sulfide. Relative blackness of the mixture is an indicator of its lack of desirable qualities. So far as is known, the addition of nicotine sulfate does not affect this reaction. It has been shown by numerous investigators that the addition of arsenate of lead to lime-sulfur increased the fungicidal value of the latter. Although the use of such a combination spray controls apple scab as well or probably better than lime-sulfur alone, the formation of soluble arsenic as a result of the reaction increases the danger of foliage burning.

It has been found by Robinson (18) that by the addition of lime to this combination spray, the percentage of the soluble, and therefore dangerous, arsenic in the combination spray can be reduced. After standing two days, most of the lime-sulfur with lime added remained unchanged, while in lime-sulfur alone, the desirable polysulfide sulfur had all been changed into lead sulfide or thiosulfate. Bourne (19) modified Robinson's method by adding milk-of-lime to lead arsenate and then adding the two together to diluted lime-sulfur. He found this resulted in very little sediment or blackening. He diluted lime-sulfur till the spray tank was nearly full. Lime (at the rate of 10 pounds to 100 gallons of the total mixture) was slaked and water added to make a milk. Arsenate of lead was stirred into the milk-of-lime, which was then strained into the spray tank with the agitator running. Krout (2) compared liquid lime-sulfur with liquid lime-sulfur plus lime in the field. In each of the three orchards where he used it, there was no russeting of the fruit by either lime-sulfur alone, or lime-sulfur with lime added, and so the benefit of the addition of lime in reducing burning was not shown. In each of the three orchards sprayed by Krout, the addition of lime to lime-sulfur was followed by an increase in the percentage of scabby fruit over the percentage on trees sprayed with lime-sulfur without lime, the increases being 10, 3, and 8 per cent, respectively.

In the experiments of 1923, there was no russeting or burning on trees sprayed with lime-sulfur or on those sprayed with lime-sulfur plus lime. Hence in 1923, as in 1922, it was impossible to prove that the addition of lime to lime-sulfur reduced the toxicity of the fungicide to the sprayed tree. In both of the orchards where these materials were compared in 1923, a larger percentage of scabby apples was produced on trees sprayed with lime-sulfur plus lime than on trees sprayed with lime-sulfur without lime added, the increase being 1.2 per cent in one case and 5.3 per cent in the other. The indications are that the addition of lime to the lime-sulfur-lead arsenate combination spray reduces somewhat the fungicidal efficiency of the latter. In seasons when climatic conditions result in toxicity to the sprayed tree by the lime-sulfur-lead arsenate combination spray, it is possible that any small decrease in fungicidal efficiency coincident with the addition of lime would be more than offset by the decreased danger of burning described by Robinson (loc. cit.) and Bourne (loc. cit.). However, further experimental evidence is needed.

According to Regan (20) the addition of calcium caseinate spreader to lime-sulfur-lead arsenate combination spray prevents the usual decomposition and formation of black sludge. He found two pounds of calcium caseinate to be more effective in preventing this decomposition than ten pounds of hydrated lime. Lovett (21) also reports that the addition of calcium caseinate materially delays the reaction between lime-sulfur and lead arsenate in the combination spray.

Laboratory tests were made by the writer to compare the formation of black sludge in the combination spray with and without the addition of calcium caseinate. Without calcium caseinate, the color of the mixture was dark citrine[1] and with it the color was yellowish citrine, that is, considerably lighter. After standing three minutes the sludge precipitated without calcium caseinate was nearly twice

[1] Colors determined by comparison with Ridgway, Robert. Color Standards and Nomenclature. Washington, 1912.

as much as the sludge in the mixture containing calcium caseinate. Apparently the addition of calcium caseinate physically improves the mixture.

In filling the spray tank, five ingredients are or may be used, *i.e.*, water, lime-sulfur, lead arsenate, nicotine sulfate and calcium caseinate. After the water is in the tank, there are twenty-four different orders in which the other ingredients may be added. The manufacturers of calcium caseinate recommend that it be added to the water in the spray tank, with the agitator running, before the other materials are added. According to Anderson and Roth (22) the lime-sulfur is first diluted, the lead arsenate added to it with agitation, and then the nicotine sulfate added. After putting the calcium caseinate in the water in the spray tank, this is probably the order most commonly followed. Britton (23) recommends the following order for filling the spray tank: first, clean water; second, nicotine sulfate; third, calcium caseinate (if used); fourth, lead arsenate; and fifth and last, lime-sulfur. He says that when mixed in this order, especially if calcium caseinate is present, little or no discoloration or precipitation of brown sludge follows.

In laboratory tests made by the writer, the ingredients were mixed in the order named by Britton; the resulting mixture was buffy olive in color, with little precipitation. In another test they were mixed in the following order: water, calcium caseinate, lime-sulfur, lead arsenate, and nicotine sulfate. The color of this mixture was ivy green, considerably darker, with more precipitation. Several other orders of mixing were compared and the best results, based on a color test and relative sludge formation, were obtained by the following sequence after the water: first, calcium caseinate; second, nicotine sulfate; third, lead arsenate; and fourth, lime-sulfur.

Spore germination tests made with the conidia of the apple scab fungus showed that the fungicidal efficiency of the combination spray is not impaired by any order of mixing tested. But the order of mixing does affect the physical qualities of the mixture and very probably the burning of the sprayed tree. It should be added that when light colored lime-sulfur combination spray is desired, special attention should be given to washing out the spray tank. The use of calcium caseinate results in a decidedly lighter colored mixture.

Results of Dusting Treatments.

A rather extensive literature on the results of dusting for the control of apple scab has come into existence. The results do not all agree, but perhaps they are no more inconsistent than the published results of spraying experiments. In general, the control of apple scab by the use of dusts has been surpassed by that of liquid sprays. This is not surprising when we consider that spraying is a much older orchard practice than is dusting. Our knowledge of the use of liquid sprays and the schedule for their application to the apple is relatively advanced. Dusts have been used in conformity with the spray schedule, rather than according to any special dusting schedule.

It should be noted that no experiments have been conducted in Massachusetts which directly compare the results of spraying with those of dusting. Owing to the topography and plan of the several orchards, spraying and dusting experiments have been carried on in separate orchards or in separate parts of the same orchard with one check plot for the spray treatment and another for the dust treatment.

In the orchards dusted by Krout (2) in 1922 the average percentage of scabby fruit in the check plots was 75.8 and the average percentage of scabby fruit in the plots dusted with sulfur was 17.2. In the orchards sprayed by Krout, the average percentage of scabby fruit in the check plots was 79.0 and the average percentage of scabby fruit in the plots sprayed with dry lime-sulfur 4–50 was 8.0. It is evident that the dust did not give a control equal to that of the spray. The results of Massey and Fitch (8) were: in one orchard, check 93.3 per cent scab, and sulfur dust 13.5 per cent scab; in another orchard, check 43.5 per cent scab and sulfur dust 3.1 per cent scab. In an orchard dusted by Parrott, Stewart, and Glasgow (13), the results were 83.9 per cent scab in the check, and 47.8 per cent scab in the plot dusted with sulfur. Results from other years and other states could be selected either in favor of or against dusting.

In 1923, the dusting experiments here reported were conducted in three orchards. At the Stowe and the Sabine orchards, the dusting schedule consisted of five applications, *i.e.*, prepink, pink, calyx, fourth dust and fifth dust. At the Frost orchard, the trees were dusted four times, no prepink application being used.

In the Stowe orchard, where check trees yielded 37 per cent scabby fruit, trees dusted with sulfur yielded 3.7 per cent scabby fruit. At the Sabine orchard, trees dusted with sulfur bore 0.5 per cent scabby fruit, and on the check trees 48 per cent of the fruit was scabby. At the Frost orchard, where no prepink application was used, trees dusted with sulfur yielded 16.9 per cent scabby fruit, as compared with 84.5 per cent scabby fruit in the check. Sulfur dust controlled apple scab satisfactorily when applications began with the prepink, but not when the prepink application was omitted.

Calcium caseinate was thoroughly mixed with sulfur at the rate of 5 pounds of calcium caseinate to 95 pounds of sulfur. This sulfur-calcium caseinate dust was used in three orchards in plots adjoining plots dusted with sulfur only. In every case, apple scab was controlled better by sulfur alone than by sulfur with calcium caseinate added.

Plots were also dusted according to a schedule which included the use of a copper dust for the prepink and pink, or the pink applications followed by sulfur dust for later applications. At two of the orchards, there was less scab following the use of sulfur throughout the season than when copper dust was substituted for sulfur for the applications before the flower buds opened. At the other orchard, there was only a negligible difference between the amounts of scab following the two different methods of treatment. No experimental evidence was secured to indicate an advantage in using copper dust instead of sulfur dust for the early applications.

Control of Primary Infection on Leaves.

As the season advances, the work of the fungicide and the conditions under which it acts become entirely different from what they were at the first of the spraying season. There is naturally and usually an increase in the mean temperature. At the time of the early applications, all infection is from the winter spores. As soon as scab lesions appear on the young leaves, there is an increasing possibility of infection by the summer spores. In some springs, the trees are for a few days, or even a few weeks, in danger of infection from both the winter and summer spores at the same time. In the absence of sufficient moisture the ejection of the winter spores may be prolonged until after the appearance of scab on the leaves.

In 1923, ejection of winter spores from the dead leaves beneath the trees was first observed on May 2. Spore ejection continued till June 16, after which none was observed. The first scab symptoms were found on the leaves May 22. It is evident from this that the first winter spores to be ejected did not infect the trees, for the incubation period with these spores of the apple scab fungus was found by Wallace (4) to be eight to fifteen days. During the period in which winter spore ejection continued, there was rain on ten days. Whenever the leaves were wet by rain, winter spore ejection was stimulated, but it was fully as abundant on certain days when the leaves were wet with heavy dew. Winter spores were not ejected in relatively great numbers at any time the last spring. Wallace (loc. cit.) reports that in order for winter spores to infect the trees, the trees must remain wet 8 to 10 hours. Such was the condition on May 12 and 21 and on June 8, and it is probable that much of the primary infection took place on these dates.

In order to secure more information on the relative fungicidal efficiency of the several treatments, the percentages of infected leaves on trees June 18 were determined. In the Frost sprayed orchard, there were at this time 39 per cent scabby leaves on the check trees, and from 0.1 to 0.3 per cent scabby leaves on the sprayed trees, with only negligible differences between the several spray treatments. All the spray treatments were practically successful in preventing the primary infection. The results were essentially the same in both of the Knights orchards, where there were 15 and 20 per cent scabby leaves on unsprayed trees, and 0.1 to 0.2 per cent scabby leaves on sprayed plots, again with negligible differences between the different spray treatments.

Upon examining the dusted orchards, it was found that the primary infection had not been as satisfactorily prevented. In one orchard where the dust treatments began with a prepink application, the check trees had 41 per cent scabby leaves, and the dusted trees had 8 to 9 per cent scabby leaves, with only minor differences between the different dust treatments. In another orchard dusted in the same way, there were 15 per cent scabby leaves on the check trees and 3 to 4 per cent scabby leaves on the dusted trees. In the third orchard, where no prepink application was used, there were at this time 53 per cent scabby leaves on the check and 21 to 24 per cent scabby leaves on the dusted trees. This indicates the necessity of a prepink application if dust is to control the primary infection. But even where both prepink and pink applications of dust were made, relatively more primary infection occurred than in the sprayed orchards. As is explained elsewhere, the dust treatments in the orchards where dusting began with a prepink application, were entirely satisfactory in preventing the further spread of scab, that is, in preventing infection later in the season by the summer spores. It would appear that if dust is equally as efficient as liquid spraying in controlling the spread of scab during the summer, it is less efficient in preventing the primary infection in early spring. If such is the case, then for those who own both duster and sprayer, a safer procedure would be to use the sprayer for the pink application and the duster for later ones. It should not be overlooked, however, that dust satisfactorily controlled scab on the fruit when the dusting schedule included both a prepink and pink application.

Effect of Fungicides on the Tree.

The literature contains references to increased dropping of the fruit following the use of lime-sulfur. There was this year in the experimental orchards no more dropping of the fruit following any of the several treatments than that which occurred on the check trees.

There was only a negligible amount of injury to fruit or foliage on any of the sprayed or dusted plots. The trees used are McIntosh. Although burning was absent in the experimental plots, it was seen on the fruit of Baldwins following the application of sulfur dust. Childs (3) and others report that sulfur dust may cause an injury to apple fruit similar to that of lime-sulfur solution. The relation of sulfur dust burning to temperature in the case of varieties susceptible to burning needs to be further considered. As has been pointed out by Safro (24) some cases of injury attributed to lime-sulfur are primarily cases of sunburn, and the same is probably true of injury by sulfur dust. The absence of spray injury from all plots made it impossible to learn to what extent the addition of lime to lime-sulfur decreases burning, and how the latter fungicide compares with Atomic Sulphur in this respect on the apple.

Relation of Temperature of the Season to the Fungicidal Efficiency of Sulfur.

We have as yet no data on the temperature necessary for sulfur to prevent the germination of the winter spores of the apple scab fungus. Doran (25) has shown that sulfur prevents the germination of the summer spores of this fungus when the temperature is 78.8° F. for five hours. If the temperature is higher, less time is necessary and if the temperature is lower, more time is necessary. This temperature or above it was recorded in the experimental orchards on fifty days between May 7 and August 31. As the results show, the temperature conditions of the season were such as to insure the fungicidal action of sulfur, and so prevent the germination of the conidia.

If there had been fewer days during this period when the temperature reached the necessary point, it is probable that the results with Bordeaux mixture and copper dust as compared with sulfur fungicides would have appeared relatively better than proved to be the case.

Summary.

A spray schedule beginning with the pink application controlled apple scab as well as a schedule beginning with the prepink application.

Sulfur dust controlled apple scab satisfactorily when it was applied five times beginning with the prepink application, but not when it was applied four times beginning with the pink application.

Liquid lime-sulfur 1–50 and dry lime-sulfur 4–50 proved of equal fungicidal efficiency for scab control.

Less than 4 pounds of dry lime-sulfur in 50 gallons did not on the whole control scab quite as well as dry lime-sulfur 4–50.

The addition of calcium caseinate spreader to the liquid spray was followed by a very slight decrease in the percentage of scabby fruit.

The addition of calcium caseinate spreader to sulfur dust did not result in a smaller percentage of scabby fruit than when sulfur dust was used alone.

Since there was no injury to the sprayed tree by lime-sulfur-lead arsenate combination spray, it could not be proved that the addition of lime to this spray decreased its toxicity to the sprayed tree.

As good a control of apple scab was secured by the use of lime-sulfur throughout the spraying season as by substituting Bordeaux mixture for lime-sulfur for the applications before the flower buds opened.

Atomic Sulphur controlled the disease as well as did lime-sulfur. Because of the absence of burning it was impossible to determine how they compare in their effect on the sprayed tree.

Sulfur dust throughout the dusting season controlled apple scab as satisfactorily as when copper dust was substituted for sulfur dust for the applications before the flower buds opened.

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APPENDIX.

TABLE I. — *Showing Treatment of Dusted Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit.*

Orchard.	Plot No.	Prepink.		Pink.		Calyx.		Fourth (or Third) Summer.		Latest Summer.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
Stowe	1	Copper-lime-arsenic-dust	May 5	Copper-lime-arsenic-dust	May 10	Sulfur dust	May 21	Sulfur dust	June 11	Sulfur dust	July 18	2.9
	2	Sulfur dust	5	Sulfur dust	10	Sulfur dust	21	Sulfur dust	11	Sulfur dust	18	3.7
	3	Check (no treatment)										37.0
	4	Sulfur dust plus calcium caseinate	5	Sulfur dust plus calcium caseinate	10	Sulfur dust plus calcium caseinate	21	Sulfur dust plus calcium caseinate	11	Sulfur dust plus calcium caseinate	18	3.9
Frost	1	Check (no treatment)										84.5
	2			Sulfur dust	8	Sulfur dust	22	Sulfur dust	13	Sulfur dust	19	16.9
	3			Sulfur dust plus calcium caseinate	8	Sulfur dust plus calcium caseinate	22	Sulfur dust plus calcium caseinate	13	Sulfur dust plus calcium caseinate	19	30.7
	4			Copper-lime-arsenic dust	8	Sulfur dust	22	Sulfur dust	13	Sulfur dust	19	17.6
Sabine	1	Check (no treatment)										48.0
	2	Copper-lime-arsenic dust	4	Copper-lime-arsenic dust	9	Sulfur dust	24	Sulfur dust	12	Sulfur dust	17	4.8
	3	Sulfur dust	4	Sulfur dust	9	Sulfur dust	24	Sulfur dust	12	Sulfur dust	17	0.5
	4	Sulfur dust plus calcium caseinate	4	Sulfur dust plus calcium caseinate	9	Sulfur dust plus calcium caseinate	24	Sulfur dust plus calcium caseinate	12	Sulfur dust plus calcium caseinate	17	0.7

TABLE II. — *Showing Treatments of Sprayed Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit.*

Orchard.	Plot No.	Prepink.		Pink.		Calyx.		Latest Summer.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
	1		May	Dry lime-sulfur 3–50 plus calcium caseinate	May 7	Dry lime-sulfur 3–50 plus calcium caseinate	May 24	Dry lime-sulfur 3–50 plus calcium caseinate	June 13	5.08
	2			Dry lime-sulfur 3–50	7	Dry lime-sulfur 3–50	24	Dry lime-sulfur 3–50	13	7.06
	3			Dry lime-sulfur 4–50	7	Dry lime-sulfur 4–50	24	Dry lime-sulfur 4–50	13	1.03
	4			Dry lime-sulfur 2–50	7	Dry lime-sulfur 2–50	24	Dry lime-sulfur 2–50	13	5.07
	5	Dry lime-sulfur 3–50	3	Dry lime-sulfur 3–50	7	Dry lime-sulfur 3–50	24	Dry lime-sulfur 3–50	13	1.2
Frost	6	Check (no treatment)								76.0
	7	Bordeaux mixture	3	Bordeaux mixture	7	Liquid lime-sulfur	24	Liquid lime-sulfur	13	0.6
	8			Bordeaux mixture	7	Liquid lime-sulfur	24	Liquid lime-sulfur	13	1.7
	9			Liquid lime-sulfur	7	Liquid lime-sulfur	24	Liquud lime-sulfur	13	2.1
	10			Liquid lime-sulfur plus lime	7	Liquid lime-sulfur plus lime	24	Liquid lime-sulfur plus lime	13	3.3
	11			Atomic Sulphur	7	Atomic Sulphur	24	Atomic Sulphur	13	4.2

TABLE II. — *Showing Treatments of Sprayed Plots with Dates of Applications, Materials used and Percentage of Scabby Fruit* — Concluded.

Orchard.	Plot No.	Prepink.		Pink.		Calyx.		Latest. Summer.		Per Cent Scabby Fruit.
		Material.	Date.	Material.	Date.	Material.	Date.	Material.	Date.	
Knights (A)	1	Bordeaux mixture	May 3	Bordeaux mixture	May 8	Liquid lime-sulfur	May 23	Liquid lime-sulfur	June 14	4.9
	2			Bordeaux mixture	8	Dry lime-sulfur 4–50	23	Dry lime-sulfur 4–50	14	1.06
	3			Liquid lime-sulfur plus lime	8	Liquid lime-sulfur plus lime	23	Liquid lime-sulfur plus lime	14	8.6
	4			Liquid lime-sulfur	8	Liquid lime-sulfur	23	Liquid lime-sulfur	14	3.3
	5	Check (no treatment)								45.5
	6	Dry lime-sulfur 3–50	3	Dry lime-sulfur 3–50	8	Dry lime-sulfur 3–50	23	Dry lime-sulfur 3–50	14	4.8
	7			Dry lime-sulfur 4–50	8	Dry lime-sulfur 4–50	23	Dry lime-sulfur 4–50	14	1.7
Knights (B)	1			Dry lime-sulfur 2–50	8	Dry lime-sulfur 2–50	23	Dry lime-sulfur 2–50	14	2.7
	2			Dry lime-sulfur 3–50 plus calcium caseinate	8	Dry lime-sulfur 3–50 plus calcium caseinate	23	Dry lime-sulfur 3–50 plus calcium caseinate	14	0.68
	3			Dry lime-sulfur 3–50	8	Dry lime-sulfur 3–50	23	Dry lime-sulfur 3–50	14	4.6
	4			Atomic Sulphur	8	Atomic Sulphur	23	Atomic Sulphur	14	3.9
	5	Check (no treatment)								59.3

TABLE III. — *Results of Three Years' Apple Spraying Experiments.*

Treatment.[1]	Per Cent Scabby Fruit — 1923.	1922.	1921.	Average.
Check	58.3	77.0	91.0	75.4
Liquid lime-sulfur	2.7	6.6	8.6	6.1
Liquid lime-sulfur plus lime	5.9	13.6	12.0	10.3
Dry lime-sulfur 4–50	1.3	8.0	6.0	5.1
Dry lime-sulfur 4–50 beginning with prepink	–[2]	0.0	–	0.0
Dry lime-sulfur 3–50	5.8	4.0	–	4.9
Dry lime-sulfur 3–50 beginning with prepink	3.0	–	–	3.0
Dry lime-sulfur 2–50	3.9	–	–	3.9
Dry lime-sulfur 3–50 plus calcium caseinate spreader	2.9	–	–	2.9
Atomic Sulphur	4.0	–	–	4.0
Bordeaux mixture at pink application followed by dry lime-sulfur 4–50	1.0	18.3	–	9.6
Bordeaux mixture at pink application followed by liquid lime-sulfur	1.7	6.0	6.0	4.5
Bordeaux mixture for prepink and pink applications followed by liquid lime-sulfur	2.7	7.0	–	4.8
Bordeaux mixture through season	–	8.6	–	8.6
Sulfur dust beginning with prepink application	2.1	17.2	–	9.6
Sulfur dust beginning with pink application	16.9	–	46.0	31.4
Sulfur dust plus calcium caseinate beginning with prepink application	2.3	–	–	2.3
Sulfur dust plus calcium caseinate beginning with pink application	30.7	–	–	30.7
Copper dust for prepink and pink applications followed by sulfur dust	3.8	–	–	3.8
Copper dust for pink application followed by sulfur dust	17.6	–	–	17.6
Copper dust through season	–	10.2	69.0	39.6

[1] Applications begin with pink unless stated as beginning with prepink.
[2] Blanks in table indicate that the treatment was not given in that year.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

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THE INHERITANCE OF FERTILITY AND HATCHABILITY IN POULTRY

By F. A. HAYS and RUBY SANBORN

Determination of fact as to inheritance of characters is essential to successful poultry breeding. This work is peculiarly within the province of the Agricultural Experiment Station, for records must be made on large numbers of individual birds, the work must extend over a period of years, a wearisome amount of data must be preserved. The data recorded in this bulletin are the result of eleven years' work. Individual records were made on 886 birds. Resulting data are now analyzed statistically in the light of all that genetic science has to offer. It is through work such as this that a basis of sound fact, in poultry breeding work, will ultimately replace one based largely on opinion and tradition.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

Publication of this Document approved by the Commission on Administration and Finance

THE INHERITANCE OF FERTILITY AND HATCHABILITY IN POULTRY.

By F. A. Hays and Ruby Sanborn.

Introduction.

The importance of a thorough understanding of the mode of inheritance of factors affecting fertility of hens' eggs needs no stressing. Neither does the value of a complete understanding of the way hatching power of eggs is inherited require emphasis, for the proper functioning of the factors for high fertility and high hatchability is of fundamental and vital importance to every poultry breeder.

The purpose of this report is to consider only the question of the inheritance of fertility[1] and hatchability[2] from as many angles as our data will permit. The inheritance of these two characteristics is discussed first from the standpoint of the dams and then from the standpoint of the sires. The fact should be recognized at the outset that numerous variable environmental factors such as weather conditions, health of birds, exposure of eggs, variation within the same and different incubators, etc., are in constant operation. The combined action of these constantly varying environmental factors may largely obscure the inherent capacity of the bird to produce fertile eggs that are largely hatchable. A further lack of knowledge of the fundamental factors concerned in breeding for high fertility and high hatchability, as pointed out by Dunn ('23), makes proper matings impossible.

Data Available.[3]

The data used in this bulletin have been collected each hatching season from 1913 to 1923. All records kept represent the pullet year or cockerel year unless otherwise stated. All records were made by pedigreed Rhode Island Red birds. The attention of the reader is called to the fact that stud matings have been used almost exclusively and this will account for a lower degree of fertility than might be obtained from pen matings. Uniform methods of incubation have been used and care has been taken to maintain a definite system of management throughout the eleven-year period. Only females whose daughters were trap-nested are included in this report.

PART I.

The Female's Rôle in the Inheritance of Fertility and Hatchability.

Fortunately a measure of individual fertility and hatchability is possible in the female. The accuracy of such a measure depends very largely upon the number of eggs laid by the pullets in question during the hatching season. Some pullets will lay fifty eggs during a two months' incubation season, while others may lay as few as five or ten eggs. Fertility and hatchability records on the first type would certainly be much more significant than those on the second type. The major portion of the records here reported upon were made between the hatching dates of March 25 and May 15 of the respective years. In some cases chicks were hatched beyond the above dates, but not as a rule. Since the flock was being bred for egg production, considerable care was exercised to use pullet breeders that would lay a goodly number of eggs during the hatching season.

Section 1. Correlation between Fertility and Hatchability.

A hen to be able to produce a large number of chicks must lay highly fertile eggs. Furthermore, her eggs must hatch well. In ordinary usage, good hatching hens are those from which almost all eggs laid give rise to vigorous chicks. Fertility and hatchability are bound together in the sense that there can be no hatch-

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[1] *The term fertility as used here refers to the percentage of eggs that are fertile; the test being made on the fifth day of incubation.*

[2] *The term hatchability as used here refers to the percentage of fertile eggs hatched.*

[3] *The data used in this report were collected by Dr. H. D. Goodale until 1921; for the year 1922, by Professor William Sanctuary and the junior author.*

ability without fertility; but there may be one hundred per cent fertility and zero hatchability, or there may be only five per cent fertility and one hundred per cent hatchability.

The above facts show that the coefficient of correlation between fertility and hatchability could neither be zero nor negative. Pearl ('09) found a correlation of $-.127 \pm .071$ between the percentage of infertile eggs and the percentage of fertile eggs hatched from pullets. Such a factor, in view of the large probable error, indicates no sensible correlation between the degree of fertility and the percentage of fertile eggs hatched.

In table 1 presented below, the percentage of fertile eggs from 758 pullets is correlated with the percentage of fertile eggs hatched. These percentages represent each pullet's average fertility record and her average hatching record for the season. The records were obtained in eleven breeding seasons. The table includes all pullets used as breeders during the period covered, except those showing zero fertility. The zero-fertility class had to be omitted because zero fertility always means zero hatchability, and if the fifty-three pullets that laid no fertile eggs were included, a spurious correlation would arise and not the true correlation coefficient.

TABLE 1.—*Correlation Between Fertility and Hatchability.*

	Pullets' Hatchability, Per Cent.																				
Pullets' Fertility, Per Cent.	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
1–4																					
5–9	4																			2	6
10–14	2						1						1							1	5
15–19	2					1					1		1							1	6
20–24	5					1	2				1	1				1	1	1		1	14
25–29	1		1			2					1		2			2	1			2	12
30–34	3		1			1				1						1				3	10
35–39	1					1			1		1	1	5	1		1				2	14
40–44	3		1	1				1			2				4		1			1	14
45–49	3					1			2				1		2	3			2		14
50–54	3				1			1			1	2	2	1	1	4	1		1	5	23
55–59	1	1			1			1	1	1			1	1	1	2			1	1	13
60–64		1		1	2		2					1	3	2	2	6	1		2	1	24
65–69	6	1		1	2	2	2	1	1	2	2	1	7	1	3	4	3			1	40
70–74	5	1	1			3	1	2		1	2	3	4	3	2	3	6	2		2	41
75–79	4	1	3	1	1		2	1	1	3	1	4	3	1	3	5	1	3	2	2	42
80–84	1	2	2		4		2	1	2		7	2	6	6	3	4	4	4		3	53
85–89	5	1		3	3	1	3	7	4	7	3	5	7	9	9	4	2	2	1	1	77
90–94	10		3	1	2	3	4	4	3	2	3	3	11	8	5	8	9	8	4		91
95–100	28	5	4	10	5	7	10	9	9	7	13	12	20	22	15	22	17	18	20	6	259
f.	87	13	16	18	21	23	29	28	24	24	38	35	74	55	50	70	47	38	33	35	758

Constants calculated from Table 1.

Mean fertility	$.688272 \pm .005466$
Fertility standard deviation	$.2231 \pm .003865$
Mean hatchability	$.637875 \pm .007119$
Hatchability standard deviation	$.2906 \pm .005034$
Coefficient of correlation	$.0672 \pm .024390$

Table 1 gives a positive correlation coefficient of $.0672 \pm .02439$ which must be interpreted in the light of a probable error of more than one-third as signifying almost complete independence between degree of fertility and hatchability.

From the genetic standpoint, the results in table 1 are significant. The table shows that a flock of pullets may carry the factors that are conducive to high fertility and yet lack the ability to be good hatchers. Stated simply, these results mean that the degree of fertility in a hen's eggs is an entity independent from the hatchability of her eggs.

The mean fertility shown in table 1 is .6883, while the mean hatchability is .6379. Of the total eggs laid by these pullets during the hatching season, 68.83 per cent were fertile, and 63.79 per cent of these fertile eggs hatched. Two possible avenues are open for increasing the number of chicks per pullet. *First,* Increase the percentage of total eggs that are fertile. *Second,* Increase the percentage of fertile eggs that hatch. Selection for high fertility and high hatchability is possible only where hens are used as breeders. Hens have been used to only a very minor extent in this flock. Hence there has not been much progress in fertility and only moderate progress in hatchability, as will be shown in section 17 of this bulletin. The general deduction must be made, therefore, from the study of table 1, that fertility and hatchability are independent of each other. The stability of each characteristic may next be considered.

Section 2. The Constancy of Fertility in Hens.

In order to test the constancy of fertility in hens, the records of 253 female breeders that were used first as pullets and again as yearlings have been placed in table 2. In practically all cases a different male was mated to these females the second year. If there is a sensible correlation in fertility between the pullet-year record and the yearling record from the same hens, the natural assumption must be that degree of fertility is more or less constant in the female, regardless of the male to which she is mated.

TABLE 2. — *Correlation Between First and Second-Year Fertility.*

		Yearling Hens' Fertility, Per Cent.																				
		0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
Pullets' Fertility, Per Cent.	0–4	3													1						5	9
	5–9									1										1		2
	10–14							1			1										1	3
	15–19		1			2																3
	20–24																1		1	2	1	5
	25–29	1													1						1	3
	30–34														1							1
	35–39				1				1				1						1		2	6
	40–44	1																			2	3
	45–49	1										1			1				1	1	2	7
	50–54	1		1															3		2	7
	55–59														1						2	3
	60–64																	2		3	1	6
	65–69	1			1		1								1	1		1	2	3	4	15
	70–74	2							1			1			1				1	3	3	12
	75–79																1	1	2	2	3	9
	80–84	2			1	2										3	1	1	2	2	6	20
	85–89	1							1	1		1	2	1		2	1	2	1	2	5	20
	90–94			1		2				1				2	1	1		3	7	5	19	42
	95–100	2		1				1			1		1		3			7	3	8	50	77
f.		15	1	3	3	6	1	2	3	3	2	3	4	3	11	7	4	17	24	32	109	253

Constants calculated from Table 2.

Pullets' mean fertility	.7589±.011288
Pullets' standard deviation	.2662±.007982
Yearling hens' mean fertility	.7825±.012111
Yearling hens' standard deviation	.2856±.008564
Coefficient of correlation	.2733±.039238

The mean fertility of the birds used in table 2 was slightly greater for the yearling than for the pullet-year. The difference, .0236±.016579, is not great enough to be significant. The range of variability measured by the standard deviation is slightly wider as yearlings than as pullets, but the closeness of agreement in the two years signifies a degree of fixedness. From the breeding standpoint, the chief deduction that may be made from a study of table 2 is that the percentage of fertility for a pullet is a good guide as to her probable fertility as a yearling.

A positive coefficient of correlation, .2733±.039238, between the first and second year fertility supports the view that fertility is a trait that is fairly constant for the individual hen. Lamson and Card ('20) have pointed out this fact in Leghorns. Pearl ('09) found a negative correlation of .1112±.092 between infertility the first year and the second year in Barred Plymouth Rocks. Our data, however, indicate that a bird with good fertility as a pullet will probably show good fertility as a yearling.

Section 3. The Constancy of Hatching Power in Hens.

The group of 253 birds studied in table 2 are correlated for hatchability in table 3 to discover if there is a relationship between the percentage of fertile eggs hatched as pullets and as yearlings. In other words, does hatchability approach any degree of constancy in the same individual in two successive years? Does a good hatching record as a pullet mean a good hatching record as a yearling?

TABLE 3. — *Correlation Between First and Second-Year Hatchability.*

		Yearling Hens' Hatchability, Per Cent.																				
		0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
Pullets' Hatchability, Per Cent.	0–4	10				2		1					2	1	1	2				1		20
	5–9	2				1							1				1					5
	10–14	3						1				1										5
	15–19	3				1		1		1			1									7
	20–24	3																				3
	25–29	2	2			1							1			1		1				8
	30–34								1				1			1			1	1		5
	35–39	3			1			2	1					1								8
	40–44		2	1		1		1	1					2	2							10
	45–49	1					3	1		1		2					1					9
	50–54	5		2		2	1		1			2		1	2	1		1	1		1	20
	55–59	1		2	1		1	3		2	3	1		2					1			17
	60–64	1				1				3	3	2	1		1	2	1	2	1		2	20
	65–69	2		1	1								1	3	3	2	2	1	2	1		19
	70–74	2		1	1					1	1		1	2	1	1	5	1	1	3	1	22
	75–79	4					1	1	1	1	1	3		3	1		3	2	2	1		24
	80–84									1		2	2		2			1				8
	85–89	1	1					1			1	1		3		2	4	1	2		1	18
	90–94	1									1	2		1			1	3	4		1	14
	95–100	2										1			4			2	1		1	11
	f.	46	5	7	4	9	6	12	5	10	10	17	11	19	17	12	18	15	16	7	7	253

Constants calculated from Table 3.

Pullets' mean hatchability	.5678 ± .011313
Pullets' standard deviation.	.2668 ± .008333
Yearling hens' mean hatchability	.4791 ± .012963
Yearling hens' standard deviation	.3057 ± .009166
Coefficient of correlation	.4346 ± .034409

The mean hatchability for pullets is .5678±.011313. The mean hatchability for the same birds as yearlings is .4791±.012963. There is a difference of .0887±.0172 in favor of using pullet breeders. This difference is significant in the light of its probable error. Stewart and Atwood's ('09) records with White Leghorns do not agree with these results. They found both the mean fertility and mean hatchability to be higher in hens than in pullets. Their records are scarcely comparable with ours because they did not compare the same birds. Furthermore, in a yearling or two-year-old flock, most of the poor hatchers will have been discarded if they were tested as pullets. Pearl ('09) obtained a slightly higher mean fertility in the pullet year and an insignificant difference in hatchability between pullets and yearlings, using the same flock of Barred Plymouth Rocks.

The range of variability measured by the standard deviation is significantly greater in the yearling hens. This difference may possibly be ascribed to variability in physical condition in the older birds. Hatchability, however, seems to be a trait that behaves with a good deal of constancy in hens. This fact makes the individual hatching record valuable, at least in making use of a hen for several years to increase flock numbers. The ability of the hen to transmit this hatching power to her daughters will be considered in section 5.

The coefficient of correlation calculated from table 3 is .4346±.034409. Hatchability is therefore more constant than fertility, for the coefficient for fertility in the same flock was only .2733. In breeding for high hatchability there is ample justification for discarding the poor hatchers the first year and retaining the good hatchers to perpetuate the flock.

Section 4. Correlation in Fertility between Mothers and Daughters.

In order to discover if there is any relationship between mothers and daughters in degree of fertility, the average fertility of pullet breeders has been correlated with each of their daughters that were used for breeding as pullets. In case only one daughter was used, there was but one insertion in the table. If a pullet dam had more than one daughter used as a breeder she is paired with each of these daughters and an insertion made in the table.

Table 4. — *Correlation in Fertility Between Mother and Daughter.*

Dams' Fertility, Per Cent.	Daughters' Fertility, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9																					
10–14																					
15–19									1									1			2
20–24																					
25–29	1																				1
30–34												1					2		1	1	5
35–39						1								1		1			1	1	5
40–44				1						1	1			1	2			2	1	4	13
45–49								1			2						2			3	8
50–54										1				1	1			2	1	2	8
55–59	1																1		3	4	9
60–64	2				1					1			1		1		2	1	1	7	17
65–69	3		2		2	1					2		1	2	1	1	2	3	3	8	31
70–74	2				1		1	1	1		1			2	1	5	2	3	4	13	37
75–79								1			1		1	4	2	2	3	2	3	5	24
80–84	5				3	1	1				2		1	1	4	2	1	2	7	17	47
85–89	5	1		1			2	2	3	1	1	2	2	1	2	4	3	7	10	17	64
90–94	12	1	1	1	1	3	1	1	3	4	5		3	7	6	4	5	10	11	45	124
95–100	23	4	2	4	6	5	5	7	6	6	8	9	15	20	21	23	31	44	45	132	416
f.	54	6	5	7	14	11	10	13	14	14	23	12	24	40	41	42	54	77	91	259	811

Constants calculated from Table 4.

Dams' mean fertility	$.8765 \pm .003503$
Dams' standard deviation	$.1479 \pm .002477$
Daughters' mean fertility	$.7378 \pm .006831$
Daughters' standard deviation	$.2884 \pm .004830$
Coefficient of correlation	$.0147 \pm .023679$

The standard deviation in dams in fertility is .1479, while the standard deviation of their daughters is twice as great or .2884. There is a positive correlation coefficient in fertility of $.0147 \pm .023679$ between the dams and the 811 daughters that were used as breeders. Since this coefficient is less than its probable error, it can have no significance. This table must therefore indicate that a pullet with low fertility is as likely to give daughters high in fertility as is a breeding pullet that shows high fertility herself. These observations are essentially in agreement with Pearl ('09), for he found a negative correlation of $.035 \pm .072$ in infertility between mother and daughter. The conclusion seems justified, therefore, that the fertility of the dam's eggs is no indication as to the probable fertility of her daughter's eggs. In section 2, the fertility record of a pullet was shown to be a guide as to her second-year fertility. Since the dam's fertility record is not a dependable index of her ability to breed true for fertility, the only satisfactory test is the progeny test, for fertility seems to depend upon many as yet unrecognized factors, or else is not an inherited characteristic.

Section 5. Correlation in Hatchability between Mothers and Daughters.

The identical group of dams and daughters used in table 4 has again been correlated in table 5, using percentage of fertile eggs hatched.

TABLE 5. — *Correlation in Hatchability Between Mother and Daughter.*

Dams' Hatchability, Per Cent.	Daughters' Hatchability, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9							1														1
10–14													1								1
15–19	1																				1
20–24	1										1										2
25–29	3											2									5
30–34	1	1		1			1			1		2	1				1				9
35–39	4					2	1						5	3	1		2	1			19
40–44	6			2	2				3	3	1	1		1			1	1		3	24
45–49	7	3	2	1	2	1		3			1	2	3		2						27
50–54	7	2	1		1	1	1		3	1	1	1	3	1	1	7	1	1	1	2	36
55–59	10	1	3	1	4	4	3	2	4	1	2	3	9	3	5	5	2	1	3	1	67
60–64	13				3	3	4	4	3	6	3	2	8	4	7	9	4	3	3	5	84
65–69	18		1	2	4	2		2	4	2	5	4	11	6	4	7	5	2	4	3	86
70–74	8	2	1	2	2	2	4	3	1	1	9	3	6	2	3	8	5	4	3	1	70
75–79	28		4	4	3		4	3	2	4	6	2	7	12	5	8	6	9	1	7	115
80–84	11			2		1	6	3	2	2	3	4	8	5	6	6	4	10	5	4	82
85–89	11	3	3	1	1	3	2	2		1	1	4	3	8	6	9	6	6	4	5	79
90–94	6	2	1	1		2	1	3	1	2	3	2	7	6	7	7	5		6	5	67
95–100	2					2		2			2	2	3	2	3	4	6	2	3	3	36
f.	137	14	16	17	22	23	28	27	23	24	38	34	75	53	50	70	48	40	33	39	811

Constants calculated from Table 5.

Dams' mean hatchability	.7064 ± .003891
Dams' standard deviation	.1643 ± .002752
Daughters' mean hatchability	.5091 ± .007340
Daughters' standard deviation	.3099 ± .005190
Coefficient of correlation	.1960 ± .022805

Table 5 undoubtedly shows that hatching power is transmitted from mother to daughter, yet while the dam's mean hatchability is .7064, her daughter's mean was only .5091. The standard deviation of dams was .1643 and their daughters' standard deviation was .3099. Thus the range of variation in daughters as measured by the magnitude of their standard deviation is almost double that of their dams. Such would be the case if a dominant factor is present for high hatchability. This relative variability is in exact agreement with the same observation on fertility as pointed out in section 4.

There is a positive correlation coefficient of .1960±.022805 between dams and daughters in hatchability. During the progress of the experiment, the pullet breeders used on successive years came from pullet mothers that showed a good hatching percentage. In other words, the pullets that were used as breeders in any one year came from pullet dams that had laid eggs of good hatching power. According to Pearson ('03) rigid selection in parents may reduce the correlation between parent and offspring for the character in question. Since we have no fertility and hatchability records for the flock as a whole, it is impossible to mathematically measure the effect of such selection on our flock.

Pearl ('09) reports a correlation coefficient of only $.031 \pm .072$ between mothers and daughters in hatchability, but only 87 individuals were studied. Dunn ('23) states that he was unable to separate high and low hatching lines by two generations of selection. He did find, however, that families tend to become different in hatching power and to retain this difference.

Table 5 clearly indicates that hatching power is transmitted from mother to daughter, even though rigid control of the many environmental factors that modify the hatching power is very difficult. These varying conditions often obscure the true hatching ability of the pullet as an individual. The use of breeding females of high hatching power is the first step toward improving the flock in this particular characteristic. We have shown in section 3 that the hatching power of a pullet is sensibly correlated with her later hatching power. Follow this by using breeding hens that transmit high hatchability to all of their daughters. The male's part in heredity of hatchability will next be considered.

PART II.

The Male's Rôle in Inheritance of Fertility and Hatchability.

Section 6. The Constancy of Fertility in Males.

In studying the question of the inheritance of fertility and hatchability, much importance should be attached to the male side of the flock, for the male is more than half the flock from a genetic standpoint because each male furnishes half the inheritance to the progeny of several hens.

The measure of the male's fertilizing ability is the mean degree of fertility from his different matings. The accuracy of such a measure will of course depend upon whether or not high fertility is governed in inheritance by dominant or recessive factors, or whether it is independent of Mendelian factors. If high fertility depends upon recessive factors, we should expect less variation in the daughters from a hen that carries these factors pure, so that she herself is genetically highly fertile, than would be the case if high fertility is dependent on dominant factors and these were not in homozygous condition. The fact that manifestation of fertility in the eggs is probably dependent on both male and female makes the classification of either males or females with regard to this characteristic a hazardous undertaking. A careful analysis of the results from mating specific males to a number of females in successive years with conditions kept uniform would help much to explain this confusing problem.

The problem of the constancy of a male's ability to transmit a certain degree of fertility to his daughters may be elucidated by correlating the fertility of his daughters sired during his first breeding year with that of his daughters sired during the second breeding year, using pullet records in all cases. In other words, if males transmit a certain degree of fertility to their daughters in successive years, a positive correlation will exist. Such a tabulation is made from data available in table 6. Unfortunately, records on only 51 pairs of daughters are obtainable for study. The number is small because few males are used as breeders after their cockerel year.

TABLE 6.— *Correlation in Fertility between Males' First and Second-Year Daughters.*

Fertility of Males' First Year Daughters, Per Cent.	Fertility of Males' Second Year Daughters, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4	2											1					1		1		5
5–9											1									1	2
10–14																					
15–19																			1		1
20–24																	1		1		2
25–29																		1			1
30–34																					
35–39																					
40–44															1					1	2
45–49																				1	1
50–54																					
55–59																				1	1
60–64			1																		1
65–69															1	1					2
70–74																	1			2	3
75–79								1		1			1							2	5
80–84											1					1				4	6
85–89																				2	2
90–94											1							1	1	1	4
95–100					1			1			1			1	1				3	5	13
f.	2	0	1	0	1	0	0	2	0	1	4	1	1	1	3	2	3	2	7	20	51

Constants calculated from Table 6.

First-year daughters' mean fertility	$.6651 \pm .031064$
First-year daughters' standard deviation	$.3289 \pm .021966$
Second-year daughters' mean fertility	$.7700 \pm .025001$
Second-year daughters' standard deviation	$.2647 \pm .017678$
Coefficient of correlation	$.2151 \pm .090076$

In table 6 the mean fertility of the first-year daughters was .6651 while the mean for the second-year daughters was .77. There is a difference of $.1049 \pm .0399$, which, judged by the magnitude of its probable error, is of doubtful significance. There is also no sensible difference in the standard deviation of first-and second-year daughters. A sensible degree of correlation between first-and second-year daughters is questionable because $r = .2151 \pm .090076$. The probable error is almost half as great as the coefficient itself. The only logical interpretation that can be placed on the limited data in table 6 is that mean fertility in the daughters of the same group of males in successive years is strikingly constant, and in the second place that a positive correlation coefficient of questionable magnitude exists between first-and second-year daughters in fertility. More data of a similar nature are required to clear up this question.

Section 7. The Constancy of Hatchability in Males.

The male's ability to transmit fertility is still questionable, as has been pointed out in section 6. In the present section the subject of the constancy of hatchability in the male, as measured through his daughters, will be considered. The same difficulties are encountered in studying this question that have already been mentioned for fertility. Possibly environmental factors are of less importance in hatchability than in fertility. Pearl ('09) believes that hatching quality is more of an innate constitutional character than is fertility. If hatching quality is dependent upon Mendelian factors in inheritance, the degree of correlation between hatchability of the eggs of first-year daughters and the eggs of second-year daughters would vary with the number of factors concerned, and with the degree of homozygosity in the males for these factors. Should there be a sensible positive correlation, it would indicate that the male as well as the female transmits hatching power to the offspring.

In table 7, the group of 51 pairs of daughters studied in section 6 is tabulated for hatchability.

TABLE 7. — *Correlation in Hatchability between Males' First and Second-Year Daughters.*

Hatchability of Males' First Year Daughters, Per Cent.	Hatchability of Males' Second Year Daughters, Per Cent.																				
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4	6		1	2	1			1				2	2		3			1	1		20
5–9																					
10–14		1																			1
15–19							1														1
20–24	1																				1
25–29	1														1		1				3
30–34	1						1				1		1		1						5
35–39									1												1
40–44									1		1										2
45–49	1																	1			2
50–54	1														1		1	1			4
55–59	2																		1		3
60–64												1				1					2
65–69																1	1				2
70–74																					
75–79															1					1	2
80–84																					
85–89					1										1						2
90–94																					
95–100																					
f.	13	1	1	2	2	0	2	1	2	0	2	3	3	0	8	2	3	3	2	1	51

Constants calculated from Table 7.

First-year daughters' mean hatchability	$.2965 \pm .025445$
First-year daughters' standard deviation	$.2694 \pm .017992$
Second-year daughters' mean hatchability	$.4484 \pm .031130$
Second-year daughters' standard deviation	$.3296 \pm .022013$
Coefficient of correlation	$.2996 \pm .085972$

Referring to table 7, the mean hatchability of first-year daughters is .2965, while the second-year daughters of the same male have a mean of .4484. The difference is $.1519 \pm .0336$, which is a significant difference. The second-year daughters appear to be superior to the first-year daughters in hatching power. To draw any conclusion, however, on such meager data would be more than hazardous. The standard deviation does not differ significantly in the two groups of daughters.

A sensible positive correlation of .2996±.085972 appears between first-year pullet daughters and second-year pullet daughters in hatchability. Table 7 thus furnishes a very small amount of evidence that hatching power is transmitted through the male, and that it is a more constant character than would be possible were it independent of heredity.

Section 8. Relation between the Fertility of the Sire's Dam and His Phenotypical Fertilizing Ability.

As there is no direct measure of a sire's phenotypical fertilizing power, it is necessary to resort to the indirect, which is the average fertility of his mates. The degree of fertility in the sire's dam may be something of a guide to his inheritance. The pertinent question at this point is: Is the degree of fertility of a cockerel's mother a guide to his ability to fertilize the eggs of his mates? If such be the case, there should be a sensible positive correlation between sire's dam's fertility and his mates' fertility. In table 8 the dams of cockerels used throughout the eleven-year period have been tabulated with the mates of these cockerels. The record of any particular dam was used against each of the mates of her son. The total number of mates was 647.

TABLE 8. — *Correlation in Fertility Between Sires' Dams and Sires' Mates.*

Sires' Dams' Fertility, Per Cent.	Sires' Mates' Fertility, Per Cent.																				f.
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	
0–4																					
5–9																		1	2	1	4
10–14																					
15–19																					
20–24				1											1	1		3	3	2	11
25–29																					
30–34																					
35–39												1	1		1			1		9	13
40–44																					
45–49																					
50–54																					
55–59															1	1	1	2	1	12	18
60–64							1	2		1	1	1	2	1	3		7	5	4	15	43
65–69						1			1	2		1	1	7	4	4	4	2	7	15	49
70–74						1	1		1					2	2	2	3	4	14	21	51
75–79					1					1				2		1		2	2	6	15
80–84			2		2		3	3	2	1	5		5	5	10	6	9	11	23	48	135
85–89									1						1	1		2	3	18	26
90–94						1		2	1	1		4	2	1	3	2	5	10	15	46	93
95–100				1			1	2	3	3	1	1	6	5	4	9	14	14	26	99	189
f.			2	2	3	3	6	9	9	9	7	8	17	23	30	27	43	57	100	292	647

Constants calculated from Table 8.

Sires' dams' mean fertility	.8157±.004492
Sires' dams' standard deviation	.1694±.003176
Sires' mates' mean fertility	.8531±.004587
Sires' mates' standard deviation	.1730±.003244
Coefficient of correlation	−.1890±.025363

The mean fertility of the sires' mates is .0374±.00642 greater than the mean of the sires' dams. This is a small but significant difference and indicates that more attention was given to fertility from the female standpoint than from the male standpoint. The standard deviation is almost identical for both groups of females. A negative coefficient of correlation of .1890±.025363 appears rather difficult to explain. It certainly does indicate that the degree of fertility shown by sire's mother is not an index to the degree of fertility that such a sire will exhibit in his mates — his phenotypical fertilizing ability. This negative correlation may be due to selection of females to be used as breeders with more regard to high fertility in ancestry than is practised in selecting male breeders; or possibly males from the very fertile ancestry were mated to pullets that were lacking in fertility but otherwise desirable.

Section 9. Relation between the Hatchability of the Sire's Dam and His Phenotypical Hatching Ability.

The question of hatchability may be considered by the same methods used in section 8 in studying fertility. The identical group of birds is again tabulated for hatchability in table 9.

TABLE 9. — *Correlation in Hatchability between Sires' Dams and Sires' Mates.*

		Sires' Mates' Hatchability, Per Cent.																				f.
		0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	
Sires' Dams' Hatchability, Per Cent.	0–4													1	1					1	1	4
	5–9																					
	10–14																					
	15–19					1							1			2	1					5
	20–24																					
	25–29									1		1		1	2	1	2		2			10
	30–34		1			1		1		4	3	4	2	4	3	1	1		1		1	27
	35–39										1	1		1				1		1		5
	40–44									1	4	1	1	2	1		2	2				14
	45–49				1	1	1	3	3	2	3	2	4	2	4	3	2	1	3			35
	50–54						2	1		4	1	3	4	4	4	4	2	2	1	2		34
	55–59						1	3	3	1	1	5	2	7	5		3	3	3	2	2	41
	60–64				1		1		2	3	4	6	3	8	4	5	10	5	2	3	2	59
	65–69				1		2	2	1	2	2	2	1	2	2	7	6	3			2	35
	70–74	1	1	1		1	2	4	6	4	3	4	7	6	7	8	9	7	6	2	8	87
	75–79				1	2	1	2	1	1	3	4	2	10	9	7	11	3	4	2	3	66
	80–84		2	1		2		1	1	1	1	8	7	5	6	6	6	7	10	9	1	74
	85–89				1	1	2	1	3		3	3	3	5	7	7	6	2	3	1	1	49
	90–94				1			1		1				3	2	6	8	4	5	5	1	37
	95–100				1		2	2		2	1	2	1	6	10	4	8	8	9	6	3	65
	f.	1	4	2	7	9	14	21	20	27	30	46	38	67	67	61	77	48	49	34	25	647

Constants calculated from Table 9.

Sires' dams' mean hatchability	.6977±.005115
Sires' dams' standard deviation	.1929±.003617
Sires' mates' mean hatchability	.6488±.005229
Sires' mates' standard deviation	.1972±.003698
Coefficient of correlation	.1579±.025856

The average hatching ability of the sires' dams is .6977±.005115, while that of the sires' mates is .6488±.005229. There is a difference of .0489±.007314, which means that the males used as breeders came from dams of higher hatching power than was inherent in the pullets to which they were mated. The almost identical standard deviation for the two groups points to a similar variability in hatching power for the two.

The coefficient of correlation between the sires' mothers and their mates is .1579 ±.025856, a small but sensible correlation. Possibly this can be interpreted as meaning that males tend to show a phenotypical hatching power comparable with that of their dams. In selecting cockerels for breeders, hatching power of their dams is something of a guide to their ability to contribute hatching power to the eggs they fertilize. There is considerable probability that the male does influence the hatching power of his mates' eggs.

Section 10. Relation of Sire's Average to his Daughters' Individual Fertility.

In considering the fertilizing and hatching power of males, it is necessary to use some measure of their phenotypical character. This fact has been pointed out by Pearl ('09) and, as he states, the average fertility and hatching power of hens mated to a male may be used as his index. In table 10 the average fertility of each sire from his different mates is tabulated against the fertility of each of his daughters. This average figure for each sire is thus inserted a number of times to correspond with the number of his daughters that were used as breeders.

TABLE 10. — *Correlation in Fertility Between Sires' Mates and Sires' Daughters.*

Sires' Mates' Fertility, Per Cent.	Sires' Daughters' Fertility, Per Cent.																				f.
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	
0–4																					
5–9																					
10–14																					
15–19																					
20–24																					
25–29																					
30–34																					
35–39																					
40–44																					
45–49																		1			1
50–54																					
55–59											1	1		2	1		2		2	4	13
60–64																			1		1
65–69								1							1		2	4	6	3	17
70–74								1	1		1		1	1			1	1	1	11	19
75–79					1		1	1		1			1		2	4	1	5	2	14	33
80–84				1							1	1	2	3	4	3	5	4	11	11	46
85–89						1				2	1	1			5	2	8	4	8	22	54
90–94						1		1	3	1	1		5		4	3	3	10	12	34	78
95–100				1	1	1		2	2	1	1	2	4	13	8	5	13	17	21	58	150
f.				2	2	3	1	6	6	5	6	5	13	19	25	17	35	46	64	157	412

Constants calculated from Table 10.

Sires' fertility mean . . . . .8761± .003522
Sires' fertility standard deviation . . . . . . .1060± .002491
Sires' daughters' mean fertility . . . . .8416± .005599
Sires' daughters' standard deviation . . . . . .1685± .003959
Coefficient of correlation . . . . .0244± .033211

A difference, amounting to .0345±.006614, will be observed between the sires' mean fertility and their daughters' mean fertility. This significant difference is easily explained if the same factors are operating to affect fertility of males and females. A wider range of variability in the daughters as compared with their sires, measured by the standard deviation, seems to indicate that there is little or no constancy in fertility between father and daughter.

No sensible correlation in fertility exists between sire and daughters as table 10 shows. In the face of this fact, there is no evidence that factors for fertility are transmitted from sire to daughter. In other words, fertility does not seem to be an inherited trait that is transmitted from parent to offspring, as has already been shown in both tables 4 and 10.

Section 11. Relation of Sire's Average to Daughters' Individual Hatchability.

The same group of birds used in table 10 is correlated in table 11 to study the relationship between sire and daughters in hatching power.

TABLE 11.—*Correlation in Hatchability between Sires' Mates and Sires' Daughters.*

Sires' Mates' Hatchability, Per Cent.	Sires' Daughters' Hatchability, Per Cent.																				f.
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	
0–4																					
5–9																					
10–14																					
15–19																					
20–24																					
25–29									1		2										3
30–34																					
35–39																					
40–44								1		1		1				2					5
45–49			1							2	3	1				2	1	2			12
50–54								4	4	1	2	5	4	8	2	4	1	2	2	2	41
55–59							1	1	1	1		6	10	1	5	3	3	4	3	1	40
60–64				2	3	1	3	2	1	4	5	1	6	6	8	6	4	5	2	3	62
65–69				2		2	1	3	2	2	2	3	5	2	5	9	4	3	1	2	48
70–74					1	2	3	1	2	2	5	5	10	10	8	10	3	8	8	4	82
75–79						1	1	2	1	2			2	1	2	5	4	2	3		26
80–84	1						1				6	1	7	10	4	11	8	4	4	3	60
85–89														1	2	2	3	2	4	1	15
90–94										1			2		5	3	2	2	2	1	18
95–100																					
f.	1		1	4	4	6	10	14	12	16	25	23	46	39	41	57	33	34	29	17	412

Constants calculated from Table 11.

Sires' hatchability mean	.6824 $\pm$ .004084
Sires' hatchability standard deviation	.1229 $\pm$ .002888
Sires' daughters' mean hatchability	.6753 $\pm$ .006217
Sires' daughters' standard deviation	.1868 $\pm$ .004396
Coefficient of correlation	.2268 $\pm$ .031523

The mean hatchability of the sires is almost identical with that of the daughters. This is in striking contrast to the mean of dams and daughters given in table 5 where the figures are .7064 $\pm$ .003891 and .5091 $\pm$ .003740, respectively. Such evidence might be interpreted as showing that a closer relationship exists between sires and daughters than between dams and daughters in hatching power. Such a relationship is probably due entirely to the somewhat dissimilar methods for measuring hatching power in sire and dam. The range of variability is greater in daughters than in sires evidently because of the variable nature of the males mated to these daughters.

The coefficient of correlation between sires and daughters is .2268 $\pm$ .031523. Comparing this factor with the factor calculated from table 5 where mothers and daughters are concerned, the two are found to be of almost identical magnitude when their probable errors are considered. Table 11 furnishes convincing evidence of the heritability of hatching power. In this instance, hatching power of sires is carried on in their daughters. Table 11 further points to the necessity of using tested males in developing a flock carrying uniformly high hatching power.

Section 12. Relation of Sire's Dam to his Daughters' Fertility.

In section 8 the relation between sire's dam and his phenotypical fertilizing ability has been considered. A negative relationship was found to exist in that case. The present section is an attempt to discover if the sire transmits to his daughters a degree of fertility similar to that of his dam, so that when these daughters are mated with other males their probable fertility may be forecasted. In table 12, 748 pullet fertility records are tabulated with the fertility records of their sire's mother as a pullet.

TABLE 12.—*Correlation in Fertility between Sires' Dams and Sires' Daughters.*

Sires' Dams' Fertility, Per Cent.	Sires' Daughters' Fertility, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9															1		1	1	1		4
10–14																					
15–19																					
20–24	1										1		1	1			1	2	1	3	11
25–29																					
30–34																					
35–39													1			2			1	3	7
40–44																					
45–49																					
50–54																					
55–59	1										2				1	1	1	2	4	5	17
60–64	2	1			4	1	1	1	1		1		2	5	4	4	2	1	3	17	50
65–69	1			1	2	3		2		2	2			1	4	4	6	5	6	28	67
70–74	5				1	2		4	2	2	2	2	1	7	4	2	7	3	7	21	72
75–79		1					1				1					1	1	3	1	9	18
80–84	15	2	1	2	1			3	1	1	3	2	4	6	6	9	5	9	27	52	149
85–89	1				1				1	1		1	1	1	1	3	3	4	4	7	29
90–94	14	1	1			1	3		2	3	6	3	4	5	7	5	10	16	14	29	124
95–100	12		1	3	5	1	3	4	6	5	4	4	9	7	12	8	13	27	19	57	200
f.	52	5	3	6	14	8	8	14	13	14	22	12	23	33	40	39	50	73	88	231	748

Constants calculated from Table 12.

Sires' Dams' Mean Fertility	$.8183 \pm .003909$
Sires' Dams' Standard Deviation	$.1585 \pm .002764$
Sires' Daughters' Mean Fertility	$.7364 \pm .007108$
Sires' Daughters' Standard Deviation	$.2882 \pm .005026$
Coefficient of Correlation	$-.0501 \pm .024599$

The mean fertility of the dams of the males used in this study is $.0819 \pm .008112$ greater than the mean for the daughters of these males. The males used, therefore, came from dams of high fertility but the daughters of these males failed to measure up to such a standard. The standard deviation of the daughters is almost twice as great as for the sires' dams, showing that the daughters are a highly variable lot. The coefficient of correlation is negative but insignificant because of the magnitude of its probable error. The conclusion seems justified, therefore, that the degree of fertility of a sire's dam is no index to the degree of fertility that his daughters will exhibit.

Section 13. Relation of Sire's Dam to his Daughters' Hatchability.

If the hatching power of a sire's dam is something of an index to his probable inheritance of factors affecting hatchability, such relationship will appear when the hatchability records of the daughters are tabulated with the records from the sires' dams. Table 13 is thus made up of the same birds used in table 12.

TABLE 13.—*Correlation in Hatchability between Sires' Dams and Sires' Daughters.*

Sires' Dams' Hatchability, Per Cent.	Sires' Daughters' Hatchability, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9																					
10–14																					
15–19				1			1				1		2			1				1	7
20–24																					
25–29	2							1	1	1		1	1	1		1		2			11
30–34	3	3	1		2	2	2	2	1		2	1	4	1	1	3	1		1	1	31
35–39		1					1	1		1			1								5
40–44	6	1	1		2		1	1	2	2	1	2	2	3		3	2				29
45–49	16	2	4	2	2	1		1	1	2	2	4			1	1		3		1	43
50–54	2			1	2	1	3		4		2	1	3	1	1	1	2	2	2	2	30
55–59	6			1	2		1	2	1	1	3	1	1	8	2	3	2	2	3	3	42
60–64	12			1	1	3	1	1		3	3	3	10	3	6	11	6	5		3	72
65–69	1						1						1		2	1	4				10
70–74	13	2	1	1	4	3	5	6	7	2	4	8	10	12	7	11	4	12	8	2	122
75–79	12		1	3	2	3	1	3		1	4	3	6	6	7	9	8	2	4	3	78
80–84	18	2	2	2		2	5	5	3	5	3	5	14	8	9	7	7	3	6	9	115
85–89	7		1		2	1	1				3		4	4	2	1	1			2	29
90–94	2					3	1	3	2	1	1	1	2	3	2	4	4	4	1	4	38
95–100	26	1	1	4		2	4	1	1	4	3	5	5	2	5	9	3	1	7	2	86
f.	126	12	12	16	19	21	28	27	23	23	32	35	66	52	45	66	44	36	32	33	748

Constants calculated from Table 13.

Sires' Dams' Mean Hatchability	$.7019 \pm .004664$
Sires' Dams' Standard Deviation	$.1891 \pm .003298$
Sires' Daughters' Mean Hatchability	$.5096 \pm .007588$
Sires' Daughters' Standard Deviation	$.3077 \pm .005366$
Coefficient of Correlation	$.0588 \pm .024576$

The mean hatching power of the hens whose sons were used for breeding was .7019. The daughters of this group of males averaged only .5096 of fertile eggs hatched. This difference in the means amounts to $.1923 \pm .008906$ and is a much more striking difference than was observed between the same group of females in fertility. The standard deviation of the two groups agrees with that found for fertility in table 12. Again the daughters of the males show almost double the range in variability of their sires' dams.

The coefficient of correlation is here positive, but of no significance since it is a little more than twice its probable error. The lack of correlation between sire's dam and sire's daughters in hatchability can scarcely be interpreted to show that hatchability is not governed by factors transmitted from sire to daughter. The hatching power of a cockerel's dam is only the phenotypical manifestation of her ability and may be affected by her mate as well as by numerous environmental factors. She furnishes, moreover, but a part of the heritage of her son. If several factors governing hatchability are transmitted equally by males and females and if both parents have an influence on the hatching power of eggs laid and fertilized, respectively, this apparent independence of hatching power in inheritance will be explained.

If fertility be governed by genes transmitted in Mendelian fashion and without sex-linkage, this fact should be brought out by correlating the sire's record with his son's record. The only measure is the fertility record of the eggs laid by females mated to such males. If it were possible to compare males by a system of mating to the same group of females, the variable factors could be reduced to the male side alone. Such a system seems impossible to attain because of numerous factors too well understood to require mention.

Section 14. Relation of Sire and Son in Fertility.

TABLE 14.—*Correlation in Fertility between Sires and Sons.*

Sires' Fertility, Per Cent.	Sons' Fertility, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9																					
10–14																					
15–19																					
20–24																					
25–29																					
30–34																					
35–39														1		2					3
40–44																		1			1
45–49					1															2	3
50–54																					
55–59																	1			1	2
60–64																				1	1
65–69										1				1	1					3	6
70–74								1								1	4	1	3	4	14
75–79																		1	2	4	7
80–84						1					1		1		1		3	3	3	6	19
85–89								1							2	1	2	2	2	5	15
90–94								1	1				1	2	2	1	2	3	3	9	25
95–100								1	3	2		1	2	3	3	3	6	6	12	32	74
f.					1	1		4	4	3	1	1	4	7	9	8	18	17	25	67	170

Constants calculated from Table 14.

Sires' Mean Fertility	.8682 ± .007041
Sires' Standard Deviation	.1361 ± .004979
Sons' Mean Fertility	.8441 ± .008660
Sons' Standard Deviation	.1674 ± .006124
Coefficient of Correlation	.0685 ± .051486

In table 14 each pullet mate of a sire is paired with a pullet mate of his son. The number of pairs concerned is 170 and the number of sires included is about the same as the number of sons included. The mean fertility of the sires and their sons is not significantly different, and the range in variability of sires and sons, as measured by the standard deviation, is about the same. The coefficient of correlation is very small and its probable error renders it negligible. The only conclusion that may be drawn from this small amount of data is that either the fertility record of a male's mates is not a reliable index to his inherent fertilizing ability, or else degree of fertility is not transmitted from sire to son.

In the next section the relation of hatchability of sire and son will be considered for the same birds that were used in studying fertility.

Section 15. Relation of Sire and Son in Hatchability.

TABLE 15. — *Correlation in Hatchability Between Sires and Sons.*

Sires' Hatchability, Per Cent.	Sons' Hatchability, Per Cent. 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–100	f.
0–4																					
5–9																					
10–14																					
15–19											1										1
20–24																1					1
25–29							1		1							1	1			1	5
30–34												1	1								2
35–39					1		1	1			1		1	1			1				7
40–44					1					3	1			1	2	1		1			10
45–49							2				1	2	1	2	1	1					10
50–54								1			1	1	2	1	1			1	1		9
55–59							1	1	1		1	1	4	4	1					2	16
60–64										1	3		1	1	3	2	1		1	1	14
65–69					1								1	1	2	4	1	2	1		13
70–74									2	1	1		1	1	1	1		1		1	10
75–79				1						1		1	3	3		4	1	2	1	1	18
80–84						1		1		1	1	2	3		1		1	1		1	13
85–89									1	2	2		3	1	3	1		1			14
90–94				1				1			1			2	2	3	1	1			12
95–100				2		1		1			1		1	1	2	2	1	1	1	1	15
f.				4	3	2	5	6	5	9	15	8	22	19	19	21	8	11	5	8	170

Constants calculated from Table 15.

Sires' Mean Hatchability	.6738± .010274
Sires' Standard Deviation	.1986± .007265
Sons' Mean Hatchability	.6418± .009720
Sons' Standard Deviation	.1879± .006873
Coefficient of Correlation	.0755± .051440

Reference to table 15 shows that the mean degree of hatchability is almost the same in sires and sons. The two groups are also closely similar in standard deviation. There is no sensible correlation between father and son in hatchability. The degree of correlation here is practically the same as that observed for fertility in table 14. If we are using the correct measure for a male's hatchability, there is no evidence in these data to show that hatching power is transmitted from sire to son.

Section 16. Mendelian Interpretation of the Inheritance of Fertility and Hatchability.

Before entering upon a discussion of the possibilities of Mendelian inheritance of factors governing fertility and hatchability, it would seem desirable to present the mean records in the flock from year to year. These means are given below in table 16 along with the number of birds tested each year.

Table 16. — *Mean Fertility and Hatchability Records from the Massachusetts Agricultural Experiment Station Flock.*

Year.	Average Fertility.	Average Hatchability.	Number of Birds.
1913	.7562±.016855	.5910±.016578	73
1914	.8300±.015294	.5793±.016514	67
1915	.8308±.012692	.5613±.013015	118
1916	.8834±.010973	.6469±.015942	62
1917	.9158±.009776	.6217±.014709	78
1918	.8821±.009917	.6502±.013599	89
1919	.8882±.014611	.6941±.014602	56
1920	.8647±.014243	.6861±.017473	51
1921	.9107±.012241	.7483±.014129	59
1922	.8746±.010910	.7449±.011125	89
1923	.7749±.011944	.7051±.011399	144

The fertility mean has fluctuated appreciably from year to year and has not increased during the past six years. The low fertility of 1923 can be attributed to no other cause than adverse weather conditions throughout the winter and spring months. The majority of the males seem to have suffered from more or less frosting of combs and wattles during the winter of 1922–23. The basis of selecting breeding males for 1923 was not voluntarily changed from that of previous years. The general deduction must therefore be made, as Pearl ('09) has done, that fertility is dependent largely upon environmental factors and that it is not an inherent characteristic that is transmitted in inheritance.

Table 16 indicates an increase of .1141±.0206 in mean hatchability from 1913 to 1923. This increase is mathematically significant. There has been a gradual upward trend in mean hatching power since 1915. This increase has accompanied the use of breeding pullets and breeding cockerels from mothers showing good hatching power. The .04 drop in hatchability in 1923 is within the range of probability and need not be considered.

Relation of Male to the Hatching Power of his Mates' Eggs.

Unmistakable evidence is available to show that the male contributes to the hatching power of his mates' eggs. For want of any more suitable term we have used "male's phenotypical hatching power" to express the male's part. In table 9 a positive correlation coefficient of .1579±.025856 was observed between the sire's dam, and his phenotypical hatching power. A sensible correlation could not exist unless the male contributes to the hatching power of his mates' eggs.

The most conclusive evidence that the male influences the hatching power of his mates' eggs lies in the fact that the same hen shows different hatching power when mated to different males in successive years or even in the same year. Such data should be placed beside data showing the degree of constancy of hens in hatchability when mated to the same male on successive years. No data are available on the last-named question from our flock, although table 3 brings out a degree of correlation between first and second year hatchability in hens, amounting to .4346±.034409. The correlation should be much greater if the male did not play a part. In section 5 a sensible correlation between mothers and daughters was discovered. Reference to the constants calculated from table 5 shows that the hatching power of a hen is an uncertain guide to the probable hatching power of her daughters. The relative magnitude of the standard deviation of dams and daughters indicates that the phenotypical hatching power of a hen is an uncertain index of her true genetic constitution. This fact would seem to indicate that the male obscures the true genotype of the hen.

Data from the flock of the Massachusetts Agricultural Experiment Station on the constancy of hatching power in males is very limited. In table 17 a comparison is made between the first-year hatching power and second-year hatching power of

15 males. The figure used for each male represents the mean for all of his mates. These males were used on the following years: — 2 in 1913 and 1914, 4 in 1914 and 1915, 2 in 1915 and 1916, 2 in 1916 and 1917, 1 in 1917 and 1918, 2 in 1919 and 1920, 2 in 1922 and 1923.

TABLE 17. — *Mean Hatchability of Males.*

MALE NO.	First Year.	Second Year.
A323	57.00	55.80
A324	59.19	57.93
68	38.67	52.17
228	59.50	67.75
619	59.00	49.75
A271	70.71	67.40
A274	50.23	63.50
3617	53.93	64.40
5470	62.00	70.75
5581	59.29	65.00
8528	71.83	72.62
B2776	67.00	75.00
B2828	64.13	85.50
C901	76.20	65.00
C938	70.57	74.44

Mean first year, .6128±.016043; Mean second year, .6580±.015825; Difference in means, .0452±.0225.

Although the data are meager in table 17, we can give it no other interpretation than as indicating that the male does partly control the hatching power of his mate through dominant factors.

The mean hatchability for the fifteen males during the first year is .6128±.016043, for the second year .6580±.015825. There is a difference of .0452±.0225. This difference is just double its probable error and can therefore be of no consequence. The point we wish to emphasize in table 17 is the striking constancy in phenotypical hatching power of the same male, even when mated to different hens on two successive years. Such a degree of constancy was not found to exist in hens, as table 3 shows. The mean pullet-year hatching power of the hens was .5678±.011313. The mean second-year hatching record of the same hens was .4791±.012963. The standard deviation is nearly three times as great for the hens as for the males. The difference in the mean hatching power for the same hens on two successive years is .0887±.0172, which is significant. The genetic interpretation given below will serve to elucidate several apparent complications.

Genetic Factors Concerned[1]

One dominant gene seems to be concerned in the production of high hatchability. We use the symbol H to designate this gene. There is no sex linkage and all results obtained are to be expected in a simple mono-hybrid ratio. With this hypothesis, three possible genotypes of males and females exist, namely, HH, Hh, and hh individuals. The genotype is obscured in most cases for both males and females. Such being the case, only the breeding test can be used as a guide for matings.

Hatching records on 886 females studied in this report show that these birds divide themselves into three general classes or phenotypes: — (1) Those showing hatchability of 85 per cent or above, we call high. (2) Those with a hatchability of 55 to 84 per cent, we call medium. (3) Those below 55 per cent, we call low. Since factor H has a cumulative effect, the range for the medium class is twice as great as for the high class. The minimum for the low class has not yet been determined. Below are summarized the males' phenotypical and genotypical classes:

[1] A detailed report on the genetics of hatchability will appear in another publication.

Males' Phenotypical Character.

HH males on HH hens give all high hatchability.
HH males on Hh hens give all medium hatchability.
HH males on hh hens give all medium hatchability.
Hh males on HH hens give all high hatchability.
Hh males on Hh hens give all medium hatchability.
Hh males on hh hens give all low hatchability.
hh males on HH hens give all medium hatchability.
hh males on Hh hens give all low hatchability.
hh males on hh hens give all low hatchability.

Males' Genotypical Character.

HH males on HH hens give all HH daughters.
HH males on Hh hens give 50% HH and 50% Hh daughters.
HH males on hh hens give all Hh daughters.
Hh males on HH hens give 50% HH and 50% Hh daughters.
Hh males on Hh hens give 25% HH, 50% Hh, and 25% hh daughters.
Hh males on hh hens give 50% Hh and 50% hh daughters.
hh males on HH hens give all Hh daughters.
hh males on Hh hens give 50% Hh and 50% hh daughters.
hh males on hh hens give all hh daughters.

Both parents must carry the H factor in order to be phenotypically good hatchers. Hens cannot rank in the first class unless they carry the gene H in homozygous condition and are mated to H-bearing males. These observations indicate a cumulative value for the factor H and show why the male by failure to contribute at least one-half H-bearing sperm ranks a genotypically high hen as a medium hatcher. Furthermore, both HH and Hh males probably give about the same hatching record from HH hens. The progeny test alone can give a clue to the genetic composition of males if pullets of unknown formulæ are used as breeders.

Selection for high and low hatchability did not give results in two generations according to Dunn ('23). The probable explanation is that he used in his low line genotypically high (HH) hens that gave medium hatching records because they were mated to hh males. If such were the case, no appreciable separation could take place in but two generations. There may also have been a lack of HH or Hh males in his high line. Selection for high hatchability with the female as a guide and using cockerels from hens that hatched well has been a slow but progressive process in our flock, as already shown in table 17. In table 9, the mean hatchability of the dams of the males used for breeders is about 70 per cent. This would indicate that, on the average, the breeding males came from Hh hens. Thus, only in the later years of the period could any considerable percentage of males have been of the formula Hh. A study of earlier records shows that practically all the males must have been of hh composition, because they came from medium or low-hatching dams.

SUMMARY.

1. No correlation was found between fertility and hatchability in 758 pullets.
2. Fertility in the hen behaves as an individual characteristic with a fair degree of constancy from year to year.
3. Fertility does not appear to be transmitted from mother to daughter.
4. Hatching power is more constant from year to year in the same hen than is fertility.
5. Hatching power gives evidence of being transmitted from mother to daughter.
6. Fertility in the male behaves as an individual characteristic and probably with some constancy in the same individual from year to year.
7. The fertility record of a hen is no index to the fertilizing ability of her sons.
8. Fertility does not appear to be transmitted from sire to daughter.
9. Hatchability is more constant from year to year in the same male than is fertility.
10. Fertility does not appear to be transmitted from sire to son.
11. The hatching power of a male cannot be judged by his dam's hatching record.

12. Hatching power gives evidence of being transmitted from sire to daughter.

13. Insufficient data are available on the transmission of hatching power from sire to son.

14. Fertility is evidently not an inherited characteristic.

15. Hatchability is evidently an inherited trait. High hatchability is dependent in inheritance upon one dominant gene. Both male and female parent govern the hatching record, thus obscuring the true genetic composition of either parent.

16. Genetically pure hens for high hatchability may be discovered through their own hatching record. Genetically pure males for high hatchability can be distinguished from males heterozygous for the factor only by the progeny test combined with mating tests. Both the mating and the progeny test should be used for choosing males to improve the flock in hatchability.

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CORRELATION STUDIES ON WINTER FECUNDITY

By F. A. HAYS, RUBY SANBORN and L. L. JAMES

In plant and animal breeding it is impossible to make or effect changes in one character without running the risk of profoundly modifying, sometimes unfavorably, other characters. Such is the common experience of poultry breeders, abundantly confirmed by scientific investigation. For this reason it is essential that the relation existing between the major character in which improvement is sought, and other characters with which it may be associated, be established. In this report the results of such a study in poultry breeding are presented. The bulletin is technical in its nature, and is addressed primarily to those poultry breeders who are attempting to make thorough study of the science on which their art is based.

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AGRICULTURAL EXPERIMENTAL STATION

AMHERST, MASS.

CORRELATION STUDIES ON WINTER FECUNDITY

By F. A. Hays, Ruby Sanborn and L. L. James

High winter egg production is very desirable from the poultry keeper's point of view for two reasons: first, prices for eggs are much more remunerative during the winter months than at any other season; second, winter egg yield is intimately correlated with annual egg yield (Hervey 1923).

The number of eggs that a pullet will lay from first egg to March first depends upon seven pairs of Mendelian factors as has been shown by Hays (1924). This being the case, winter egg production cannot be correctly considered as a simple physiological character but rather as the manifestation of the interaction of the characters of a complex. Such traits as sexual maturity, winter pause, intensity, and broodiness have a definite and measurable relation to the number of winter eggs when large numbers are considered. Each of these four major traits affecting winter fecundity is unquestionably subjected to and modified by varying conditions that we may call "environmental" for lack of a more specific term.

In the studies reported below an attempt has been made to measure by means of the coefficient of correlation the degree of association of some measureable variables with winter egg yield. The chief value of such a study lies in the fact that, knowing the relative importance of the variables considered in relation to winter production, the breeder should be able by controlling major variables such as age at first egg, hatching date, rate of growth, etc., to attain higher winter averages and to secure greater uniformity in the winter fecundity of his flock. For example, if the flock is mated in such a way as to secure only genetically early maturing pullets, the age at first egg will range from about 150 to 210 days, while in a flock such as ours that is not genetically pure for early maturity the age at first egg ranges from 150 to 300 days.

Data Available.

A total of 959 Rhode Island Red Pullets hatched in eleven weekly broods from March 25 to June 3, 1923 are studied. This flock includes rather heterogenious breeding when winter fecundity is considered. Included in this flock are birds bred for the following characteristics: high winter and annual fecundity, non-broodiness and broodiness, good color, inbred and outbred, and hatching power of eggs. Taken as a whole, this flock may be considered good, but not equal to the standards set by those birds bred for fecundity alone. The mean of 803 birds that have complete winter records is 45 eggs.

Coefficient of Correlation

Coefficient of correlation is here used as a measure of association or dependence of one trait upon another. For example, in a particular flock of pullets if the degree of correlation between age at first egg and winter egg record is −.64, such a constant indicates that large winter records depend on early maturity in 64 birds out of every hundred, and that sexual maturity is one very important factor in determining the winter record of such pullets. A + sign before the coefficient .64 would mean that late sexual maturity is associated with large winter egg records. Other factors, such as hatching date, 150-day weight, weight at first egg, daily gain in weight, etc., may be measured in a similar manner. A comparison of the coefficients of correlation for these different factors furnishes a measure of their relative importance. Selection based on the coefficient of correlation should be applied to flocks rather than to individual birds as is evident in tables 1 and 2.

The word *mean* has the same meaning as average. *Standard deviation* shows the range of variation of a group of individuals above or below the mean or average. If the mean hatching date is 6.68 and its standard deviation is ±2.95, the interpretation is that the average range in hatching date of the flock in question is from 3.75 (6.68 − 2.95 = 3.75) to 9.63 (6.68 + 2.95). The *probable error* is written with a ± sign after each coefficient of correlation. It is used as a measure of the reliability of the figure given. Thus the degree of correlation between hatching date and weight at 150 days is −.3293 ± .0194. The meaning is that if we add .0194 to the coefficient of correlation and also subtract .0194 from the coefficient of correlation, we obtain two figures, namely, .3099 and .3487. The chances are even that the true coefficient of correlation between hatching date and 150-day weight lies inside or outside of these limits. A coefficient of correlation at least three times as large as its probable error is considered as significant.

Hatching Date

Part of the data is presented below in tabular form to show the general relation of hatching date to weight at 150 days, weight at first egg, age at first egg, and winter production, together with the average number of birds concerned in all four cases. This table will be particularly useful for general reference.

Table 1.

Hatches	Avg. No. of Birds	Wt. at 150 Days—lbs.	Wt. at First Egg—lbs.	Age at First Egg—Days	Winter Egg Prod.
March 25 (1)	41	4.22	5.73	212	58
April 1 (2)	55	4.27	5.75	211	56
April 8 (3)	61	4.23	5.94	212	57
April 15 (4)	76	4.11	5.92	221	46
April 22 (5)	69	4.18	5.94	215	48
April 29 (6)	80	3.99	5.69	217	47
May 6 (7)	105	3.89	5.62	219	39
May 13 (8)	83	4.05	5.50	208	42
May 20 (9)	113	3.72	5.22	206	41
May 27 (10)	91	3.74	5.15	202	38
June 3 (11)	82	3.72	5.13	201	34

The 150-day weight is observed to decrease rather regularly as the date of hatching advances. This fact substantiates common observation that early hatching seems to be associated with rapid growth. The weight at first egg for the different hatches shows little consistency, but as a rule, the earlier hatched birds appear to be somewhat heavier than the late hatched. The inconsistency is no doubt due in large measure to the wide range in age at first egg. Age at first egg seems to be but little dependent upon hatching date. In the last three or four hatches, however, there appears to be a reduction in the average age at first egg. Hatching date is intimately associated with winter production. In other words, the early broods as a rule lay more winter eggs than later broods. In general, hatching date appears to influence the weight at 150 days and the winter production with probably some influence upon weight at first egg and age at first egg.

As already stated, the pullets were hatched at one week intervals beginning March 25 and ending June 3. Thus eleven different age groups are represented with a range in age of 70 days. Hatching date is studied in relation to weight at 150 days, weight at first egg, age at first egg, and winter production:

Hatching Date versus Weight at 150 Days

Number of birds	959
Mean hatching date	6.68
Hatching date standard deviation	±2.95
Mean 150-day weight	3.96
150-day weight standard deviation	±.56
Coefficient of correlation	−.3293±.0194

The fact will be noted that the mean hatching date is 6.68 (May 4) instead of 6.00 (April 29) as would be the case if each hatch had produced the same number of birds. The actual date may be calculated easily in each case. It is interesting to note that the pullets averaged 3.96 pounds at 150 days old.

The coefficient of correlation between hatching date and 150-day weight is $-.3293 \pm .0194$. This is a significant correlation and substantiates common observation that early hatching tends to give larger pullets at a given age than does late hatching. In about one case out of three there was direct association between early hatching and heavy weight. In the other two cases out of three there was no relation between 150-day weight and hatching date. Other influences were operating in two cases out of three to overcome any effect of hatching date on weight at 150 days.

Hatching Date versus Weight at First Egg.

Number of birds	820
Mean hatching date	6.66
Hatching date standard deviation	± 2.92
Mean weight at first egg	5.65
Weight at first egg standard deviation	$\pm .75$
Coefficient of correlation	$-.3807 \pm .0201$

The mean weight at first egg is 5.65 pounds. The coefficient of correlation between hatching date and weight at first egg is $-.3807 \pm .0201$. The correlation shows that early hatched pullets tend to be heavier when they lay their first egg than do their later hatched sisters. This fact is in accord with the observations on weight at 150 days. In four cases out of ten the weight at first egg is directly associated with hatching date. Possibly the degree of correlation between time of hatching and weight at first egg is greater than that between time of hatching and 150-day weight because late hatching tends to reduce the mean age at first egg as will be shown below.

Hatching Date versus Age at First Egg.

Number of birds	840
Mean hatching date	6.64
Hatching date standard deviation	± 2.92
Mean age at first egg	210.99 days
Age at first egg standard deviation	± 28.91
Coefficient of correlation	$-.1487 \pm .0228$

The mean age at first egg is 210.99 days and its standard deviation is 28.91. Thus the age range is wide as will be observed from the relative magnitude of standard deviation and mean.

The coefficient of correlation is negative and amounts to $.1487 \pm .0228$. Thus in one case out of seven late hatching is associated with early sexual maturity. Such a constant suggests that late hatching tends to reduce the length of growth period prior to laying and this is in part responsible for the lighter weight at first egg in late pullets compared with early ones as was pointed out in the previous section.

Hatching Date versus Winter Production.

Number of birds	802
Mean hatching date	6.59
Hatching date standard deviation	± 2.97
Mean winter production	44.48
Winter production standard deviation	± 23.06
Coefficient of correlation	$-.2920 \pm .0218$

The mean egg production of the 802 birds studied up to March first is 44.48. The magnitude of the standard deviation shows a wide range in winter fecundity within the flock. This wide range in fecundity is to be expected because of the range in hatching date and because of the range in age at first egg as well as because of genetic differences in the individuals in winter pause, intensity, and broodiness.

A negative coefficient of correlation amounting to .2920±.0218 exists between hatching date and winter production. All other conditions being the *same*, there could not but be a negative correlation because the early hatched pullets have longer to lay. The fact that in less than one case out of three is early hatching directly associated with greater winter egg yield can be due only to the condition that a good percentage of early hatched pullets complete their winter cycle of laying and lose considerable time in winter pause while fewer later hatched pullets actually pause.

By reducing the range in age at first egg, a more accurate measure of the degree of association between early hatching and high winter egg production is obtained. The coefficient of correlation has been calculated between hatching date and winter egg record using only those birds beginning to lay at 206 days or less. The constants obtained on this group are as follows:

Number of birds	418
Mean hatching date	6.96
Hatching date standard deviation	±3.19
Mean winter production	54.93
Winter production standard deviation	±21.06
Coefficient of correlation	−.4790±.0254

In the above group of birds the 70 day range in hatching date is greater than the 50 day range in age at first egg. In other words, all birds maturing at 206 days or less are the same genetically for sexual maturity as was pointed out earlier (Hays 1924). With such a group of birds high winter fecundity is associated with early hatching in fifty per cent of the cases.

Evaluating hatching date entirely from the standpoint of desirable characteristics that are associated with winter fecundity, these deductions seem warranted from the preceding four correlation studies: 1. That early hatched pullets are heavier in weight both at 150 days old and when they lay their first egg than are late hatched ones; 2. that late hatching tends to reduce the age at first egg; and 3. that early hatching gives greater winter egg yields, but there must be a certain optimum hatching time which gives the most uninterrupted winter egg production.

Winter Production.

The total number of birds is divided into classes of winter producers with a range of ten eggs beginning with those laying from 0 to 9 eggs and ending with those laying from 130 to 139 eggs during the winter season. Winter production is studied in its general relation to hatching date, age at first egg, weight at 150 days, weight at first egg, and daily gain in weight between 150 days old and age at first egg.

Table II

Winter Egg Production	Avg. No. of Birds	Hatching Date	Age at 1st Egg	Wt. at 150 Days—lbs.	Wt. at 1st Egg—lbs.	Daily Gain Between 150 Days Old and Age at 1st Egg—lbs.
0–9 (1)	36	7.32(M.8)	266	3.65	5.95	.021
10–19 (2)	78	6.94(M.5)	244	3.87	5.97	.024
20–29 (3)	112	7.32(M.8)	219	3.92	5.68	.025
30–39 (4)	134	7.32(M.8)	212	3.89	5.52	.027
40–49 (5)	110	7.05(M.6)	205	3.92	5.37	.026
50–59 (6)	124	6.71(M.4)	203	4.05	5.47	.027
60–69 (7)	93	5.97(A.29)	196	4.16	5.46	.029
70–79 (8)	57	5.14(A.23)	193	4.17	5.46	.029
80–89 (9)	26	4.07(A.15)	189	4.27	5.51	.032
90–99 (10)	11	4.00(A.15)	177	4.67	5.61	.040
100–109 (11)	9	2.78(A.6)	179	4.37	5.30	.029
110–119 (12)	4	2.25(A.3)	182	4.19	5.25	.032
120–129 (13)	1	5.00(A.22)	165	4.57	5.75	.057
130–139 (14)	1	2.00(A.1)	165	4.27	4.75	.032

Some degree of association exists between low production and late hatching but there is lack of consistency. A striking and consistent degree of relationship is seen in table 2 between winter egg record and age at first egg. Winter egg record and 150-day weight also show considerable dependence. There is some evidence that the low producers are heavier at first egg than the high producers. The average daily gain in weight increases as we advance down the table to the heavy winter layers. The general deduction seems warranted from table 2 that low winter egg records depend in part upon late hatching, too great an age at first egg, light 150-day weight, and slow rate of gain in body weight between 150 days old and age at first egg. In order to determine specifically how important these various relations are it is necessary to resort to the coefficient of correlation.

Age at First Egg versus Winter Production.

The degree of correlation between age at first egg and annual production in Rhode Island Reds for a period of years was found to be $-.4380 \pm .0134$ (Hays and Bennett 1923). The fact that winter egg yield is definitely ended March first while annual egg record does not terminate until 364 days after a pullet lays her first egg makes the correlation more intimate between age at first egg and winter record than between age and annual production.

The correlation coefficient between age at first egg and winter production has been calculated on 803 pullets hatched in 1923 without regard to the difference in hatching date. Constants calculated from this study follow:

Number of birds	803
Mean age at first egg	210.96
Age at first egg standard deviation	± 28.62
Mean winter production	44.46
Winter production standard deviation	± 23.04
Coefficient of correlation	$-.6061 \pm .0151$

Mean age at first egg is 210.96 days. Standard deviation of age is 28.62 which exhibits the wide range in age at first egg. The mean winter production is 44.46 eggs with a standard deviation of 23.04. Again winter fecundity shows its extreme variability as would any trait dependent upon so many hereditary factors and environmental influences.

A significant negative coefficient of correlation of $.6061 \pm .0151$ appears. Thus in six cases out of ten in these pullets hatched over a period of seventy days, there is definite association between early age at first egg and high winter egg record. In other words, the length of time that a pullet has opportunity to lay previous to March first should be given very weighty consideration in breeding for winter fecundity.

To secure an exact figure on the degree of correlation between age at first egg and winter fecundity it would be necessary to make hatching date constant by studying only those pullets hatched at the same date. Such a study, we believe, would reduce the number of individuals to such an extent that the mathematical error of calculation would be inordinately large. Below are presented the constants calculated on the 154 birds in the first three hatches. The hatching date range is thus reduced to fourteen days. Constants are as follows:

Number of birds	154
Mean age at first egg	211.58
Age at first egg standard deviation	± 39.80
Mean winter production	56.90
Winter production standard deviation	± 27.61
Coefficient of correlation	$-.6413 \pm .0320$

When the range in hatching date is reduced from 70 days to 14 days the coefficient of correlation between age at first egg and winter production increases from $-.6061 \pm .0151$ to $-.6413 \pm .0320$. This fact clearly proves that hatching date is of far less importance from the winter fecundity standpoint than is age at first egg. There are two possible reasons for this: first, early sexual maturity is associated with high winter fecundity to a greater extent than merely the time element; second, late hatching has already been shown to reduce the age at first egg.

Weight at 150 *Days versus Winter Production.*

In selection of pullets to put into winter quarters or in deciding upon birds to be placed in egg laying contests, the breeder desires to know just how much stress should be laid on physical characters. Weight is one characteristic that can be definitely measured. The weight at 150 days old was secured on 800 pullets that later completed winter records. The degree of correlation has been determined between weight at 150 days and winter production. Constants calculated are as follows:

Number of birds	800
Mean weight at 150 days	3.99
Weight at 150 days standard deviation	±.54
Mean winter production	44.54
Winter production standard deviation	±23.02
Coefficient of correlation	+.2758±.0220

The mean 150-day weight on the 800 pullets is 3.99 pounds with a standard deviation of .54. The mean winter production is 44.54 with a standard deviation of 23.02. Weight records show the fluctuations at the age of 150 days to be between 13 and 14 per cent.

The 800 pullets show a positive correlation coefficient amounting to .2758 ±.0220. This may be interpreted that in about one pullet out of four there is direct association between heavy weight at 150 days and a large number of winter eggs. In this particular flock, selection for heavy winter records would be about 28 per cent accurate if made on greatest 150-day weight alone.

In order to reduce the effect of hatching date on winter egg yield, studies have been made on two hatches, namely, April 15 and 22. This gives a range of but seven days in hatching date, which is practically insignificant. Constants calculated on these two hatches follow:

Number of birds	135
Mean weight at 150 days	4.16
Weight at 150 days standard deviation	±.51
Mean winter production	47.31
Winter production standard deviation	±23.93
Coefficient of correlation	+.2475±.0545

The coefficient of correlation for the two hatches does not differ significantly from that for the 800 pullets. This is evidence that hatching date had little if any effect upon the relation between 150-day weight and winter fecundity.

Weight at First Egg versus Winter Production.

The question: may the weight of a pullet in any particular variety at the time she lays her first egg be associated with high or low winter record? is of interest and importance. Should the breeder who is striving for high winter records select the heaviest pullets at first egg? These questions may be answered in general by correlating weight at first egg with winter record. Such studies have been made on 793 pullets with weight records and winter egg records. The calculated constants follow:

Number of birds	793
Mean weight at first egg	5.74
Weight at first egg standard deviation	±.73
Mean winter production	44.56
Standard deviation winter production	±23.04
Coefficient of correlation	−.1894±.0231

Mean weight at first egg is 5.74 pounds with a standard deviation of .73. The range of variability in weight is about 13 per cent and is about the same as was found at 150 days. Here is evidence that pullets weighing the most at 150 days will in general weigh the most when they lay their first egg even though there is a wide range in age at first egg.

A negative correlation coefficient of .1894±.0231 exists between weight at first egg and winter egg record. There appears to be an association between light weight at first egg and winter fecundity in about 20 per cent of the flock. The coefficient is small but significant and suggests that weight at first egg is of no very great importance in selecting for high winter record, yet there is a tendency for smaller birds to lay more winter eggs than larger birds.

By tabulating only the first eight hatches the effect of hatching date on weight is somewhat reduced. Records on 529 pullets from the first eight hatches are available for study. The constants calculated on this group are as follows:

Number of birds	529
Mean weight at first egg	5.76
Weight at first egg standard deviation	±.73
Mean winter production	47.71
Winter production standard deviation	±24.34
Coefficient of correlation	−.2963±.0269

With this group of pullets light weight at first egg is associated with high fecundity in about one case out of three. Hatching date thus appears to affect the degree of correlation.

Weight Increase versus Winter Production.

Does the rate of daily gain of pullets between the age of 150 days and the time they lay their first egg show any relationship to the number of winter eggs they will lay? Can rate of gain in the fall be considered an index to future winter production? Records are available for study on 788 pullets from which the rate of daily gain has been tabulated against number of winter eggs. The following constants appear:

Number of birds	788
Mean daily gain	.027 lb.
Daily gain standard deviation	±.00846
Mean winter production	44.59
Winter production standard deviation	±23.03
Coefficient of correlation	+.2899±.0220

This study shows the mean daily gain to be .027 pound with a standard deviation of .00846 or a range of variation in gain of about 31 per cent. The length of time over which this gain was measured varies directly with the age at first egg. Very early maturing pullets would begin laying in a comparatively few days after their 150-day weight was taken, while late maturing pullets would not begin laying until more than two months after their 150-day weight was secured. The average daily gain over a two-months' period is scarcely comparable with the average daily gain over a two-weeks' period. Yet from the standpoint of age the two are absolutely comparable in that age bears such a vital relationship to winter fecundity.

The coefficient calculated for this group is positive and amounts to .2899 ±.0220. This factor shows that in about one case out of three heavy daily gains between 150 days old and time of first egg are associated with high winter record. Heavy gainers tend to be heavy winter layers to a certain extent. In a previous section we find that the weight at 150 days is fully as reliable a guide to future winter fecundity as is rate of gain from 150 days to time of first egg.

If we eliminate the genetically late maturing birds we should expect either a higher or lower degree of correlation between weight increase and winter production than was found for the entire flock depending on whether or not the pullets gain at a different rate shortly before laying than two months or more before they lay their first egg. The records of the 413 pullets that began to lay at 206 days or less have been tabulated to show the degree of correlation between gain in weight and winter fecundity. Constants derived are as follows:

Number of birds	413
Mean daily gain	.0292
Daily gain standard deviation	±.0090
Mean winter production	54.94
Winter production standard deviation	±21.09
Coefficient of correlation	+.2055±.0318

The mean rate of gain on this group of pullets beginning to lay at from 150 to 206 days old is slightly greater than that for the entire flock. This seems to indicate that there is a tendency for the rate of gain to increase shortly before laying. But the coefficient of correlation is .2055±.0318 as compared with a coefficient of .2899±.0220 for the entire flock. Such a difference must be interpreted as evidence that the rate of gain shortly before the first egg is a less reliable indicator of future winter fecundity than is the rate of gain over a longer period before the first egg.

Weight at 150 Days versus Age at First Egg.

In order to discover if the weight of a pullet at a particular age previous to the time she lays her first egg is an index to the probable age at which she will begin laying, the 150-day weights on 846 pullets have been tabulated with their respective ages at first egg. Constants obtained are as follows:

Number of birds	846
Mean weight at 150 days	4.02
Weight at 150 days standard deviation	±.54
Mean age at first egg	210.35
Age at first egg standard deviation	±27.74
Coefficient of correlation	−.2135±.0221

A negative coefficient amounting to .2135±.0221 was obtained. Such a constant indicates that heavy weight at 150 days is associated with early production in about one case out of five. In other words, if all other conditions were kept constant, selection on the basis of heavy weight at 150 days would be advantageous for winter production.

Weight at First Egg versus Age at First Egg.

Does body weight at first egg vary directly with age at first egg or are there other influences operating so that the element of time is not alone responsible for the weight? If the element of time were alone responsible for weight variation in any particular breed, selection for early sexual maturity would reduce body weight because sexual maturity tends to check skeletal development so that later weight accumulation is largely of adipose tissue. The degree of correlation between weight at first egg and age at first egg has been calculated on 821 pullets to discover how important a relationship does exist between weight and age. The constants obtained follow:

Number of birds	821
Mean weight at first egg	5.56
Weight at first egg standard deviation	±.69
Mean age at first egg	210.66
Age at first egg standard deviation	±28.34
Coefficient of correlation	+.4604±.0185

The coefficient of correlation here shows that about half of the large pullets owe their weight to the time element. The other half are large because they possess a different capacity for growth than the first. By developing those influences, factors, or whatever they may be, to a maximum, the mean body weight should not diminish in an early maturing flock. On the face of it, the major problem here seems to be to discover just what these influences are and to make all conditions optimum for their manifestation.

Daily Gain versus Days Between 150 *Days Old and Age at First Egg*

The degree of importance of the time element in relation to daily gains may be ascertained from the degree of correlation between daily gain and number of days between 150-day age and age at first egg. Records on 814 pullets have been tabulated for study. The constants derived follow:

Number of birds	814
Mean daily gain	.0269
Daily gain standard deviation	±.0084
Mean days between weights	60.78
Days between weights standard deviation	±28.12
Coefficient of correlation	−.4145±.0196

A negative coefficient of .4145±.0196 substantiates the opinion that pullets tend to accumulate weight very rapidly just before they begin laying. We have already shown that relative rate of gain is not of much importance in selection for winter fecundity, and that the 150-day weight is just as accurate a basis of selection as rate of gain and entails only half the labor.

Winter Production versus Annual Production.

It is important to know the degree of correlation between winter production and annual production since winter egg record may conveniently be used as a basis for selecting pullet breeders. Furthermore, winter record could be used as a basis of culling for high annual records and as a basis for determining the intensity of pullets. Annual records are not yet complete on the flock being studied, consequently the winter record of three previous flocks has been tabulated against their 365-day record. A total of 845 individuals hatched in 1920, 1921, and 1922 have been studied. Constants have been calculated as follows:

Number of birds	845
Mean winter production	70.26
Winter production standard deviation	±25.07
Mean annual production	193.95
Annual production standard deviation	±40.25
Coefficient of correlation	+.6214±.0142

The above coefficient shows that in approximately six cases out of ten high winter record is directly associated with high annual record. In other words, selection for annual egg yield would be about sixty per cent accurate if made on winter trap-nest records alone. This fact makes very evident that winter egg record is of very great importance in its relation to annual record and that it is of great value in selecting pullet breeders.

In previous sections the relative importance of different measurable characteristics in relation to winter production has been discussed and the degree of correlation calculated in each case. These findings help to make clear why winter egg record as determined on a calendar basis is subject to wide variation aside from the variation caused by hereditary factors known to affect it. Such facts being known, the difficulty and uncertainty of properly classifying the pullets in distinct genotypes becomes very apparent. Such variables as have been considered must be reduced to a minimum in order to make proper matings for purposes of reducing genetic variability to a minimum. When the genetic nature of each breeding bird is discovered, definite types of matings may be made and progress assured. There can be no short road in the establishment of a flock breeding *true* for high winter fecundity.

SUMMARY

Based upon the foregoing data, the following figures show the degree of correlation between the characters stated:

1.	Between hatching date and weight at 150 days (for the entire flock)	$-.3293\pm.0194$
2.	Between hatching date and weight at first egg	$-.3807\pm.0201$
3.	Between hatching date and age at first egg	$-.1487\pm.0228$
4.	Between hatching date and winter production (for the entire flock)	$-.2920\pm.0218$
5.	Between hatching date and winter production (for the genetically early maturing birds alone)	$-.4790\pm.0254$
6.	Between age at first egg and winter production (for the entire flock)	$-.6061\pm.0151$
7.	Between age at first egg and winter production (first three hatches only)	$-.6413\pm.0320$
8.	Between weight at 150 days and winter production (for the entire flock)	$+.2758\pm.0220$
9.	Between weight at 150 days and winter production (for the hatches of April 15 and 22 only)	$+.2475\pm.0545$
10.	Between weight at first egg and winter production (for the entire flock)	$-.1894\pm.0231$
11.	Between weight at first egg and winter production (for the first eight hatches only)	$-.2963\pm.0269$
12.	Between average daily gain, 150 days old to age at first egg, and winter production (for the entire flock)	$+.2899\pm.0220$
13.	Between average daily gain, 150 days old to age at first egg, and winter production (for the genetically early maturing group alone)	$+.2055\pm.0318$
14.	Between weight at 150 days and age at first egg	$-.2135\pm.0221$
15.	Between weight at first egg and age at first egg	$+.4604\pm.0185$
16.	Between average daily gain and number of days, from 150 days old to age at first egg	$-.4145\pm.0196$
17.	Between winter and annual production, for three previous flocks	$-.6214\pm.0142$

The most important single characteristic upon which to select pullets for winter production is age at first egg. Weight at 150 days and hatching date are of equal importance in such a selection, but of much less significance than age at first egg.

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INDEX

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MASSACHUSETTS AGRICULTURAL COLLEGE

BIENNIAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

REPORT OF THE DIRECTOR FOR THE FISCAL YEARS ENDING NOV. 30, 1925 AND 1926, PUBLISHED IN ACCORDANCE WITH THE PROVISIONS OF SECTION 32 OF CHAPTER 30 OF THE GENERAL LAWS

Being Parts III and IV of the Sixty-Fourth Annual Report of the Massachusetts Agricultural College

A Record of the Forty-Third and Forty-Fourth Years from the Founding of the State Agricultural Experiment Station

DEPARTMENT OF EDUCATION
THE COMMONWEALTH OF MASSACHUSETTS

Publication of this Document approved by the Commission on Administration and Finance

2500. 9-'27. Order 9936.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

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Vegetable Gardening and Market Garden Field Station.	Victor A. Tiedjens, M.Sc., *Assistant Research Professor.* (Market Garden Field Station, Waltham.) Miss Edith E. Meehan, *Stenographer.* (Waltham.)
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Rural Engineering.	Christian I. Gunness, B.Sc., *Professor.*
Veterinary Science and Animal Pathology.	G. Edward Gage, Ph.D., *Professor.* Norman J. Pyle, V.M.D., *Assistant Research Professor of Avian Pathology.* Harold F. Rowley, B.Sc., *Technical Assistant.*

[1] Began work January 1, 1927. [2] Deceased. [3] On leave. [4] Temporary.

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Miss Rebecca L. Mellor, *Clerk, Poultry Disease Elimination.*

REPORT OF THE DIRECTOR.

Sidney B. Haskell.

Organization under the Purnell Fund.

Since my last report the resources of the Station have been increased by the passage of the national Purnell act. This brings to the Station additional Federal appropriation, commencing at $20,000 annually in 1925, and increasing yearly until a total of $60,000 is expected to be reached in 1929. The Station is now in the middle of its second year under the Purnell fund appropriation.

As with other government funds, expenditures can be made only on the basis of project approved at Washington. In certain of their aspects these problems are of regional nature, in which the Station coöperates with other experiment stations in fulfilling the purposes of the Purnell act.

While the bill authorizing the appropriation of funds is somewhat general, yet it specifically contemplated three lines of work to be carried out under this fund: namely, in agricultural economics, in farm management, and in home economics. Following the provisions of the bill, therefore, the efforts of the Station have been intensified in these three lines.

The first outstanding product of the Purnell act in the field of agricultural economics was in participation by the Station in the New England-wide survey of the New England orchard industry. This gives to actual and potential orchardists means of estimating production in years to come. It gives the industry an opportunity had by no other similar industry to anticipate a constantly growing market program. It shows what may be done by well thought out economic research for the guidance of agricultural industries.

Work in farm management was not formally organized until the very end of the year (1926), although it was projected a year earlier. This contemplates detailed study of the competitive position of the more important farm enterprises of Massachusetts. It is expected that this work will be valuable in two directions: first, in giving our growers certain standards of efficiency to which they must approximate if they are to meet the competition of these other regions; and second, in giving our educational forces a body of data on which to base their work. In times past lack of such fundamental data has been responsible for much poorly directed effort.

Research studies in home economics were instituted in the fall and winter of 1925 and 1926. The subject chosen was "Food Consumption of School Children in Relation to Health." This was frankly a survey study, designed to determine the facts in the field, and to find where, if at all, the research service of the Station may be of service to Massachusetts country life. For the purpose of making the study the College loaned to the Station the services of Miss Helen Knowlton, Assistant Professor of Home Economics. She gave good service. On account of difficulties in filling the place permanently, it was not possible to effect final organization until toward the end of 1926.

Work of a different nature has been instituted in the departments of horticultural manufactures and of dairy manufactures. The central thought in both has to do with food conservation, partly through prevention of waste, partly through manufacture, and finally through relieving market glut by enabling producers to remove a part of their product to be manufactured and placed on the market at other seasons. In the department of dairy manufactures there is the added objective of developing ways and means through which manipulation of dairy products in milk-handling depots, creameries and ice-cream plants may be made more efficient and kept under better control.

To a very small degree increased resources due to the Purnell Fund have been used in supporting existing projects, particularly those in the department of poultry husbandry. In the genetics work of this department data have been accumulating beyond the ability of the available force of the Station to analyze and adjust. For this reason a small apportionment was made to the department, by means of which this work is being cleared up.

Organization of the Market Garden Field Station.

Since my last report the research staff at the Market Garden Field Station has been completed. This now consists of a plant physiologist, a plant pathologist and an entomologist. The last two also give service to the orchard industry, and for this reason are assigned to the Field Station from the home offices, rather than having direct membership in the Field Station staff. To all intents and purposes, however, they represent a part of the scientific manpower mobilized in the eastern part of the State, to assist in solving those problems which handicap our market gardening and vegetable growing industry.

The advance made in the research study of many vital problems since the transfer of the plant from Lexington to Waltham abundantly justifies the wisdom of the Trustees in making this transfer, and in securing from the Legislature appropriation for the purpose.

Rebuilding the Cranberry Station.

The building at the Cranberry Station was destroyed by fire on the night of May 30, 1926. All equipment was lost. Fortunately all records and reports were in a fire-proof safe, which went through the fire without damage to the interior. In addition to the loss to the Station was the loss of personal equipment used in the Station service and owned by the superintendent of the Station, Dr. H. J. Franklin, by Mr. Lacroix, by Dr. N. E. Stevens, detailed by the United States Department of Agriculture, and by the Cape Cod Cranberry Association.

In rebuilding, the Station profited by the experience of the past dozen years, and now has a laboratory better suited to the needs of the Station. The new buildings are of cement, with garage separate from the main building. There is more laboratory space, and better toilet facilities than in the building which was destroyed.

Service of the Cranberry Station.

The service of the Cranberry Station continues to be appreciated. The frost warnings, developed by Dr. Franklin as a result of intensive study of meteorological phenomena, have come to be widely utilized, with the distribution of the warnings at the expense of the growers. The fact that most of the insect enemies attacking the cranberry bog are now under control in one way or another goes back to the many successful entomological studies conducted in the past twelve years by Dr. Franklin. It is expected that the results of these studies will be shortly brought together in a comprehensive bulletin.

Development of Station Land.

I am glad to be able to report continued progress in the development of the Brooks Farm, purchased through funds appropriated by the Legislature in 1922, for experimental purposes. The first objectives of this purchase, namely the study of certain problems connected with tobacco and with onion culture, are in a fair way of being attained.

In tobacco, by agreement with the Connecticut Agricultural Experiment Station which also carries on research with this crop, the Massachusetts Station is taking as its special field the problem of soil inhabiting diseases as influenced by management practices followed. The whole promises to give a contribution, not alone to a local industry of considerable importance, but to a better understanding of certain fundamental principles of soil fertility.

Owing to lack of funds the special work with onions was not started until the spring of 1925. The main item in the research program for this industry has to do with finding and improving that source of seed which will give to Massachusetts producers the best possibility of competing with other regions. In addition a considerable area is laid out to comparative experiments with lime and with fertilizers. These investigations will become more valuable with every passing year.

In both phases of the work the Experiment Station has the benefit of coöperation and advice from committees of growers, respectively Advisory Committee on Tobacco and Advisory Committee on Onions. The thanks of the Station are due to the members of these committees, for the care and thought which they give to the problems relating to their particular industries, and the oversight which they give to the development of a sound research program.

The equipment at the Tillson Farm has been greatly improved by the addition of the cottage for the plant foreman, with laboratory quarters for staff members. With this equipment the farm is now being used in the service of four departments: poultry husbandry having the first call on land facilities; the department of botany with station administration making certain studies in the pastures; the department of botany carrying on certain of its tobacco disease studies on the area; and finally, the department of pomology conducting its study on hardiness in peaches.

One more piece of major equipment is needed, a combined grain storage and root cellar, to make the farm more nearly self-supporting. When this is built, little more in the way of expensive equipment or apparatus will be needed.

The Station Research Program.

The catalog of active projects of the Experiment Station represents the research program as it is at any given moment. Rarely can such a program represent a well-rounded effort to meet all of the research needs of any agricultural industry of the State. Recognition must always be given to research being carried on in other states; problems of finance and of personnel may prevent certain necessary projects from being undertaken. The time factor in carrying out the several projects often prevents institution of new work. It goes without saying, however, that through the aid of advisory committees of farmers and of staff committees, the attempt is being made at all times to keep our research programs in line with existing need.

Catalog of Active Projects, December 1, 1926.

Agricultural Economics.

9. Study of taxation of farm property. Assistant Research Professor H. W. Yount. The work on this project is nearly completed, and the results will soon be published.

10b. A study of the performance of different varieties of apples, and market value of product. Assistant Research Professor L. P. Jefferson. Carried on in coöperation with a number of growers in different parts of the State. These growers have agreed to lay before the Station harvesting and marketing records to be secured over the next few years.

10c. The consumer demand for apples. Assistant Research Professor L. P. Jefferson. Contemplates a detailed study of sales and sales resistance both within and without the State.

11. A study of the supply and market distribution of Massachusetts poultry products. Assistant Research Professor H. W. Yount.

12. A study of the prices of eggs and poultry in Massachusetts. Assistant Professor D. W. Sawtelle and Assistant Research Professor H. W. Yount.

The preceding projects overlap somewhat. They recognize the fact of serious competition between New England poultry products and those imported from other sections, and are designed to give a basis for the sound competitive development of the Massachusetts industry.

Agricultural Engineering.

1. Investigation of apple storage houses. Professor C. I. Gunness. Data in support of this project are being taken in coöperation with operators of orchard storehouses in different parts of the State.

2. Refrigerating and mechanical factors involved in freezing ice-cream. Professor C. I. Gunness.

Agronomy.

2. Tobacco cropping system investigation. Research Professor J. P. Jones. The most marked result secured to date has been that of establishing the superiority of continuous cropping of tobacco over rotation cropping. In this respect our Massachusetts results differ from those which have been reported from other tobacco sections. Since, as a matter of convenience in meeting existing market demand, Massachusetts growers find it necessary to shift from one crop to another fairly frequently, it will be advantageous if methods may be found whereby rotation cropping rather than continuous cropping may be developed.

2a. Accessory tobacco rotation plots. Research Professor J. P. Jones.

4. Study of residual effects of fertilizers. Research Professor J. P. Jones.

5. A field study of tobacco production in Massachusetts. Professor A. B. Beaumont. Represents a survey study of tobacco production in Massachusetts.

Originally it was expected that records would be taken for three or more years. Delay in sorting and curing the tobacco has made this impossible, and raised question as to whether the method is entirely sound. The project will be discontinued in another year.

7b. Investigation of the rôle of organic matter in the production of onions. Part II, field work. Research Professor J. P. Jones. Attempts to maintain the supply of organic matter by the use of different cover crops. To date the most marked result is the raising of question as to the necessity of any particular provision for the maintenance of organic matter in continuously cropped, heavily fertilized onion soils.

8. Study of the growth of onions as influenced by differential liming. Research Professor J. P. Jones.

9. Effect of varying the ratio, amount and concentration of plant nutrients applied in onion growing. Research Professor J. P. Jones.

11. Study of the effect of crops plus their specific fertilizers upon those which follow, with special reference to tobacco. Research Professor J. P. Jones. Supplements Agronomy 2, and is designed primarily to determine the influence of different previous crops on the tobacco crop.

15. A study of the relative efficiency of "based" and "unbased" sulfate of ammonia as carriers of nitrogen. Professor A. B. Beaumont.

16. Study of the relation of inorganic and organic toxins to brown root-rot of tobacco. Research Professor J. P. Jones.

17. The nitrogen intake of Havana tobacco. Professor A. B. Beaumont.

18. Onion breeding work. Research Professor J. P. Jones. Owing to the fact that very little onion seed is now raised in Massachusetts, growers are finding poorer control over varieties and seed sources than was formerly the case. The Station is attempting to determine the factors which lead to good type of a storable market onion.

19. The determination of the influence of varying the quantity of fertilizer nitrogen on the yield and quality of Havana tobacco when topped at different heights. Research Professor J. P. Jones.

20. Testing onion sets and seed in the greenhouse. Research Professor J. P. Jones. By means of testing in the greenhouse it was hoped to get advance measurements of seed and set potency in the growing of onions. To date the attempt has been unsuccessful.

Botany.

3. Investigation of black root-rot of tobacco. Research Professor W. L. Doran. Results thus far secured are reported in Bulletin 229, "Soil Reaction and Black Root-Rot of Tobacco."

9. Investigation of a carrot blight. Assistant Research Professor E. L. Guba. Carried out in coöperation with the Market Garden Field Station at Waltham, and practically ready for publication.

13. Ecological study of pasture vegetation. Director S. B. Haskell and Professor A. V. Osmun. A brief progress report is printed in Bulletin 230, under the title "Better Feed from Permanent Pastures."

18. Control of diseases of greenhouse vegetables. Research Professor W. L. Doran.

18a. Investigation of downy mildews of cucumber and lettuce. Research Professor W. L. Doran.

19. Investigation of tobacco brown root-rot. Research Professor W. L. Doran. Complementary to Agronomy 16, mentioned above. It represents one of three diverse lines of attack on that problem.

21. Investigation of the use of chemicals for eradication of nematodes and parasitic fungi in greenhouse soils. Assistant Research Professor L. H. Jones.

Plant and Animal Chemistry.

4. Record of the Station herd. Professor J. B. Lindsey and Assistant Research Professor J. G. Archibald. Consists in the routine measurement of feed consumed and milk produced. The work has now been carried on for thirty-one years.

14. A study of the availability of soil potash with the object of developing a system of diagnosis for soils of the State. Research Professor F. W. Morse.

17. Investigation of the rôle of physical condition in artificial feeds for calves.

Professor J. B. Lindsey and Assistant Research Professor J. G. Archibald. Results have been published in Bulletin 223, "Milk Substitutes in the Rearing of Young Calves," and in the article "Skim Milk Powders in the Rearing of Young Calves" in Bulletin 230. Owing to the increasing sale of milk in a fluid form, it has been difficult for Massachusetts dairymen to raise replacement stock; and on account of quarantine restrictions it has also been difficult safely to purchase such stock. This project, therefore, was instituted as part of a study to develop ways and means of meeting the situation. The appearance on the market of artificially dried skim milk of various kinds gives a satisfactory source of food which may meet the need.

19. The value of inorganic calcium phosphate in the promotion of growth and milk production. Professor J. B. Lindsey and Assistant Research Professor J. G. Archibald. Results to date reported in the article "Mineral Matter for Dairy Cows" in Bulletin 230; and in Scientific Contribution 46, "The Value of Calcium Phosphate as a Supplement to the Ration of Dairy Cows."

20. A study of the fundamental factors affecting adhesiveness, toxicity, and general efficiency of copper fungicides. Research Professor E. B. Holland. A partial report has been printed in Scientific Contribution 52, "The Preparation and Effectiveness of Basic Copper Sulphates for Fungicidal Purposes."

21. Study of nitrogen fixation in the presence of, or as the result of, growth of legumes versus non-legumes under certain defined agronomic conditions. Research Professor F. W. Morse. Carried on in coördination with Microbiology 4. Some of the old fertilizer experiment plots of the Experiment Station, which have had no fertilizer or other applied nitrogen for forty years, are being used in the study.

24. Chemical changes which occur in the cranberry during ripening and after harvesting. Research Professor F. W. Morse.

25. Studying the mineral requirements for the growth of dairy heifers. Professor J. B. Lindsey and Assistant Research Professor J. G. Archibald.

Cranberry.

1. Injurious and beneficial insects affecting the cranberry. Research Professor H. J. Franklin. One insect has been reported in Scientific Contribution 47, "The Life History and Control of the Cranberry Weevil, Anthonomus Musculus Say (Coleoptera: Curculionidae.)

2. Cranberry disease work. (In coöperation with the Bureau of Plant Industry, United States Department of Agriculture.) Research Professor H. J. Franklin.

3. Weather observations with reference to frost protection. (In coöperation with the Weather Bureau of the United States.) Research Professor H. J. Franklin. Frost warnings are sent out in the spring and fall at critical times, at the expense of the growers. This represents an effective application of a difficult research study in meteorology.

5. Blueberry investigations. Research Professor H. J. Franklin.

Dairy Manufactures.

2. A study of washing powders for dairy use. Assistant Research Professor A. W. Phillips.

3. The quinhydrone electrode in the dairy laboratory. Assistant Research Professor A. W. Phillips.

Entomology.

10. Dates of hatching of scale insects and when to spray for them. Assistant Research Professor A. I. Bourne.

12. Determination of best strength of lime-sulfur. Assistant Research Professor A. I. Bourne. Progress report, "Tests of Lime-Sulfur Solution and Some of Its Substitutes against San Jose Scale," printed in Bulletin 226.

16. Investigation of materials which promise value in insect control. Assistant Research Professor A. I. Bourne.

17. Control of onion thrips. Assistant Research Professor A. I. Bourne. Progress report, "A Study of the Life History and Control of the Onion Thrips," in Bulletin 227. Field work on the control of onion thrips has been completed with development of a spray which, applied properly, gives control. Unfortunately, up to the time of writing, no machine has been developed capable of spraying under high pressure on closely planted rows such as we have in the onion fields. This project is being carried until such time as the proper machine becomes available, or can be developed.

18. Adaptation of the recommended spray schedule for the control of orchard insects to Eastern Massachusetts conditions. Assistant Research Professor W. D. Whitcomb.

19. Control of plum curculio in apples. Assistant Research Professor W. D. Whitcomb.

Farm Management.

2a. A study of competitive status of Massachusetts farm enterprises. R. L. Mighell.

Fertilizer Control.

1. To study the availability of the nitrogen contained in several processed organic ammoniates and other products for which a high availability is claimed. Professor H. D. Haskins.

Grounds.

1. Demonstration experiment — lawns, lawn grasses, and lawn management. Assistant Professor L. S. Dickinson.

Home Economics.

1. Food consumption of school children in relation to health. Assistant Professor E. S. Davies. A survey study carried on in three rural towns, with the coöperation of the schools and of the State Department of Health.

Horticultural Manufactures.

1. The extraction of fruit juices in the manufacture of fruit jellies. Research Professor C. R. Fellers.

2. Manufacture and preservation of cranberry products. Research Professor C. R. Fellers.

3. Utilization of onions by canning. Research Professor C. R. Fellers.

Market Garden Field Station.

7. Study of the factors influencing heading of greenhouse lettuce. Assistant Research Professor V. A. Tiedjens. A report of one phase of this study was printed as Scientific Contribution No. 31, "Stimulation of Plant Growth by Means of Electric Lighting."

8. Study of conditions affecting the production and vegetative propagation of asparagus. Assistant Research Professor V. A. Tiedjens. Some of the results of this study are reported in Scientific Contribution 36, "Some Physiological Aspects of Asparagus Officinalis." Supplements the earlier work of the Experiment Station in coöperation with the United States Department of agriculture in breeding the rust-resistant Washington asparagus. It was found that this asparagus, although of very high quality, was quite variable between hill and hill, which gave rise to the attempt to propagate vegetatively and thus retain the best produced by seed. Encouraging progress has been made, although the method is not yet ready for general distribution.

9. Investigation of susceptibility to corn borer attack of varieties of sweet corn as influenced by time of planting. P. W. Dempsey. Carried on on the basis of a five-year program and financed coöperatively by the Corn Borer Laboratory at Arlington, supported by the United States Government, and the Market Garden Field Station. Marked differences in susceptibility to attack are associated with time of planting; but thus far injury-free dates have not been established.

10. Variety improvement through seed and root selection: (a) The improvement of beets (*Beta vulgaris*) through selection of roots and seed production; (b) The improvement of carrots (*Daucus carota*) through selection of roots and seed production. Assistant Research Professor V. A. Tiedjens.

11. Control of red spiders on cucumbers in greenhouses. Assistant Research Professor W. D. Whitcomb. Merged with the project immediately following, owing to the fact that both insect and disease have to be cared for in a single spray or dusting.

11a. Control of greenhouse red spider and powdery mildew of cucumbers by a combination spray. Assistant Research Professor W. D. Whitcomb and Assistant Research Professor E. F. Guba.

12. Biology and control of garden cutworms. Assistant Research Professor W. D. Whitcomb.

13. The genetics of greenhouse cucumbers in relation to shape, size, color and

set of fruit. Assistant Research Professor V. A. Tiedjens. A preliminary report was published as Bulletin 225, "Yellow Pickle in Greenhouse Cucumbers."

14. Cold resistance in sweet corn in its relation to quality, size and earliness. Assistant Research Professor V. A. Tiedjens.

15. The control of eggplant wilt caused by *Verticillium albo-atrum* R and B. Assistant Research Professor E. F. Guba.

Microbiology.

4. Addition to "Study of nitrogen fixation in the presence of, or as the result of, growth of legumes versus non-legumes under certain defined agronomic conditions. Assistant Research Professor L. A. Bradley.

Pomology.

1. Study of interrelation of stock and scion in apples. Research Professor J. K. Shaw. Progress report, "Effect of Stock on Scion," in Bulletin 226. Project started in 1912, on the basis of a twenty-year program. As the orchards were set out on leased land, it must come to maturity before 1932. Significant differences in the interrelation of stock and scion have been shown.

2. A study of the tree characters of fruit varieties. Research Professor J. K. Shaw. Supplements the project on Leaf Characters of Apple Varieties which is the basis of present work in nursery certification.

3. The genetic composition of peaches. Research Professor J. K. Shaw. Scientific Contribution 40, "Autumn Development of Peach Fruit Buds," is a report on certain studies made in connection with this project.

5. Comparison of cultivation and sod mulch in a bearing orchard. Research Professor J. K. Shaw. Scientific Contribution 39, "Sod-Nitrate vs. Cultivation in Apple Orchard." Trees in nitrated sod mulch have made better growth and given larger yields than trees under cultivation. Results differ from those secured in other sections, but apparently are fairly typical of much of the orchard area of southern New England.

8. Test of cover crops for apple orchards. Research Professor J. K. Shaw.

9. Testing methods of pruning. Research Professor J. K. Shaw. Progress report in Bulletin 226, "Pruning Young Apple Trees."

12. Apple variety fruit spur study. Research Professor J. K. Shaw and Assistant Research Professor C. P. Jones.

13. A study of varieties of tree fruits. Research Professor J. K. Shaw. A routine project, consisting of the taking of many records on some thousands of fruit trees annually, these being available for classification in terms of variety, soil, fertility treatment, management, etc.

14. Study of the relation of winter injury of brambles to differential fertilization with potash salts. Research Professor J. K. Shaw, Assistant Research Professor C. P. Jones and Professor A. V. Osmun.

16. Test of different amounts of nitrate of soda. Research Professor J. K. Shaw.

17. A study of the cultivation of the high bush cranberry. (*Viburnum opulus*). Research Professor J. K. Shaw.

18. Comparison of cultivation and heavy mulching for apples and pears. Research Professor J. K. Shaw. Heavy mulching with material brought into the orchard has produced a growth typical of a plentiful nitrogen supply. Chemical analysis has shown enormous production of nitrates beneath the mulch.

19. A study of the effects of fertilizer limitation on fruit plants. Research Professor J. K. Shaw. Scientific Contribution 38, "Some Unusual Results in Fertilizing Fruit Plants." Carried on on the old North Soil Test, full reports of which were published in Bulletin 212. The trees have a staged condition brought about by many years of differential fertilization. Differences in growth are enormous.

Poultry Husbandry.

1. Broodiness in poultry. Research Professor F. A. Hays. Technical Bulletin 7, "Broodiness in Relation to Fecundity in the Domestic Fowl."

2. Breeding poultry for egg production. Research Professor F. A. Hays. Scientific Contribution 30, "The Application of Genetic Principles in Breeding Poultry for Egg Production"; also Bulletins 211 and 215, published several years ago.

2a. Statistical study of heredity in Rhode Island Red breed of poultry. Research Professor F. A. Hays. Technical Bulletins 8, "Winter Cycle and Winter Pause in Relation to Winter and Annual Egg Production" and 9, "Annual Persistency in Relation to Winter and Annual Egg Production; also Bulletin 220 published several years ago.

3. A genetic study of Rhode Island Red color. Research Professor F. A. Hays. Scientific Contribution 43, "Inheritance of Plumage Color in the Rhode Island Red Breed of Domestic Fowl."

4. Determination of genetic laws governing results in inbreeding of poultry. Research Professor F. A. Hays.

5. The hatchability of eggs. Research Professor F. A. Hays. Manuscript now in press; also Technical Bulletin 6, published several years ago.

Veterinary Science.

7. The standardization of avian diphtheria, roup, or bird pox virus and vaccines with special reference to improving the treatment of the disease. Assistant Research Professor N. J. Pyle.

8. Ascertaining what percentage of pullets in a breeding flock should be laying before blood should be tested for indications of bacillary white diarrhoea infection. Professor G. E. Gage and H. Van Roekel. Project carried on by the Poultry Disease Control Service, in response to evidence from the field indicating decreased effectiveness of the test when applied too early in the life of the pullet flock.

Projects Completed or Discontinued.

Agricultural Economics.

7. Boston food supply study. Research Professor R. J. McFall. Completed, not yet published.

7a. The determination of amount of food products received in the New England consuming area. Research Professor R. J. McFall. Completed, manuscript submitted.

8. Study of the costs of marketing apples. Assistant Research Professor L. P. Jefferson. Completed, results published in Bulletin 224, "The Cost of Marketing the Apple Crop of 1923."

10. Economic factors underlying the supply and market distribution of New England apples. Assistant Research Professor L. P. Jefferson, Completed, results published in Bulletin 226, article entitled "The Apple Situation"; and Bulletin 228, "An Economic Study of the Massachusetts Apple Industry."

10a. Study of the market outlets for Massachusetts (and New England) apples. Assistant Research Professor L. P. Jefferson. Completed, manuscript nearly ready for publication.

13. Study of the competitive factors influencing the supply of market milk and cream in Massachusetts. Research Professor R. J. McFall. Discontinued, manuscript being prepared for publication as a bulletin.

Agronomy.

1. Investigation of the value of Hubam or annual sweet clover as compared to the biennial clovers. Assistant Professor C. A. Michels. Discontinued as a Station project.

3. Soil fertility studies on the South Soil Test. Research Professor J. P. Jones. Discontinued on account of unavoidable disturbance from surrounding buildings.

6. Test of meadow fescue versus timothy under varying drainage conditions. Professor A. B. Beaumont. Discontinued on account of soil variation being discovered.

7a. Investigation of the rôle of organic matter in the production of onions. Part I. Pot work with soils deficient in organic matter. O. E. Street. Discontinued as methods were found unsatisfactory.

10. Effect of fractional application of fertilizer materials on growth, maturity and quality of onions. Research Professor J. P. Jones. Combined with Project 9.

12. Study of relationship of soil moisture content to yield and quality of tobacco. Research Professor J. P. Jones. Discontinued, methods unsatisfactory.

13. Examination of the influence of source of seed in onion production. O. E. Street. Combined with Project 18.

14. The determination of the influence of certain nitrogenous fertilizer materials on the yield and quality of Havana tobacco. Research Professor J. P. Jones. Replaced by Project 19.

Botany.

1. Optimum conditions of light for plant response. Assistant Professor O. L. Clark. Discontinued on account of resignation of Professor Clark from the Station staff.

5. Experimental spraying for control of cucumber mildew under glass. Professor A. V. Osmun. Merged with Project 18.

6. Investigation of onion diseases. Professor A. V. Osmun. Completed. Results reported in Technical Bulletin 4, "Development and Pathogenesis of the Onion Smut Fungus"; Bulletin 221, "The Smut Disease of Onions"; Scientific Contributions 4, "An Improved Formaldehyde Tank for the Onion Drill"; 15, "The Relation of Soil Moisture to Formaldehyde Injury of Onion Seedlings"; 32, "Controlling Onion Smut with Kalimat"; 42, Comparative Susceptibility of Onion Varieties and of Species of Allium to Urocystis Cepulae"; Bulletin 227, article entitled "Onion Blight or Downy Mildew."

14. Investigation on control of tobacco wildfire. Research Professor P. J. Anderson. Completed, results reported in Bulletins 203, "Tobacco Wildfire — Preliminary Report of Investigations"; 213, "Tobacco Wildfire in 1922"; Scientific Contributions 27, "Overwintering of Tobacco Wildfire Bacteria in New England"; and 33, "Susceptibility of Nicotiana Species, Varieties and Hybrids to Tobacco Wildfire."

16. Relation of soil character to occurrence of onion smut. Research Professor P. J. Anderson. Completed. For reports, see bulletins and articles listed under Project 6.

17. Study of apple black rot control and the dusting schedule. Research Professor W. L. Doran. Completed, results published in Bulletin 222, "Experiments on the Control of Apple Scab and Black Rot and Spray Injury in 1924."

20. Investigation of nematode eradication in greenhouse soils by the use of calcium cyanide. (In coöperation with American Cyanamid Company.) Assistant Research Professor L. H. Jones. Superseded by Project 21.

Plant and Animal Chemistry.

22. Determining the nutritive value of hydrolized sawdust. Professor J. B. Lindsey and Assistant Research Professor J. G. Archibald. Completed, results published in Scientific Contribution 48, "The Composition, Digestibility and Feeding Value of Hydrolized Sawdust."

23. Study of coloring matter in cranberries. Research Professor F. W. Morse. Manuscript submitted for publication.

Cranberry.

6. Cranberry bud development investigation. D. S. Lacroix. Completed. Results published in Scientific Contribution 50, "Cranberry Flower-Bud Investigations."

Dairy Manufactures.

1. Determining factors influencing volume weight in ice-cream. Assistant Research Professor A. W. Phillips. Completed, manuscript submitted.

Entomology.

4. Control of squash vine borer. Assistant Professor H. N. Worthley. Completed, results published in Bulletin 218, "The Control of the Squash Vine Borer in Massachusetts."

5. Control of the squash bug. Assistant Professor H. N. Worthley. Discontinued. Reports published in Scientific Contributions 7, "The Squash Bug in Massachusetts (*Anasa tristis* De Geer) with Notes on the Parasite *Trichopoda pennipes* (Dipt., Tach.)"; 19, "The Biology of *Trichopoda pennipes* Fab. (Diptera, Tachinidae), a Parasite of the Common Squash Bug."

9. Number of generations of codling moth in Massachusetts and whether spraying for a second generation is advisable. Assistant Research Professor A. I. Bourne. Completed, manuscript nearly ready for publication.

13. Study of possible injurious effects of Scalecide on trees. Assistant Research Professor A. I. Bourne. Preliminary report in Bulletin 226, entitled "Some Results from Spraying with Scalecide"; final report being prepared.

14. Does spraying orchards kill bees? Assistant Research Professor A. I. Bourne. Completed, manuscript nearly ready for publication.

15. A study of the factors influencing the efficiency of nicotine in dusts and spray mixtures. Assistant Professor H. N. Worthley. Discontinued on account of the resignation of Professor Worthley. Manuscript submitted.

Farm Management.

1. Investigation of farm organization and labor efficiency on Massachusetts farms. Professor J. A. Foord. Discontinued.

Microbiology.

2. Soil fertility as influenced by micro-organisms in their relation to the presence and disappearance of organic matter. Assistant Professor C. H. Werkman. Superseded by Project 4. A report of some of the results was published as Scientific Contribution 37, "Biological Investigation of Peat."

Pomology.

7. Test of fertilizers in a sod mulch orchard. Research Professor J. K. Shaw. Discontinued on account of injury to orchard.

15. Orchard fertilization. Research Professor J. K. Shaw. Discontinued. A report of the fertilizer studies in this orchard was published several years ago in Bulletin 209.

20. Test of fertilizers for pears. Research Professor J. K. Shaw. Discontinued on account of attack of blight.

21. Study of fruit harvesting and storage. G. J. Raleigh. Completed, results published in U. S. D. A. Department Bulletin 1406.

Veterinary Science.

6. The therapeutic efficiency of avian diphtheria, roup, or bird pox vaccines. Assistant Research Professor N. J. Pyle. Completed, results published in Technical Bulletin 10, "The Therapeutic Efficiency of Avian Diphtheria, Roup, and Bird Pox Vaccines and Bacterins."

Publications, 1925–1926.

During the period covered by this report, and as a measure of economy which leads also to efficiency in distribution of material, many of the reports of the various projects have been published through technical and scientific journals, rather than in the regular bulletin series of the Experiment Station. With the development of the Extension Service, the primary audience to which results of research work in agricultural science are presented consists of teachers and extension specialists rather than of actual farmers. It is believed that this change in no way decreases the service of the Station to its main constituents, the farmers of the State. Furthermore, the definite preparation of manuscript for a restricted audience leads to more efficient preparation of manuscript than is possible when the audience consists of diverse groups. The following shows the publications of the years in question:

Annual Report.

Thirty-seventh annual report with index.

Bulletins.

No. 221. The Smut Disease of Onions, by P. J. Anderson and A. Vincent Osmun.

No. 222. Experiments on the Control of Apple Scab and Black Rot and Spray Injury in 1924, by W. L. Doran.

No. 223. Milk Substitutes in the Rearing of Young Calves, by J. B. Lindsey and J. G. Archibald.

No. 224. The Costs of Marketing the Apple Crop of 1923, by Lorian P. Jefferson.

No. 225. Yellow Pickle in Greenhouse Cucumbers, by Victor A. Tiedjens.

No. 226. Research Service to the Massachusetts Apple Industry: Progress Reports, by Lorian P. Jefferson and Hubert W. Yount, J. K. Shaw, William Doran, J. S. Bailey and A. I. Bourne.

No. 227. The Connecticut Valley Onion Industry: Progress Reports of Experimental Work, by Lorian P. Jefferson, A. B. Beaumont and O. E. Street, A. Vincent Osmun and A. I. Bourne.

No. 228. An Economic Study of the Massachusetts Apple Industry, by Hubert W. Yount and Lorian P. Jefferson.

No. 229. Soil Reaction and Black Root-Rot of Tobacco, by P. J. Anderson, A. Vincent Osmun and W. L. Doran.

No. 230. Research Service to Massachusetts Animal Industry: Progress Reports, by J. B. Lindsey, J. G. Archibald and Sidney B. Haskell.

Bulletins, Technical Series.

No. 7. Broodiness in Relation to Fecundity in the Domestic Fowl, by F. A. Hays and Ruby Sanborn.

No. 8. Winter Cycle and Winter Pause in Relation to Winter and Annual Egg Production, by F. A. Hays and Ruby Sanborn.

No. 9. Annual Persistency in Relation to Winter and Annual Egg Production, by F. A. Hays and Ruby Sanborn.

No. 10. The Therapeutic Efficiency of Avian Diphtheria, Roup, and Bird Pox Vaccines and Bacterins, by Norman J. Pyle.

Bulletins, Control Series.

No. 31. Control of Bacillary White Diarrhoea, 1924–1925, by P. E. Bransfield.

No. 32. Inspection of Commercial Feedstuffs (1925), by Philip H. Smith and Frank J. Kokoski.

No. 33. Inspection of Commercial Fertilizers (1925), by H. D. Haskins, L. S. Walker and George B. Dalrymple.

No. 34. Inspection of Agricultural Lime Products (1925), by H. D. Haskins, L. S. Walker and G. B. Dalrymple.

No. 35. Control of Bacillary White Diarrhoea, 1925–1926, by P. E. Bransfield.

No. 36. Inspection of Commercial Feedstuffs (1926), by Philip H. Smith and Frank J. Kokoski.

No. 37. Inspection of Commercial Fertilizers (1926), by H. D. Haskins, L. S. Walker and M. W. Goodwin.

No. 38. Inspection of Lime Products Used in Agriculture (1926), by H. D. Haskins, L. S. Walker and M. W. Goodwin.

Meteorological Reports.

Nos. 433–456, inclusive.

Scientific Contributions.

No. 30. The Application of Genetic Principles in Breeding Poultry for Egg Production, by F. A. Hays. In Poultry Sci. 4:43–50. 1924–25.

No. 32. Controlling Onion Smut with Kalimat, by P. J. Anderson. In Phytopathology 14:569–574. 1924.

No. 33. Susceptibility of Nicotiana Species, Varieties and Hybrids to Tobacco Wildfire, by P. J. Anderson. In Phytopathology 15:77–84. 1925.

No. 34. The Availability of Subsoil Potash, by Sidney B. Haskell. In Soil Sci. 19:105–114. 1925.

No. 35. Annual Crops from Biennial Bearing Apple Trees, by Brooks D. Drain. In Amer. Soc. Hort. Sci. Proc. 300–302. 1924.

No. 36. Some Physiological Aspects of Asparagus Officinalis, by Victor A. Tiedjens. In Amer. Soc. Hort. Sci. Proc. 129–140. 1924.

No. 37. Biological Investigation of Peat, by Arao Itano. In Jour. Bact. 10:87–95. 1925.

No. 38. Some Unusual Results in Fertilizing Fruit Plants, by J. K. Shaw. In Amer. Soc. Hort. Sci. Proc. 281–286. 1924.

No. 39. Sod-Nitrate vs. Cultivation in the Apple Orchard, by J. K. Shaw. In Amer. Soc. Hort. Sci. Proc. 328–337. 1924.

No. 40. Autumn Development of Peach Fruit Buds, by J. S. Bailey. In Amer. Soc. Hort. Sci. Proc. 30–33. 1924.

No. 41. The Economics of Fertilizer Use in the United States, by Sidney B. Haskell. In Jour. Amer. Soc. Agron. 17:198–210. 1925.

No. 42. Comparative Susceptibility of Onion Varieties and of Species of Allium to Urocystis Cepulae, by P. J. Anderson. In Jour. Agr. Research 31:275–286. 1925.

No. 43. Inheritance of Plumage Color in the Rhode Island Red Breed of Domestic Fowl, by F. A. Hays. In Genetics 11:355–371. 1926.

No. 44. The Digestibility and Energy Values of Feeds for Horses, by J. B. Lindsey,

C. L. Beals and J. G. Archibald. In Jour. Agr. Research 32:569–604. 1926.

No. 45. Life History of Ustilago Striaeformis (Westd.) Niessl which Causes a Leaf Smut in Timothy, by W. H. Davis. In Jour. Agr. Research 32:69–75. 1926.

No. 46. The Value of Calcium Phosphate as a Supplement to the Ration of Dairy Cows, by J. B. Lindsey and J. G. Archibald. In Jour. Agr. Research 31:771–791. 1925.

No. 47. The Life History and Control of the Cranberry Weevil, Anthonomus Musculus Say (Coleoptera: Curculionidae), by Donald Sewall Lacroix. In Jour. Econ. Ent. 19:819–829. 1926.

No. 48. The Composition, Digestibility and Feeding Value of Hydrolyzed Sawdust, by J. G. Archibald. In Jour. Dairy Sci. 9:251–271. 1926.

No. 49. The Bacteriophage in Relation to Salmonella Pullora Infection in the Domestic Fowl, by Norman J. Pyle. In Jour. Bact. 12:245–260. 1926.

No. 50. Cranberry Flower-Bud Investigations, by Donald Sewall Lacroix. In Jour. Agr. Research 33:355–363. 1926.

No. 51. The Balance of Trade in Farm Products, by Lorian P. Jefferson. In Jour. Farm Econ. 8:451–461. 1926.

No. 52. The Preparation and Effectiveness of Basic Copper Sulphates for Fungicidal Purposes, by E. B. Holland, C. O. Dunbar and G. M. Gilligan. In Jour. Agr. Research 33:741–751. 1926.

Control Activities of the Experiment Station.

In addition to its main functions of a research agency, the Experiment Station administers four control laws, namely, providing for chemical control of commercial feedstuffs sold within the State, and of commercial fertilizers and lime, providing for the testing of poultry for bacillary white diarrhoea, and inspection of dairy glassware. In the first three of these, which are the major control activities of the Station, reports were published covering the operations of both 1925 and 1926. Further comment on this phase of the work is not needed at this time.

Increase in knowledge regarding the properties of certain agricultural commodities, and conditions governing their effective use, make necessary three changes in existing control laws, as follows:

1. The great increase in the use of cod liver oil and other vitamin carriers, in both animal and human nutrition, makes necessary a form of guarantee under which they may be sold, different from any which has previously been in common usage. Existing knowledge as to conditions governing vitamin potency does not warrant hard-and-fast control such as is now exercised to a degree on ordinary commercial mill feeds. Without doubt, also, the United States Government has a function in the matter, which may better be exercised than the authority of individual states. Until such time as the Government takes over this function and exercises it in an effective way, purchasers are at the mercy of unscrupulous manufacturers and dealers. The principle involved should be that of the correct labeling act, to the effect that whatever is claimed for the product sold should be subject to check by a neutral state-supported agency.

2. In the field of fertilizers and other products sold for the purpose of increasing the productivity of the soil, there is now an array of inoculants which is giving rise to serious thought as to effective use. These are classified in two groups: first, so-called legume inoculants, the use of which is fairly well established, but which in this State are sold without examination by any neutral agency to check statement made; and general inoculants, the use of which is not yet well established. While there have not yet been standard control methods worked out to govern the sale of these products, yet the general application of a correct labeling principle will be fair to the manufacturer and give to our farmers and other users a degree of protection which is sadly needed.

3. A more elastic financial system is needed in the administration of the poultry disease law. This activity is now practically self-supporting. It is impossible, however, to foresee the need in any given year. Our budgets, of necessity, are made out practically a year before they become effective. I therefore suggest that in administering this law the Trustees ask for a sum materially greater than now allowed — $14,000 or $15,000 — and arrive at an understanding whereby

expenditures above a certain minimum — possibly the present appropriation of $10,000 — be allowed only in so far as income is produced to match the increase. This plan, if allowed, will preserve the system of a fixed budget with responsibility to State authorities for expenditures, and at the same time introduce the principle of a revolving fund.

Service Activities of the Station and Institution.

In addition to the formal research service, which represents the primary function of the Experiment Station, and the miscellaneous items of chemical and biological control which are administered by the Station as a matter of convenience and tradition rather than of logical organization, there is a mass of border-line work which for lack of a better term has been called "service." This includes participation in spray service for orchardists with reference to the time of applying sprays for control of insect and disease; frost warnings issued from the Cranberry Station; diagnosis of poultry diseases, plant diseases and soil troubles; miscellaneous analytical work on products sent in for examination; supplying legume inoculants; chemical and bacteriological analysis of water and bacteriological examination of milk; participation on a small scale in potato seed certification and supplying neutral specialists for orchard certification; and other similar services. In as far as is possible this work is done on a fee basis, it being expected that the fee will be sufficiently large to meet actual costs. It is the hope of the station, furthermore, to discontinue this service as rapidly as coöperative or commercial organizations develop so as to make the service unnecessary. At the present time, however, the fact of this service is a rather serious drain on research funds, and in at least one department has been carried on to such an extent as almost to inhibit successful prosecution of fundamental research. In the opinion of the writer this work should have a formally recognized status in the College, and should attempt to correlate in one office all of such work regardless of where or under what division it may be done.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 221 December, 1924

THE SMUT DISEASE OF ONIONS

By P. J. Anderson and A. Vincent Osmun

This bulletin records six years' experiments on the control of smut, the most destructive disease of onions in New England and presents practical recommendations based on these experiments. It also includes an account of the origin, history and economic importance of the disease and the development of the causal organism.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

3500-2-4-25 Order No. 817

THE SMUT DISEASE OF ONIONS

By P. J. Anderson and A. V. Osmun

INTRODUCTION

Commercial onion growing in Massachusetts sixty years ago was confined to the eastern part of the state, centering especially in Essex county about the Danvers section. But continuous cropping brought diminishing yields year by year until the growers found that they could no longer produce a profitable return on onions even in that fertile section. New land must be found, and the industry shifted gradually to the west until now practically all of the Massachusetts domestic supply of surplus onions is produced in the Connecticut Valley. The fertile acres of the Danvers section, famous onion center since colonial days, are no longer planted to onions.

When we inquire into the reasons for the diminishing crops and the westward shifting of the industry we find that the most important contributing factor was the increase in the prevalence and destructiveness of smut until the toll which it took wiped out the profits. A field once thoroughly infested with smut was permanently eliminated from profitable onion growing, and since no method of checking the disease had been discovered at that time, the inevitable result was the migration of the industry from a section so largely planted to onions.

The Connecticut Valley region, however, did not long escape. Year by year, smut became more prevalent; fields were being planted to other crops and the history of Danvers was in a fair way to be repeated along the Connecticut, when the formaldehyde method of controlling smut was discovered and the industry saved for the Valley.

But the formaldehyde method as worked out by the pathologists of twenty years ago was far from satisfactory. The formulas of application which they recommended were cumbersome and the machinery inadequate. The writers were unable to find a single grower in the Connecticut Valley who was applying the formaldehyde according to the rates of dilution and distribution which were recommended by the pathologists. Finding these inconvenient, the practical growers modified them in various ways to suit themselves. The results obtained were more various than the rates of application. Some were successful; many had partial control; others ruined the crop. Lack of uniformly successful results caused many to condemn the method and either to plant the fields to less profitable crops or to omit the formaldehyde and tend the onion crop at a reduced profit or an actual loss.

Such was the situation when the writers began their investigation of onion smut in 1918. The whole field of control seemed ripe for a reworking.

It was necessary that a formula of applying the formaldehyde be determined and standardized for Connecticut Valley conditions, a formula which should be practical for the grower and at the same time could be depended on to control the disease and not cause serious injury to the onions. The machine for application must be improved. The behavior and life-history of the smut fungus throughout the whole year must be carefully studied with the special object of finding a better method of combating the disease. Many other minor problems were yet unsolved.

During the last six years the investigation has been prosecuted in the laboratory and greenhouse during the winter and in the fields of the onion growers of Sunderland, Amherst and Leverett and on the Experiment Station farm during the growing season. It was essential that the field control experiments be continued through a series of years on different farms because it was found that the season and other environmental conditions influenced the results of the treatment and it was desirable to develop a method which would be suitable for every year under a wide range of conditions. The writers believe that after six years of experimenting they are ready to publish definite recommendations. In the present bulletin there are also presented the experiments and data on which the recommendations are based, along with the results of some other accessory lines of investigation on onion smut.

HISTORY OF THE DISEASE

Onion smut is probably a disease of American origin, although its history previous to 1857 is unknown. Onions have been cultivated and used by all the civilized races of the world in all ages. Starting with the inscriptions on the pyramids, there is an enormous amount of ancient and modern literature on all phases of onions and onion culture, but it contains no mention of smut or any trouble which might be interpreted as smut previous to the middle of the 19th century, when it was first found in New England. If smut is of Old World origin, this omission is certainly nothing short of remarkable. Is it not more probable that it occurred in an inconspicuous way on some other closely related American plant and thence passed over to the onion which it found to be a more suitable host? To be sure, we have no published record of its occurrence on any other American plant (except for one record of a wild onion, *Allium Nevadense*, in the Far West); but when one recalls that new diseases and new hosts of disease organisms are being discovered every day, and that it may occur on its wild host plant only as an inconspicuous seedling disease, this does not seem to be a serious objection. The fact that the disease has been found on twenty-six other species of plants of the same genus not previously reported as affected by smut (p. 8) indicates that all of the host plants of the onion smut have not yet been found.

The first published record of the existence of onion smut which the writers have seen is in the Proceedings of the Essex Institute for 1857 (31: 207, 211–214)*.

Since this interesting article seems to have escaped the notice of other students of the disease† and is in a rather inaccessible publication we quote it in full. At a field meeting of the society at Beverly, Mass., on June 24, 1857, a letter was read by the secretary from Mr. J. W. Proctor,‡ a Danvers farmer. This letter according to the report of the secretary, Mr. Wheatland,

> "treated of the smut of the onion and of a maggot, which attacks that vegetable, threatening serious injury to the onion crops. He considered that at least half the estimated crop of the present season would be lost. This letter was referred to a committee consisting of Messrs. S. P. Fowler, George D. Phippin, and Henry F. King, in order that it might make the necessary investigation, and report on the subject at some subsequent meeting of the Society."

At the next meeting, which was held at Wenham on July 10, 1857, Mr. Geo. D. Phippin of Salem, made the following report on onion smut:

> "As to the second agency found so destructive in the cultivation of the onion your committee report that the smut found growing in the leaves of the onion plant has been examined under the microscope; but the specimens used were so imperfect that no information of a decisive character has been obtained. It is evident that the smut of the onion is a parasitical fungus which originates and develops itself within the cellular tissues of the leaves looking in some stages of growth like the filaments of a Botrytis. It makes its appearance on the first leaf and descends toward the root destroying the texture and rendering the leaf spongy and streaked with a black dust. Perhaps then it may originate from the use of too much putrescent

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*Numbers in parenthesis refer to bibliography in the back of this bulletin. Numbers after the colon give the page on which statements referred to may be found.

†All the writers on onion smut who have mentioned the matter at all (Farlow, Thaxter, Stone, Walker, Cornu, *et al.*) quote as the first published record, the observation of Ware (51), 12 years later. Probably a more thorough search through the agricultural literature of Essex County just previous to 1857 would reveal earlier allusions to smut.

‡Ten years previous to this date Mr. Proctor, who appears to have been an onion grower of considerable prominence, presented "An Essay on the Cultivation of the Onion" before the Essex Agricultural Society (33) in which he gave considerable attention to the pests and enemies of the onion, but no mention is made of smut. The fact that a practical, keen observer like Mr. Proctor had never seen smut leads us to believe that it was not present at that early date in the Danvers section.

matter in the soil, helped toward development by a peculiar low and damp atmosphere. The use of muscle-bed mud for culture of onions is well known but we have not ascertained whether such manuring is liable to the fly or not. An overmanured soil made so by too much putrescent animal or vegetable matters could be treated with lime ashes or charcoal, which by helping to absorb the ammonia would check the fermentary process so favorable to the growing of fungi of every kind.

"It would be interesting to ascertain whether this particular species of smut is to be found upon the leaves of the wild garlic (*Allium canadense*) for it may be that a more succulent condition of the cultivated plant as in our field onion, may be more susceptible to this disease from the high culture which it obtains. Such parasitic plants destructive to crops, indicate the tendency toward extinction of a particular variety, and the remedy may lie in changing the seed or by inducing some newer form not liable to be thus affected."

The next published record of the disease is in the appendix of the 17th annual report of the Massachusetts Board of Agriculture (51:10) in which is printed an address by Mr. Benjamin P. Ware, a Marblehead farmer, before the Essex Agricultural Society on September 29, 1869. He states that smut is "very destructive, turning the most promising fields . . . to scenes of desolation," and that it "so impregnates the land with its spore as to render it unsafe to plant onions for several years on land thus affected." In view of our present knowledge of the long time required for impregnation of the land, these statements indicate that smut was not a new disease in Essex County in 1869, but that it must have existed for many years. There is evidence according to Thaxter (44:131) that it occurred in Connecticut as early as 1860, although there is no published record. In his report of the U. S. Department of Agriculture for 1869 (7:224) the commissioner, Mr. Horace Capron, devotes a page to onion smut, but mentions no locality except Massachusetts. From this, one judges that it was not known to occur in other states at that time. In the U. S. Commissioner's report for 1872, (43:193) Mr. Thomas Taylor, the microscopist, mentions a field of four acres in Swampscott where the disease was so bad that the field was abandoned. In the same report, he published the first figures of onion smut spores. The first accurate scientific description of the disease and its causal fungus is by Farlow (14:164) in the appendix of the report of the Massachusetts Board of Agriculture for 1876. He states that at that time it was not known to occur anywhere except in Massachusetts and Connecticut and presents convincing evidence that it was of recent origin.

Summing up all the evidence in regard to the origin of smut we may say that in all probability it existed on some native American plant closely related to the onion and first made its appearance on the cultivated species about 1850 in New England.

From New England it has spread to all of the onion-growing regions of the northern United States, but is not known to occur in the southern states. In 1889 it was known to be present in Ohio and Pennsylvania (44:135) and in Vermont (25:141), New Jersey in 1890 (20:352), New York, previous to 1869 (37), Iowa, about 1900, (30:216) and reached the Pacific coast about 1911 (6:187). The date of introduction into other states is not recorded, but at present it is known to occur in Indiana, Illinois, Wisconsin, Missouri, North Dakota, Delaware, Kentucky, Tennessee, West Virginia, Kansas and Minnesota.

It is probable that it spread from America to Europe and other parts of the world. It was reported from near Amiens, France, as early as 1872 (12:40), from southern France in 1877 (34:379) and from the neighborhood of Paris in 1879 (10:51). It is said by Frank (17:186) to have been found the same year in Germany near Leipzig, but Zillig (54:298) questions this since he finds the first official report of its occurrence in Germany in 1909. If it occurred in Germany during the intervening years it must have been very inconspicuous. Zillig (1923) states that in that country it sometimes causes a loss of 60 per cent. of the crop. The first published record of smut in England was in 1919 (13:168) but there is evidence that it occurred in the British Isles as early as 1900 (52:443). Walker (49:15) reported it as common in Holland. It has also been reported from Denmark. The writers were also informed by Dr. Ito of the Sapporo Experiment station that it is not uncommon in Japan. The losses from smut in countries other than America have not usually been considered serious.

LOSSES FROM SMUT

Onion smut has caused—and is now causing—great losses to the onion growers because:

1. Many acres of land best suited for the growing of onions have had to be turned to the growing of other crops because the land was so impregnated with smut that a good crop of onions could no longer be grown.
2. It costs just as much to tend a crop where smut has reduced the stand as it does to tend a full stand but the returns are less. The diminished yield frequently leaves no margin between cost of production and the selling price.
3. The price of chemical, special apparatus and extra labor for application of chemical, where preventive measures are used, must be added to the production cost.

The Plant Disease Survey of the United States Department of Agriculture (32:210) estimated the loss from this disease in the United States in 1918 at 754,000 bushels. In individual fields in Massachusetts losses may vary from 0 to nearly 100 per cent.

At attempt to calculate the losses in dollars would be conditioned by so many modifying factors that it would necessarily be the merest guess and no such attempt will be made by the writers. It is, by all odds, the most important disease of onions occurring in America, and time or money spent in controlling it is well worth while.

SYMPTOMS

The first signs of smut appear on the young seedlings within two or three weeks after the seed are planted. In fact, the very first recognizable indication of disease has been observed here (1:131) within ten days from the date of planting. The cotyledon (or seed leaf) which is the first part to appear above the ground is marked by a slight distortion and swelling instead of being perfectly straight as is the case with a healthy plant. A few days later, when one holds the plant up to the light and looks through it, he sees a dense black, opaque, elongated area (or several of such) inside the seed leaf. Many of these weakened plants "damp off" and fall at this stage. Even if they do not damp off they gradually shrivel and die if the attack is severe. If one crushes these dead cotyledons he finds them filled with a black powder (spores). The heaviest loss in an infested field is during this cotyledon stage; the grower notices that his rows become thinner day by day, until only a fraction of the seedlings which came up remain standing. If, however, the initial attack was not very severe the plants do not die in the cotyledon stage but the successive leaves develop and in many cases are perfectly healthy, the disease having been sloughed off with the cotyledon. But usually smut will appear as long dark streaks in each of the succeeding leaves. Such plants remain stunted and the leaves are short, brittle, and distorted (Fig. 1A). They continue to die in various stages of development throughout the summer. Very few of them develop bulbs of any size. Even if they continue to live until time of harvesting, they are never stored because in the last stages they develop "bottom rot" and are thrown out. As the diseased plants grow larger, the black smut pustules (or lesions) also increase in size. They may be several inches long or extend throughout the entire length of the leaf. As the leaf becomes old and dried these lesions split open and the spores fall out (Fig. 1A). Frequently they rupture to the inside of the hollow leaf. On the bulb itself, the pustules are raised and appear gray as one looks at the black mass through the white covering of the scales (Fig. 1B). When the outer scales die the black spores fall out into the soil (Fig. 1). The appearance of a row of diseased onions as compared with a row of healthy onions is shown in Fig. 2.

THE CAUSE OF SMUT

Smut is produced by the growth inside the tissues of the onion of a parasitic fungus of the order Ustilaginales. The spores of this fungus were first distinguished and figured by Taylor in 1872 (43:193 and Fig. 29), but the first accurate description is by W. G. Farlow of Harvard University in 1876 (14:175). C. C. Frost of Brattleboro, Vt., had previously examined it and found that it belonged to the smut genus,

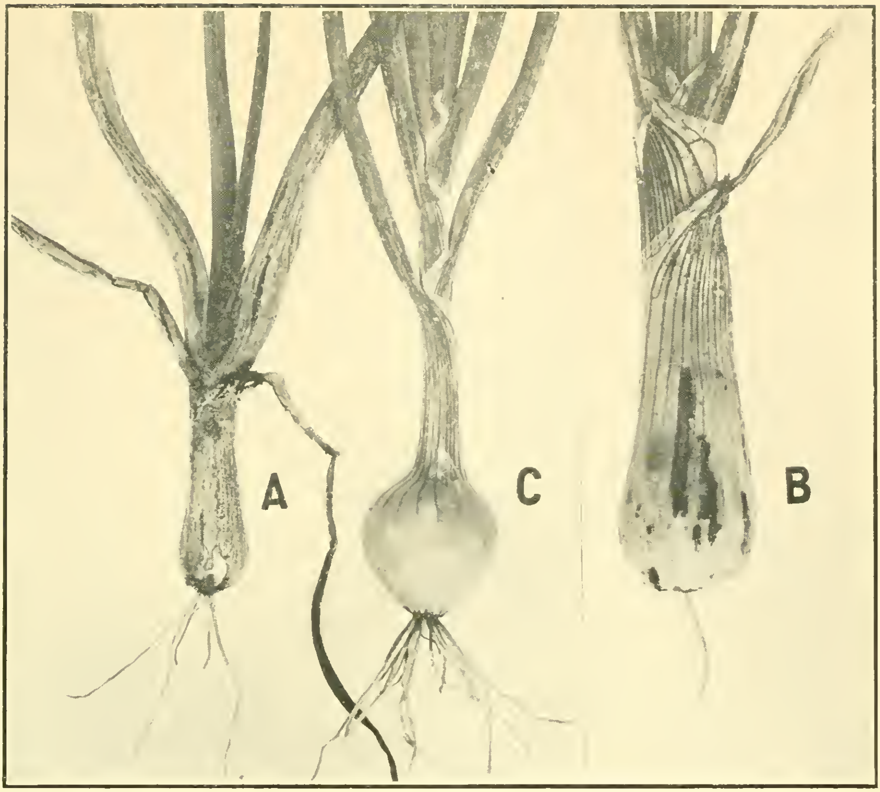

Fig 1.—Symptoms of smut on mature onions. A. Showing distorted leaves with ruptured pustules exposing black spore powder. B. Smut pustules on bulb. C. Healthy onion for comparison. Note failure of diseased plants to develop normal bulbs.

Fig. 2.—Formaldehyde treatment for smut. 2 rows in center received no formaldehyde.

Urocystis, and had sent some specimens to Farlow with the appended name *Uro cystis cepulae* (*cepulae* means *of the little onion*). Farlow adopted Frost's name and published a description but indicated Frost as the author of the species (although the latter apparently never made a description). Some of the European writers (*e.g.* Cornu and Frank) quote Farlow as the author. It is usually referred to as *Urocystis cepulae* Frost.

Shortly after Farlow described this as a new species there was considerable discussion among students of fungi as to whether this really was a new species or whether it was identical with some previously described smut. No smut fungus had been described previously from the cultivated onions but some had been described from wild species of the same genus and from closely related genera of the Liliaceae. Thus *Urocystis magica* was described from Italy on *Allium magicum.* Farlow, in his second paper (15:114) expresses the opinion that *U. cepulae* is identical with *U. magica* Pass. Another closely related smut is *U. Colchici* Schlecht which occurs on *Allium rotundum* and a number of species of the Liliaceae outside the genus Allium. Farlow pointed out the differences between *U. Colchici* and *U. cepulae* and considered them as distinct. Cooke (9:634) however, considers the difference insufficient for specific rank and calls the onion fungus *U. Colchici var. cepulae.* Magnus (28:348) also considered *U. cepulae* as distinct from *U. Colchici.* Schroeter and Winter (Die Pilze, p. 121, 1884) would unite all the above species under *U. Colchici.* Magnus and Cornu agree with Farlow in keeping the two distinct. Clinton in his monograph of the North American Ustilagineae (8:451) says, "There has been some discussion whether the American species is distinct from *Urocystis Colchici* and *Urocystis magica* of Europe, the latter species also occurring on species of Allium. The three while very closely related are distinct. The species described here (*U. cepulae*) differs from both in having smaller spores and spore balls and also from *U. Colchici* by rarely having more than one spore in a ball." Another species of Urocystis on Allium is *U. Allii* (Belham) Schellenberg on *Allium subhirsutum.* The writers have not examined this species, but both Liro and Schellenburg regard it as distinct from *U. cepulae.* Inoculation experiments by Anderson showed *A. subhirsutum* to be one of the few species of Allium which are immune to *U. cepulae.*

Liro (27) has recently merged the genus Urocystis with the older genus Tuburcinia because he was unable to distinguish any morphological differences between them and has proposed the name *Tuburcinia cepulae* (Fr.) Liro as the correct name for the onion pathogene. This change has been adopted by European writers but as yet has not appeared in American literature. In both of these genera, the spore —more commonly called the "spore ball"—is not a single cell but is composed of a globose ball of a number of cells permanently bound together. In Tuburcinia all of these cells are fertile, *i.e.* capable of germination, while in Urocystis only the central ones are fertile while the peripheral ones are sterile and called accessory cells. In opposition to this usual conception Liro maintains that no such distinction exists, but that in all these species there is a covering layer of sterile cells. When Fries erected the genus Tuburcinia, the first species which he placed under it was *T. Orobanches,* the spore ball of which is composed of 1-3 larger central cells surrounded by a compact layer of smaller, flatter cells. Contrary to the opinion of most previous students of this genus, Liro considers the smaller outer cells as the sterile accessory cells and therefore, that this spore ball differs from that of ordinary species of Urocystis in no way. From examination of slides of Fries' original specimen kindly furnished by Dr. Liro, the writers were able to confirm Liro's conclusions in regard to the relative size of the cells; but it should be kept in mind that the separation of the genera is not based on differences in size of central and peripheral cells but on their ability to germinate. Microscopic examination of these slides did not disclose any difference in the outer cells which would prevent germination. Brefeld (Untersuch. A.D. Gesammtg. d. Myk. Heft. 12:180 and Pl. XI. 1895) has published excellent figures of the germination of the spores of *Tuburcinia primulicola*, a species very similar to *T. Orobanches*, and he shows the peripheral cells germinating in large numbers. He was unable to find any sterile cells outside of those which germinated. Liro does not mention any germination studies and there is no record in the literature that the germination of the spores of *T. Orobanches* has been observed. Until the germination of these spores has been studied, and until there is some concord of opinion among mycologists as to the constancy of the sterile layer of covering cells, we prefer to retain for the onion smut organism the name which has been in continuous use for the last fifty years.

The true onion smut fungus *U. cepulae* Frost, does occur, however, on other species of Allium. Clinton (8:451) reported it on specimens of *A. Nevadense* from Nevada. In England the disease is said to be more severe on leeks (*A. Porrum*) than on onions (13:170) and was reported from France on this host as early as 1881 (29:277). Quite recently (55:57) Zillig has reported that he was able to infect *A. fistulosum* L., *A. globosum* Red., *A. odorum* L. and *A. Porrum* L.

One of the writers, before he was aware that Zillig was working on the same problem in Germany, began a series of inoculations by planting seed of all obtainable species in soil which was very heavily infested with *U. cepulae*. Records taken every week after the plants came up gave the total percentage and severity of smut infection for each species. A full description of these experiments and the results are published elsewhere (4). Briefly, it was found that out of 39 species which were tested, 8 proved to be immune to smut, while 31 showed varying degrees of susceptibility. Thirteen species were just as susceptible as the common onion in that the disease affected them in just the same way throughout the season. In five others it caused heavy mortality in the cotyledon stage but did not persist throughout the season. In 13 others the cotyledons were sometimes affected, but the plants rarely if ever died from the effects of smut. These results lead us to believe that if the numerous other species—there are some 250 species in the genus—were tested in the same way, a large proportion of those which reproduce by seeds would be found to be susceptible. (Many species escape the disease by reproducing only by bulblets.)

Within the species *Allium Cepa*, the cultivated onion, there are numerous varieties, but up to the present there are no data or observations to indicate that any of them show any degree of resistance to smut. It has been stated at various times, however, that the white varieties are somewhat more susceptible than the red or yellow ones. Walker and Jones (50:236) tested several varieties, and Whitehead (52:449) tested 21 varieties of onions and 11 varieties of leeks (*A. Porrum*) but none was found which showed resistance. Anderson (4) tested 54 varieties of cultivated onions but found no significant indication of resistance among them.

*Morphology and Life-History of the Smut Fungus**

If one examines microscopically the dusty black mass from the leaves or bulbs, mentioned above, he will find that each particle of dust is a spore (chlamydospore) of the fungus which causes smut. It is a compound spore composed of one large central brown cell, to the surface of which are attached 15–40 smaller hemispherical cells (see Fig. 3A). The dark central cell is the fertile cell, while the numerous smaller surrounding cells, which are transparent, but with a brownish tint, are the sterile cells (pseudospores or accessory cells).

The spores get into the soil either by the rupturing of the sorus (pustule) or by decay of the infected part of the onion which has fallen to the ground. In the soil they may germinate at once or after a few weeks or months, or they may remain for years before germination occurs. In either case they grow into long slender branching tubes (the mycelium) and in a favorable soil this growth may be sustained for many years even though onions are not planted again on the same field. The mycelium does not produce other spores (*sporidia* or *conidia*) but it may break up into short pieces which are able to lie dormant for long periods and then germinate on the return of favorable conditions. The soil becomes so infested with spores, mycelium and these detached mycelial segments that without preventive measures onions can no longer be raised on it.

Method of germination of the spores. In a previous publication Anderson (1:108) has described the process of germination as it occurs during the first few months after maturity of the spores. Briefly it is this: A globose hyaline body, at first no larger than one of the sterile cells but later becoming as large as the fertile cell, develops on the surface of the fertile cell (Fig. 3B). From this body one to eight germ tubes grow out (Fig.

*In a previous publication from this station (1) the reader will find more detailed information on the full life history of *Urocystis cepulae*. In the present publication the seasonal life-cycle is outlined very briefly.

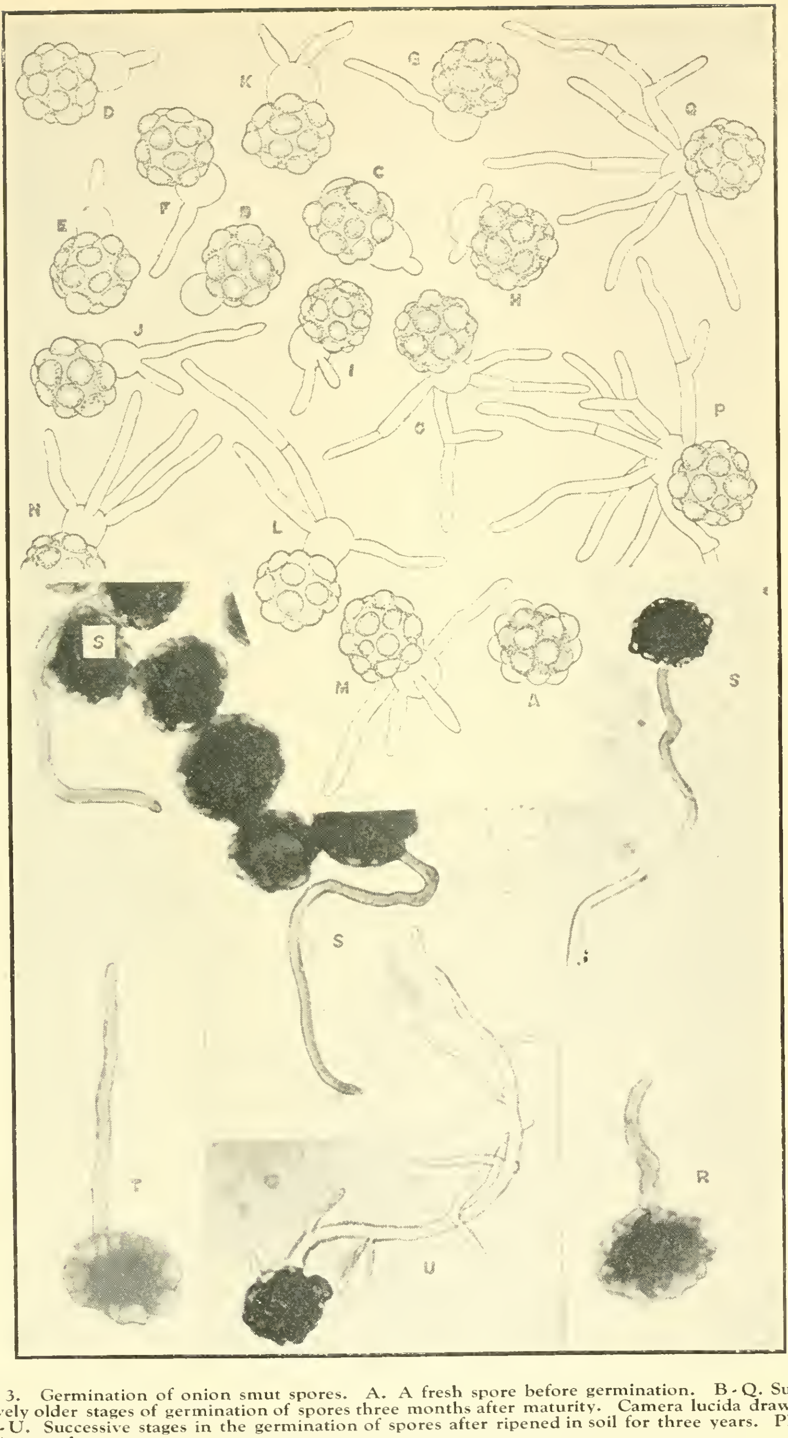

Fig. 3. Germination of onion smut spores. A. A fresh spore before germination. B - Q. Successively older stages of germination of spores three months after maturity. Camera lucida drawings. R - U. Successive stages in the germination of spores after ripened in soil for three years. Photomicrographs.

3C-Q) and by elongation, branching and septation form a dense mycelium without any indication of sporidia. Subsequent to the publication of these results, smutted leaves were placed in damp soil in test tubes where they were kept for three years. At the expiration of that time the spores were again tested for germination by the same method as was used in the previously reported tests. The process of germination was now found to be quite different from that which took place during the first three months after maturity. Most of the sterile cells had now collapsed and no longer presented the plump appearance which they have on fresh spores. Germination began within 2-5 days after the spores were sowed on the cold agar plates. The first striking difference was that there was no large globose body developed on the face of the fertile cell, but a single slender tube grew out directly from the central cell (Fig. 3R-U). Occasionally two tubes seemed to come from the same place, but the second one may have been merely a branch of the first arising very close to the surface of the spore. Usually the germ tube remained simple and unbranched until it had reached a length of 20–30 times the diameter of the spore. Then it became septate and branched sparingly. The protoplasm disappeared from the older cells but remained dense in the advancing tip cells. No sporidia were observed at any time even when the further development was examined daily until masses of mycelium a half-inch or more in diameter were formed. All the further development and behavior of the mycelium was the same as previously described after the germination of the spores according to the first process. The process of germination of these "after-ripened" spores is very similar to that described by Thaxter (44:142) and Whitehead (53) except that both of them found sporidia. The difference in germination between fresh spores and after-ripened spores is susceptible of various interpretations, but none will be attempted until after further investigations have been made.

It is commonly stated in the literature on onion smut that the chlamydospores live for many years—any number up to 25 may be found—in the soil and then germinate to infect the seedlings when onions are again planted. Such statements are erroneously based on the observation that smut recurs on a certain piece of land which has not been planted to onions for that particular number of years. It seems more probable that the smut is carried through those years in the form of mycelium living on the organic matter in the soil. Another possibility is that the spores or other organs of the fungus may have been washed or carried in some other way from fields where onions had been grown in the interim. During the season of 1923 smut occurred in destructive form on a plot of land on the experiment station farm which, as the records showed, had not been planted to onions in at least 40 years, but this plot was adjacent to another field where onions had been grown during many years. A similar case is reported by Whitehead (52:444). There are numerous ways in which it could be spread from one field to another, *e.g.*, by surface washing, wind, tools, animals, direct spread of the mycelium, workmen, etc.

From the soil the mycelium enters the very young seedlings by boring directly through the epidermis. Infection may occur only during a very limited period while the epidermis is tender. The exact length of this period was determined by Walker and Jones (50:238) and by Anderson (1:120). Walker and Jones found that "the plants became immune . . . between the nineteenth and twenty-fourth days after sowing, when the cotyledon had about attained its full growth and as the first leaf was emerging." Anderson found that they were no longer susceptible after the 17th day under greenhouse conditions, but that "the period of susceptibility is not limited by the number of days during which the seeds have been in the soil, but by the length of time required for the seedling to pass through certain stages of development" and that "susceptibility begins to diminish from the time that the knees emerge from the ground and little if any infection occurs after the first leaf has emerged from the side of the cotyledon." Thus the conclusions from these two investigations—carried out at the same time, but entirely independently, were identical—that all infection occurs before the first leaf is developed—a period which may be roughly stated as 3 weeks after planting. Walker and Jones very ingeniously demonstrated that immunity after this period depends on the maturity of the tissues of the cotyledon or the successively developed leaves each of which in turn forms a protective sheath about the base of the next developing leaf.

As soon as the infecting mycelium has passed through the epidermis of the cotyledon, it spreads rapidly in all directions, deriving its food from the cells of the young onion. After growing for a period of 5–10 days the mycelium forms dense knarls between the cells of the host plant and then the knarls are transformed into masses of black spores which have been previously described. It must not be understood, however, that the mycelium from a single point of infection grows throughout the whole length of the cotyledon. On the contrary, a single mycelium probably never extends more than a quarter of an inch from the point of infection and the ripe sorus is developed at that point. If there are a number of sori in the cotyledon—which is usually the case—they are the result of the same number of separate infections. Very long sori in the cotyledon are the result of anastomosing shorter sori.

Just at the junction of the young cotyledon and the first root there is a slight swelling known as the root joint. Immediately above this is the growing point,—a region of less than a half inch,—from which place all new leaves start. This point remains stationary throughout the further development of the onion bulb. If an infection occurs near the growing point the mycelium reaches this rapidly dividing tissue and as each leaf grows up it carries with it some of the infecting mycelium which spreads and sporulates in the leaves. When an onion once becomes infected in the growing point, it never recovers. If, however, the cotyledon is infected only in the upper part the mycelium does not reach the growing tissues and the disease is sloughed off with the cotyledon and the plant develops normally.

RELATION TO ENVIRONMENTAL FACTORS

Most plant diseases vary greatly in prevalence and severity according to the season. Certain kinds of weather favor them, others retard them. They ruin the crop one year and are entirely absent during other years. Onion smut, however, differs from most common diseases in this respect: It is about the same every year. Some growers think they find it more severe during a dry year; just as many others think a wet year favors it. The writers have had occasion to watch the course of the disease for many years but have never noticed any marked difference in its severity from year to year on the same field. Walker and Jones (50:240) conducted controlled experiments in the greenhouse to determine the effect of variation in the moisture of the soil on the percentage of smut infection and concluded "that soil moisture does not function as a factor limiting infection with onion smut within the limits at either extreme where good germination and growth of the host occur."

A similar experiment was conducted by the writers at the Massachusetts Experiment Station in which the seedlings were grown in pots of naturally infested soil kept at moisture contents at intervals of 2 per cent. from 12 to 40 per cent. of the dry weight of the soil. Below 12 per cent. this soil was too dry for good germination, while at the upper limit it began to decline rapidly from 34 per cent. Within this range the smut loss was almost total. Above 34 per cent. there was a decline in the percentage of infection, but the soil was very muddy and it is not likely that any grower would plant onion seed in soil so wet as this. It is conceivable, however, that rains immediately following the planting might keep the ground so wet that infection would be reduced, but probably the loss of germination on account of wet soil would more than counterbalance the gain from decreased infection. The practically identical results of these two experiments conducted independently in Wisconsin and Massachusetts indicate that the moisture condition of the soil in the spring is without influence on prevalence of the disease during that year.

Neither is there any indication that a warm spring in the Connecticut Valley is any more or less favorable than a cold one. All the onions here are planted in the early spring before the soil becomes very warm. Walker and Jones (50:247) conducted experiments on the effect of soil temperature on infection and concluded "that a high percentage of infection may be expected up to 25° C. (=77° F.) above which there is a rather abrupt reduction, leading to complete inhibition at 29° C. (=84° F.). There appears to be no lower limit of temperature for infection within the range where onion seeds will germinate and normal growth occur." They explain the absence of smut from the southern onion regions, *e.g.*, Texas and Louisiana, as due to the fact that in those regions the seed is planted in late summer when the soil temperature is too high for infection to occur.

The temperature experiments of Walker and Jones were also duplicated at the Massachusetts Experiment Station and the results were practically the same. Onion seed germinated at all temperatures between 8° and 35°C., but the percentage drops off rapidly above 27° and is much retarded below 13°. It required 33 days for the plants at 8° to show above the surface of the soil. The optimum is between 15° and 27°. Smut was not entirely absent at any temperature tried, but the percentage dropped off suddenly and rapidly above 27°. Below 27° there were no significant differences at any temperature. There seems to be no lower limit of infection within the range of germination of the onion seeds. This suggests the possibility that smut might be avoided or diminished by delaying the planting here until the soil became warm. Late planting, however, is not conducive to good crops in the Connecticut Valley and, in addition, this method has been tried (50:237) here without any beneficial effect.

It is apparent from the results of the experiments just mentioned that the only soil temperatures which could influence prevalence of smut would be from 27°C. (81°F.) upward. Does the soil of the Connecticut Valley onion region ever approach such high temperatures during the infection period, *i.e.*, approximately during April and May? We have no local continuous seasonal records for the soil, but since all infection occurs within the upper inch of soil we may approximate it from the air temperature records during those months. The soil temperature during the heat of the day, to be sure, may rise several degrees above that of the air, but we may allow a latitude of ten degrees or more and still reach some conclusion. Weather records at Amherst for the ten-year period 1915–24 show the mean hourly temperature for the month of April to be 45.8°F. and for May, 56.5°F. Even though the soil temperature in parts of the field were 20° higher than that of the air —which is beyond reasonable limits for any length of time—it would still not be high enough to limit infection. As far as Massachusetts is concerned then, soil temperature seems to be as unimportant as soil moisture.

We may conclude, therefore, that variations in weather conditions are without effect on the severity of smut infection. There is, on the contrary, very good evidence that certain soil factors may have a deciding influence. A survey of the Connecticut Valley region shows that fields are very unevenly infested. Onions always suffer most in certain fields. In the same field, certain spots are very heavily infested while other parts of the field suffer little. The location of these spots remains approximately the same year after year although the whole field is planted to onions each year and the treatment of all is the same. Such a condition cannot result from any lack of opportunity for the fungus to spread. It can apparently mean only that there is some soil factor which is right for the growth of or infection by the fungus in that part and not in the other parts of the field. Investigation with the object of determining this factor (or factors) is now in progress at this station, but it has not progressed to the point where any conclusions can be drawn.

PREVENTION OF SMUT

When the ravages of smut first began to attract attention of New England onion growers (1850–75), it was thought to be connected in some way with the character of manures applied to the soil, guano being held especially responsible. Remedies were therefore sought through change of fertilizers. Thus Horace Capron (7:224) suggests: "A remedy for this disease must be sought by using less manure, or manures which are less stimulating and afford less nitrogen for the fungus to feed upon. Alkaline manures are very destructive to the fungus. Wood ashes, lime, gypsum and seaweed are very efficacious."

Taylor (43:195), who first made a study of the spores and laid stress on their presence in the soil as a means of carrying the disease over winter and spreading it about, recommended that they be destroyed and the disease thus controlled, by burning heaps of dry weeds and rubbish on the infested fields. This recommendation was repeated by various writers during the next fifteen years, but it does not appear from the literature that anybody tried it. Walker (47:6) has recently recommended burning the onion tops after harvest and the avoidance of returning onion refuse to the soil.

Farlow (14:174) was the first to suggest rotation of crops as a means of control. He was led to believe from the statements of growers that the spores do not live in the soil more than four years and thought that if a smut-infested field were planted to other crops for four years, it would then raise a smut-free crop of onions. He did not think that the spores were carried by wind and in order to prevent the carrying of spores to uninfested fields, he recommended thorough cleaning of all tools which had been used on smut-infested land. Thaxter (44:138) on the other hand, finds that a badly infested crop of onions was grown on a field which had not been planted to onions for twelve years. Sirrine and Stewart (37:149) find in regard to the value of crop rotation: "it is the common experience of onion growers that even an occasional change of the crops for one or two years gives appreciable relief; and it is our belief that a systematic rotation of crops would very considerably reduce the amount of loss from smut." Farlow was also the first to recommend that all smutted onions be pulled during the growing season while the crop is being weeded, and that they be removed from the field and burned. It is not recorded in literature that this method was tried by any grower.

The first accurate experiments of any value on control are those of Thaxter (44:146) who was at that time mycologist of the Connecticut Agricultural Experiment Station. He applied various dry chemicals to the soil in the drills to see whether any of them would prevent infection of the seedlings by the fungus. The chemicals used were copper sulfate, iron sulfate, sodium sulfide, potassium sulfide, potassium chloride, calcium chloride, sodium hyposulfite and flowers of sulfur. Air slaked lime was tried also in combination with some of them. The mixture of air slaked lime and flowers of sulfur gave a fair percentage of control. The others injured the germinating seeds, or were of little or no value in preventing smut, or their use was impracticable. He repeated the experiments the following year (45:103) and again was able to increase by a ratio of about 5:1 the number of onions which could be raised on badly infested land, by the use of flowers of sulfur. Thaxter, himself, however, was not very enthusiastic in his recommendation of the method and two years later his successor, Sturgis (41:14) writes concerning it: "It seems probable now that the measure of success attending this treatment will hardly warrant its extended adoption."

The sulfur-lime treatment was thoroughly tested by Sirrine and Stewart (37:152), their field experiments extending over a period of five years. As a result of all their experiments they conclude (37:145) "that the yield of onions on smutty land may be greatly increased by the application of 100 pounds of sulphur and 50 pounds of air-slaked lime per acre in the drills at the time of sowing the seed. In several instances the yield has been increased at the rate of more than 15,000 pounds per acre as compared with untreated plats. Sulphur alone has considerable value as a preventive of smut, but seems more efficient when mixed with lime. The sulphur and lime should not be applied broadcast as they appear to have no effect on the smut when applied in that way. The sulphur-lime treatment is recommended whenever the loss from smut is as much as one-third of the crop."

Thaxter (44:146) found that infection occurred only in the very young seedling stage. Thus, when the plants were started in sterile soil and then transplanted to the field, they never suffered from smut. Sturgis (42:176) made extensive field tests of this method and demonstrated that it was an absolute preventive of smut. It was also recommended by Sirrine and Stewart (37:145). This most effective of all methods of control has not been adopted by onion growers in general because the amount of labor and time required for transplanting is so great as to render it impracticable where onions are grown on a large scale.

Burying of the surface soil has been tried with some success, but the labor involved is excessive (37:149).

The use of larger quantities of seed on smut infested land has been tried (37:149) but as pointed out by Sirrine and Stewart "there comes a time when it is impossible to obtain a stand no matter how much seed is used." Such a method is also impractical on a field which is unevenly infested, because the onions are too thick on lightly infested parts of the field and laborious thinning is necessitated.

In 1900 Selby (35:76) began experiments in Ohio, using the lime and sulfur treatment as recommended by Thaxter, various other chemicals, quick lime and formaldehyde. After the first year's experiments (1900) he abandoned all but the formaldehyde and the quick lime since they alone gave promising results. All the experiments were on seed sowed very thickly (about 40 pounds per acre) for the production of sets. During the second year he used only the quick lime and the formaldehyde or a combination of the two and obtained a considerable degree of control. In regard to his method of application we quote from his summary (36:51).

"To apply formalin, use at rate of one pound commercial formalin in 25–30 gallons of water (1 oz. to 1½–2 gals.) and apply with drip attachment on seed drill at rate of 500–700 gallons of solution per acre for onion set-seeding (about ⅕-¼ as much for field onions) or apply with sprinkler upon the scattered seeds until well moistened, then cover with earth promptly.

"Apply ground quick lime or stone lime, better the former, at the rate of 75 to 125 bushels per acre just before seeding, on the freshly prepared soil. If applied by drill, harrowing will not be required; if broadcast, harrowing should precede planting."

Stone (39) recommended formaldehyde at the rate of 1 lb. to 30 gals. (1–240) or 1 oz. to a gal. of water (1–128). With the improved tank which he describes in detail he found that about 1200 ft. of drill could be treated with one gallon of the solution.

Within recent years all other methods except the application of formaldehyde have been abandoned, since this has given good results and is the most convenient. Various concentrations of the solution and quantities per acre or given length of row have been recommended. The most recent and thorough investigations have been those in Wisconsin by Walker (47). After experiments of several years' duration he recommended the use of formaldehyde* at a dilution of 1–128 applied at the rate of 200 gallons per acre, or one gallon to about 185 feet of drill (1–128–2960, or approximately equal to our 1–128–3000 formula).

In England, Whitehead (52:444) recently made control experiments in which he treated the seed with various percentages of sulfuric acid and with paraform, other experiments in which the soil was treated with soot and salt, paraform, bleaching powder, lime, nitrate of soda, sulfur and lime, calcium cyanamide, carbon bisulfide and formaldehyde. In the summary of the work he recommends only formaldehyde.

We may briefly summarize the methods of control which have been recommended in the past and their present status:

1. Modification of the fertilization of the land has been of no avail. We do not believe, however, that the possibilities of this field of investigation have been exhausted.
2. Removal or destruction of diseased onions or refuse is wasted time.
3. Rotation of crops is of little, if any, value because of the length of time during which the fungus lives in the soil and because of the facility with which it may be introduced from neighboring fields. It is also not economically practicable on high-priced onion land.
4. Search for resistant varieties has yielded nothing up to the present, but should be continued.
5. Burying the surface soil is too expensive to merit consideration.
6. Sterilization of the entire field by heat or chemicals is also too expensive.
7. The use of larger quantities of seed is ineffective.
8. The use of transplanted seedlings is an absolute preventive, but such a method of culture is considered too laborious by growers of the Connecticut Valley region.
9. The use of sets is just as sure a preventive. This is being practiced more extensively every year, not only because of the smut situation but also because of less damage from thrips and of larger yields. The early harvesting of the crop, however, has distinct disadvantages from the storing and marketing standpoint.
10. Chemicals other than formaldehyde have proved worthless, injurious, or at best, very much inferior to that chemical. Sulfur and lime have given the most promise, but are no longer used.
11. The use of formaldehyde is the only treatment which is now recommended or extensively used. The principal objections to the formaldehyde method are—
    (1) the use of large quantities of water which greatly increases the labor at planting time, and
    (2) danger of injury to the seed.

*Walker also tried (48:323) the sulphur and lime method described by Sirrine and Stewart but found it inferior to the formaldehyde method "both as to efficiency in controlling the disease and ease of proper application."

It was with the object of reducing these difficulties to the practical minimum that field experiments were undertaken by this station. The problem was to find a formula of application* in which the water should be reduced to the lowest possible amount, but without serious damage to the germinating seeds.

The Cowls Farm Experiment, 1919

This experiment was located on a field so heavily infested with smut that the loss was almost complete during the preceding year. Three formulas were used, 1–64–3200, 1–96–3200 and 1–128–3200. The rows were 150 feet long, two untreated rows alternating with each plot of four treated rows and the whole series in triplicate, thus giving a total of 1800 feet of row treated according to each formula. Plots were planted on April 22. The soil was fairly moist when planted; there was only a slight precipitation during the next week, but the month of May was very rainy. No difference between the rows was apparent when they first came up but within a short time the treated rows looked greener and were thicker because of the dying of the smutted plants in the untreated rows. This dwindling continued throughout the summer as more of the smutted onions died and disappeared. On June 2, the number of onions in measured lengths of the rows was counted. Also the percentage of smut among those standing was determined. From an inspection of these data (Table I) it is apparent that there had been a large shrinkage from smut before that date and that half, at least, of those still standing in the untreated rows were smutted. Smut was not eliminated from the treated rows but it was so reduced in amount that the rows were too thick for the growing of bulbs of good size. During August thrips did serious injury, causing the tops to die prematurely. The bulbs on the check rows were much larger than on the treated rows because, after most of the seedlings died, they were far apart and had thus opportunity to grow larger. Very few of the diseased onions were still standing at harvest time and most of them were rotted at the base. Only rarely did one attain a diameter of one inch. The number of sound bulbs in each row was counted as they were pulled. After they had dried for a few days, each plot was also weighed separately. The data is summarized in Table I (p. 27). The comparative yields of treated and untreated rows are also shown in Fig. 4. The difference between the results secured by any of the three formulas is not large. Any of the three shows a gain of over 250 bags (100 lbs. in a bag) per acre. The control secured by the use of any one of the formulas was satisfactory.

If one prefers to measure the efficiency of the treatment by the gain in pounds, the 1–96 formula was somewhat the best. If, however, he wishes to consider the *number* of healthy onions at harvest time as the basis of comparison, the 1–128 formula is somewhat better.†

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*Formaldehyde (*i.e.* the 32–40 per cent. solution of the gas in water) cannot be applied in the concentrated form to the seeds in the row because even a very small quantity prevents the seeds from germinating. It is therefore necessary to dilute it with water. The first question to be answered then is: how much should it be diluted? This is the first variable in the experiments but this variable depends in turn on a second variable viz. the rate at which the diluted solution is to be applied to the row. For example, a 1–50 dilution is excellent if a gallon of it is applied to 700 feet of row but disastrous when applied to 200 feet and worthless when applied to 1400 feet. The numerical expression of these two variables is called the "formula of application." For all of our experiments it is written in terms of pints of formaldehyde—pints of water—feet of onion row. To illustrate: the formula 1–50–3000 means one pint of formaldehyde is diluted to 50 pints with water and the 50 pints of diluted solution applied to 3000 feet of onion row. Thus the first and second figures express the rate of dilution while the second and third figures express the rate of application of the diluted solution to the row in terms of pints of solution and feet of row. In the literature on onion smut control the rate of application is commonly expressed as so many gallons per acre of onions. This is undesirable because we do not treat acres but rows, *i.e.*, the amount of solution should be proportionate to the number of feet of row and not to the area of the field. The number of feet of row in an acre varies according to the distance between the rows. Different growers plant the rows at different intervals. Even in the restricted area of the Connecticut Valley one may find fields of onions planted at 12, 13, 14 or 15 inches and none of them is uncommon. In other sections of the country under different methods of culture other intervals are used. In order that results obtained at one place may be compared with those from another, it is desirable that formulas be expressed according to length of row treated and not acres. It should also be kept in mind that a direct comparison cannot be made between the results of the use of two formulas in which both variables are fluctuating at the same time: One must remain constant while the other is being changed.

†*Methods of calculating the results*: The writers have given considerable thought and attention to the question of the most accurate method of calculating and comparing the results obtained by the use of the different formulas of application. The methods which we have tried—most of which are in use by other investigators—are:

1. By counting the number of smutted seedlings when they are *in the cotyledon stage.* This method is

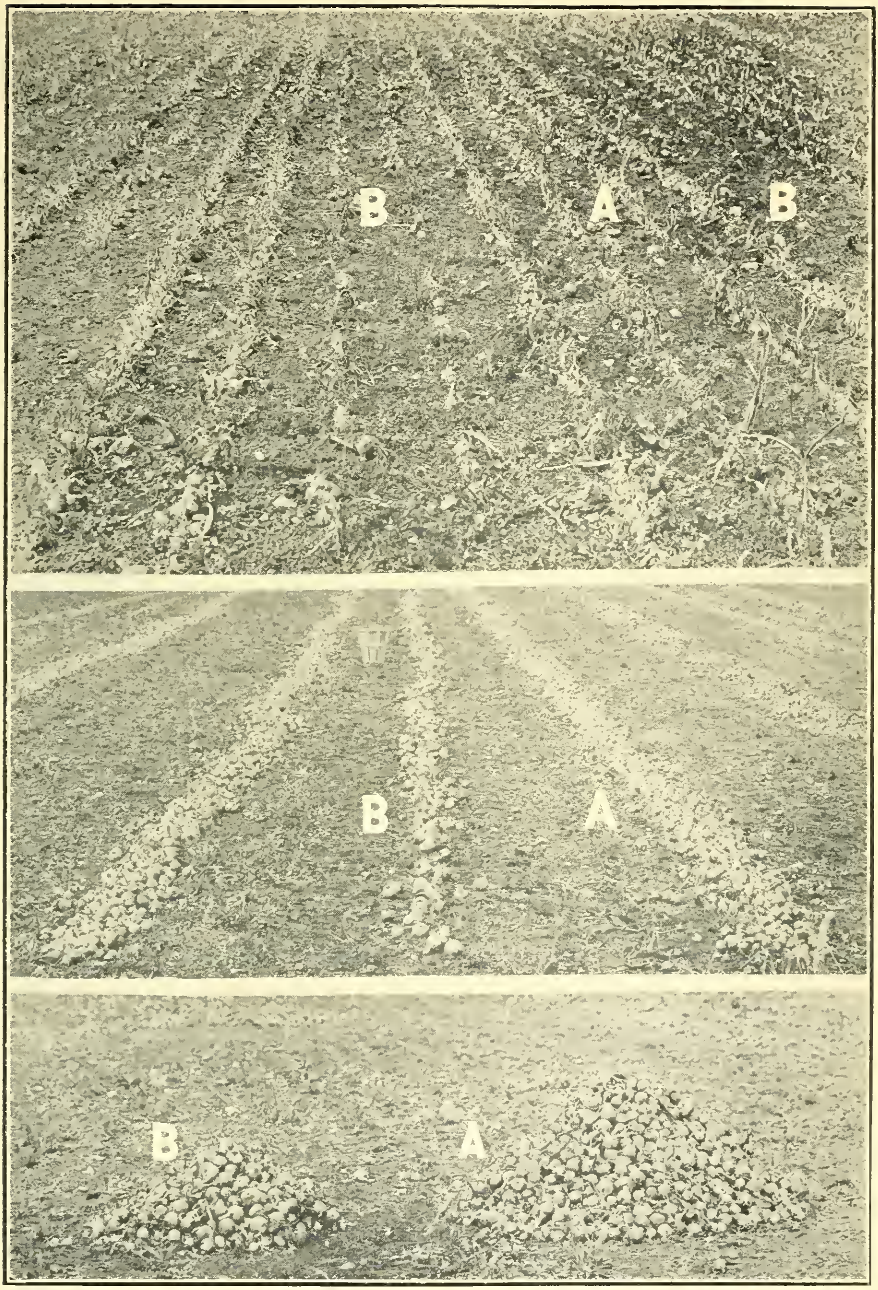

Fig. 4.—Formaldehyde treatment for smut. Yield from 4 treated rows (A), compared with 4 untreated rows (B).

Station Farm Experiment, 1919

The experiment on the Cowls farm was duplicated as regards treatments, but on a smaller scale, on a badly infested plot on the Station farm.

The check rows gradually dwindled throughout the summer while the stand on the treated rows remained excellent. No differences between the results obtained by the use of any of the three formulas could be observed. Through a mistake, the onions of this plot were harvested in the absence of the writers and final data on yield were not obtained. Unquestionably, however, they would have paralleled the yield data for the Cowls farm.

Greenhouse Experiments, 1919–20

During the winter a greenhouse bench 4 x 16 feet was filled with soil from a badly infested field. Three crops of onions, raised in succession, were treated with formaldehyde of different formulas. Commercial formaldehyde was applied at the rate of one pint to 2400, 2800, 3000 and 3200 feet of row. Dilutions from 1–8 up to 1–128 were used. Without presenting all the data, we may state the tentative conclusions at which we arrived as a basis for the field experiments of the following year:

1. The percentage of control was not appreciably greater when one pint of commercial formaldehyde was applied to 2400 or 2800 feet of row than when applied to 3000 or 3200 feet.
2. Concentrated formulas such as 1–48–2400, 1–32–2800 and stronger cause serious injury and cannot be used.
3. The most important indication of the series was that within wide limits, the amount of dilution is not a factor of any great importance *as far as control of smut is concerned.*

C. A. Clark Farm Experiment, 1920

This experiment was on land in Sunderland where onions had been grown for 40 or 50 years. The soil, however, was not as thoroughly infested as that on the Cowls farm used during the previous season. The part selected for experiment included 30 rows, 267 feet long, 12 inches apart, seeded at the rate of 7 pounds per acre. The plots were seeded May 3, the soil at that time being wet and heavy after a backward

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inaccurate because it makes no distinction between those which are badly affected and will die and those which are slightly affected and may produce good onions. Also we have found that it is impossible to distinguish all the diseased plants because many of the lesions are below the surface of the soil.

2. By counting the percentage of smutted plants among those which are standing at some definite period *in the early summer, but after the cotyledon stage.* This was done in the Cowls farm experiment just described and is commonly used by other workers on onion smut. This method is worthless because it does not count those which have already died from the disease and disappeared. We have repeatedly noted that seedlings begin to die within three weeks after planting and the mortality is then heavy for a few weeks. When a young plant dies it shrivels and decomposes so quickly that no trace of it can be found after a very few days. Obviously such plants cannot be taken into consideration in calculating by this method

3. By removing and counting the plants *as fast as they succumb to smut.* This requires a thorough inspection about twice a week for a period of some four weeks, after which all diseased plants may be pulled since it is certain that they will not recover. This is certainly the most accurate method, but under field conditions involves so much labor that it is precluded. We have, however, used it in greenhouse experiments with satisfaction.

4. By counting and comparing the number of *healthy* bulbs in the row at harvest time or shortly before. This does not assume that all onions which have disappeared from the rows during the summer have succumbed to smut, but that all other agencies which would destroy the plants previous to this time would operate equally on all the rows. Therefore, the benefit derived by the grower can be determined by direct comparison of the figures thus obtained. From the experimenter's standpoint it is not quite satisfactory because it does not take into consideration the number of plants which were prevented from germinating on account of the use of formaldehyde of a certain formula. In the experiments of the last season we have determined the amount of such injury by comparing the number of plants which came up and then computing the control on the basis of those which remain. This fourth method has been used throughout the experiments here as being the most nearly accurate practical method of comparing the results obtained by a given treatment.

5 By comparing the *yield of onions in pounds or bushels.* This method is inaccurate because, as every onion grower has observed, the onions in a thin row (such as they are when thinned by smut) being further apart, are larger than in a thick row; therefore, bulb for bulb, are heavier. This difference, however, represents the gain in weight secured by growing bulbs further apart, and in no case could be interpreted as having any relation to the application of formaldehyde. If larger bulbs are desired, the result could be much more economically obtained by planting a smaller quantity of seed per acre while using the formaldehyde. This fifth method was used by the writers during the field experiments of 1919 and 1920 and the final weights are included in the tables, but they should not be considered as accurately gauging the results of the experiments.

spring. Also it rained within 24 hours after the seed was planted and the entire season was rainy.

The formulas used in this experiment require a few words of explanation. Since there was considerable smut in the treated rows during 1919 it was thought best to cut down the distance treated with one pint of the commercial formaldehyde from 3200 to 3000 feet. This also had the advantage of being approximately the same rate of application as was being used in the other states; therefore, our results could be more readily compared. The formulas 1–48–3000 and 1–32–3000 were added to see whether a more concentrated solution would give better control without injury under field conditions. In order to test the effect of increasing the length of row treated with one pint of commercial formaldehyde, the formulas 1–50–4000 and 1–50–5000 were added. From the standpoint of the growers, the 1–50 dilution is the most convenient because most of them use 50 gallon barrels for drawing the water and they all have gallon jugs or cans. It is, therefore, a simple matter to add a gallon of the commercial solution to each barrel of water.

Observations on the course of the disease throughout the summer coincided with those of the previous season. The percentage of smutted plants was not counted during the growing season for reasons previously stated. All the onions were pulled and counted on September 4. A week later they were topped and weighed. The data taken are recorded in Table II (p. 27).

In interpreting the results of this experiment the fact that the soil was very wet at the time of planting must be taken into consideration. The important influence which this factor exerted was understood only after the experiments of later years. We may draw the following conclusions from the data presented in Table II:

1. The highest percentage of control was secured by the use of the concentrated solutions: thus, the 1–64–3000 was the best*, but not much better than 1–32–3000 and 1–96–3000.

2. No advantage was gained by the extreme dilution and use of the large amount of water required for the 1–128–3000 formula. Three of the other formulas gave better control and others were not much inferior.

3. The decided drop in the percentage of control secured by the 1–50–5000 formula indicates that (during a wet spring) the amount of formaldehyde was insufficient. It resulted in a fair amount of control—40 per cent. increase over the untreated plots—but much below the benefit secured by the use of more formaldehyde per acre. The 1–50–4000 formula gave good control, but the yield was not quite so high as for some of the others.

The poor showing made by the 1–48–3000 formula is unexplainable in view of the good showing of the formulas just above and just below it.

The Kuzmeski Farm Experiment, 1920

The field on which this experiment was located is in Leverett and was seriously infested only in spots. The seed was planted May 3, the soil moisture conditions being about the same as previously noted for the Clark farm. Only two formulas were used, viz., the 1–96–3000 formula which approximated the formula which gave the best control during the preceding season, and the 1–50–5000 formula previously mentioned in the account of the C. A. Clark farm experiment. Eight rows, each 436 feet long, 13 inches apart, were treated with each formula, and four rows were left untreated as a check. Data for this experiment are recorded in Table III (p.27).

The results shown in the table confirm the conclusion from the Clark farm experiment that the use of one pint of formaldehyde to 5000 feet of drill is insufficient for the control of smut during a wet spring. Entirely satisfactory control was obtained by the use of the 1–96–3000 formula.

C. A. Clark Farm Experiment, 1921

The experiment of 1920 on this field was practically duplicated during the season of 1921 but with the addition of some more concentrated formulas. The soil, how-

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*In this connection, it may be noted that Walker (48:324) during two years out of his four years' experiments secured his highest yields by the use of the 1–64 dilution, while during the third year, it was such a close second to the 1–128 dilution that the difference was almost negligible. Despite these results, he recommended the 1–128 dilution.

ever, was dry and there was no rain for at least two days after the seed was sowed on April 13. The weather continued cold and the seed came up very poorly. When it did come up there was a striking difference between the treated and untreated rows. The checks were much thicker and appeared so throughout the season. There was a very obvious injury from the formaldehyde, irrespective of the formula used. The writers were informed by onion growers who were in a position to know the facts of the case, that growers all through the section had the same trouble with formaldehyde during 1921 and that many fields of onions were plowed under because of the reduced stand.

No yield data were taken in 1921 because the onions were harvested by mistake in the absence of the writers and no records were kept.

After the experience of 1921 it was decided that further progress in the search for the best formula could not be made until the factors which cause formaldehyde to injure were determined. The investigation of this problem was not finished until 1922, but since it has an improtant bearing on the subsequent experiments, we shall consider the findings at this time.

Formaldehyde Injury

At first it was thought that the injury of 1921 was due to some difference in the composition of the chemical. Samples from all available sources were therefore collected, including among them samples of the same material which we had used during the previous years and which had not caused injury. Chemical analyses of the samples by Dr. Holland of the Chemistry department, revealed no differences in composition which were of sufficient size or character to warrant a suspicion of their toxic effect. The manufacturers assured us that there had been no change in the method of manufacture of formaldehyde. The most apparent difference was in the percentage of methyl alcohol contained in the various samples. The sixteen samples were next tested simultaneously on onion seed sowed in greenhouse benches, using for each the formulas 1–50–5000, 1–50–3000, 1–100–3000 and leaving untreated rows between the plots. In order to see what effect variation in the percentage of methyl alcohol would have, samples containing known percentages from 0.4 per cent. to 16 per cent. alcohol were included in the tests. Without discussing the results in detail, they may be briefly stated as follows:—

1. The source of the formaldehyde was without influence on the percentage of plants which came up.
2. Variation in the percentage of methyl alcohol made no difference.
3. With all samples and every formula used, formaldehyde *retarded* germination for a day or two and
4. With all samples and formulas, formaldehyde *prevented* the germination of a certain percentage of the seed, this loss being more apparent when a more concentrated solution was used or where the quantity of the solution was increased.

The results of these experiments eliminated the possibility that the losses of 1921 were referable to difference in the character of the formaldehyde.

Since there had been no differences in the formulas or method of application of formaldehyde nor in the treatment of the soil in 1921, there appeared to remain only the character of the season itself as a possible explanation of the trouble. The character of the spring weather could obviously affect the soil—where the injury occurs—in two ways: (1) in the percentage of moisture and (2) in the temperature. Experiments were undertaken with the object of determining to what extent the percentage of injury is influenced by variation in the percentage of moisture in the soil. The effect of the soil temperature on injury has not been determined as yet.

These experiments have been described in detail in a previous publication (2). For our present purpose it will be sufficient to quote from the summary of that paper:

"When a concentrated formula like 1–50–3000 is used, the amount of injury depends on the moisture condition of the soil. Injury varies inversely as the percentage of moisture.

The amount of injury may be reduced by diminishing the amount of the solution applied per unit of row, but the percentage of smut control is probably also reduced.

The amount of injury in a dry soil may be reduced by increasing the dilution of the formaldehyde without at the same time reducing the actual amount of formaldehyde per unit of row.

The amount of injury can be predicted from the moisture condition of the soil on the day of planting. It is not affected by weather conditions during the subsequent days.

The grower could save time and labor by changing his formula according to the soil condition at the time of planting.

More seed should be applied when formaldehyde is used."

The final results of the formaldehyde injury investigation were not available before the experiments of 1922 were started. Hence the soil moisture and the percentage of loss from formaldehyde injury were not determined.

C. A. Clark Farm Experiment, 1922

The experiment was repeated on the same field during 1922. Twenty-six rows 500 feet long, 12 inches apart were sowed at the rate of six pounds of seed per acre on April 26. The soil was dry and no rain fell during the next week which was windy, cool and dry. Different samples of formaldehyde were tried in which the percentage of methyl alcohol was extremely small (4 per cent.) or very high (16 per cent.). Also comparative tests were repeated with the 1–128–3000, 1–64–3000, 1–50–5000, and 1–50–4000. Formaldehyde injury was evident when the seed came up but unfortunately no records of its comparative extent or of the soil moisture conditions were made. The onions were harvested on August 25. The yield data are recorded in Table IV (p. 28). It will be noted from this table that the results are quite different from those obtained in 1920 on the same field (cf. Table II). The highest yields were secured with the dilute formula, 1–128–3000, while in 1920 it was the concentrated formulas, 1–32–3000 and 1–64–3000, which gave the highest yields. In 1920, the 1–50–5000 gave the lowest yield while in 1922 it was next to the best. This difference can be easily explained, however, in view of the difference in the moisture conditions of the soil at seeding time. The low yields obtained by the concentrated formulas like 1–50–3000 in 1922 were due to reduction of the stand through formaldehyde injury when the soil was very dry. They do not indicate a lack of control because, when less formaldehyde was used (1–50–5000) the yield was increased.

As to the effect of the methyl alcohol, the data show a much larger yield through the use of formaldehyde with a low percentage of methyl alcohol. Up to the present, however, the writers have not had opportunity to repeat this test and would hesitate to draw any conclusions from the results obtained on these two rows during one season.

Kuzmeski Farm Experiment, 1922

This was on the same field as was used in 1920. On April 25 when the seed was sowed the soil was very dry and continued so for the next week or more. The experiment included 16 rows, 220 feet long, 13 inches apart, seeded at rate of four pounds per acre. The observations throughout the summer coincided with those made on the C. A. Clark farm the same season. Smut was serious only in spots; therefore, the harvest data do not really show how complete was the control (since all the onions in the entire row were counted and therefore considerable stretches of row where there was little smut to control were included). In the worst places hardly any onions remained standing in the check row while there was a normal number in the treated rows. Only one dilution was used on this field but it was applied to the row at three different rates. The final results (presented in Table V (p. 28) confirm the conclusions drawn from the C. A. Clark farm experiment of the same year; viz., that the largest yield is obtained by using the 1–50–5000 formula, during a season when the seed must be sowed in a dry soil. The difference is due to formaldehyde injury and not to lack of control of smut.

The Objects of the Field Tests of 1923

Differences in yields secured by the various formulas in 1922 were the results of variation in (1) the control of smut and (2) the number of seeds prevented from germinating by the formaldehyde. The presence of these two variables made the interpretation of the yields very uncertain. An effort was made in the experiments of 1923 to determine to what extent each of these factors was responsible for the variation in yield. This was accomplished by first determining the extent of the chemical injury. During the third or fourth week after planting, when it was thought that practically all the plants which would come up were visible and before any of them had disappeared from smut or damping off, the number of plants in each row was determined irrespective of whether they were diseased or not. Comparison of these with the untreated rows determined the extent of the chemical loss. The relative amount of loss from smut was determined at harvesting by subtracting the number of sound bulbs from the number of seedlings which escaped chemical injury. It is not thereby assumed that all the plants which died in the interim were killed by smut but that other agencies acted equally on all the rows. Also in order to check up under field conditions the influence of soil moisture at planting time, the percentage of moisture in the soil one inch below the surface was calculated for each experimental field on the day of planting.

Allen Clark Farm Experiment, 1923

This experiment was located in North Amherst on land heavily infested with smut at one end but very lightly at the other. It included 28 rows, 283 feet long, 13 inches apart, seeded at the rate of six pounds per acre. The ground was fairly moist, containing 17 per cent. water with a retentive capacity of 65 per cent. of the dry weight. It was planted on April 27 and there were heavy rains on the 28th and 29th. The rain probably came soon enough to affect the results of the treatment. Inspections while the onions were coming up and comparison by counting the seedlings at the end of a month showed the chemical injury to be negligible in this field. On September 4, when the onions were ready to harvest, the sound bulbs in 100 feet of each row on the more heavily infested end of the field were counted. The results, presented in Table VI (p. 28) are about what might be expected when the soil was neither extremely dry nor extremely wet. The highest yields were secured with the formulas of medium dilution (1–64–3000, 1–75–3000) or where the rate of distribution was medium (1–50–4000). None of the formulas failed to control, but the 1–50–5000 was least satisfactory. The appearance of the field four weeks before harvesting is shown in Fig. 2.

Kuzmeski Farm Experiment, 1923

This experiment was on the same field as the experiments of 1920 and 1922. It consisted of 24 rows, 436 feet long and 13 inches apart, seeded at the rate of six pounds per acre on April 21. The soil was extremely dry and dusty. A high wind during the day and the succeeding days kept the upper layer in the same condition for a week. The moisture was 6 per cent. and the retentive capacity 45 per cent. of the dry weight of the soil. All conditions were ideal for a high percentage of formaldehyde injury.

Examination when the onions were coming up and counting the number of seedlings when it was judged that all had come up, showed that the injury was certainly all that was predicted. On September 3 the number of sound bulbs remaining were counted. The data on this experiment are summarized in Table VII (p. 29). These data show that there was severe injury with all formulas used. The 1–50–5000 formula caused the least loss but that was 20 per cent. Even when the solution was diluted 1–100 there was a loss of 36 per cent. It is doubtful whether any practical formula can be used under these very dry conditions which will eliminate this loss. Under these conditions it is probably best to use the 1–50–5000 formula and increase the amount of seed enough to offset the formaldehyde injury.

Station Farm Experiment, 1923

This was the same field on which the experiment of 1919 was located. It consisted of 40 rows, 12 inches apart and 75 feet long, seeded on April 26 at rate of six pounds per acre. The soil was very dry and remained so for 48 hours after planting.

The moisture was 12 per cent. and the retentive capacity 64 per cent. of the dry weight. Such a condition was favorable for a high percentage of formaldehyde injury and when the onions came up the injury was apparent. The percentage of chemical loss was determined on June 1 and the yield data were taken on August 30. The data, presented in Table VIII (p. 29) show that the highest gain was obtained by the use of the 1–50–5000 formula and the next by the 1–64–3000 formula. The injury caused by the 1–50–3000 formula was so severe that there was an ultimate loss even though smut was controlled very effectively. On such a soil the 1–50–5000 formula is undoubtedly the best.

Conclusions from all of the Formaldehyde Experiments

After five years of experimentation, the writers came to some fairly definite conclusions in regard to the control of onion smut with formaldehyde. These conclusions, which will now be briefly stated, are supported by the data which have just been presented.

1. Smut can be controlled in any field in the Connecticut Valley and during any season by the use of a formaldehyde solution.
2. Extreme dilutions such as one part of formaldehyde in 128 parts of water, involving the use of a large amount of water, extra labor and inconvenience, are not necessary under the conditions which prevail here.
3. Within fairly wide limits, the control of smut is not dependent on the dilution, but on the actual amount of formaldehyde applied per unit distance of row. Thus, the concentration is not limited by lack of control, but by danger of injury to the seeds.
4. Any formula for the application of formaldehyde which is strong enough to control smut, also causes a certain percentage of the seeds to fail to germinate. This injury is especially noticed when the soil is very dry at planting time.
5. Formaldehyde injury varies inversely with the moisture content of the soil, and directly as the concentration of the solution and the amount of such solution applied per unit length of row.
6. The grower may reduce the loss from formaldehyde to a very small percentage and at the same time get better control of smut by changing his formula of application according to the moisture conditions of the soil on the day when the seed is planted.
7. From the standpoints of (a) profitable (but not necessarily maximum) prevention of smut, (b) minimizing the labor of drawing water, (c) ease of mixing the solution, (d) maximum reduction of the weight of water which must be carried on the drill, and (e) avoidance of severe chemical injury, we recommend the following as the most practical method of application:

   If the soil is very dry, use the 1–50–5000 formula; if fairly moist, the 1–50–4000, and if wet, the 1–50–3000 formula.

   Or this might be expressed to the grower thus:

   Put one gallon of formaldehyde into a 50-gallon barrel and fill to the top with water. If soil is very dry, apply at rate of one barrel to one acre of onions (13 inches apart). If the soil is medium moist, apply 1¼ barrels, and if wet and heavy, 1⅔ barrels per acre.
8. On a dry soil the amount of seed per acre should be increased.

The Formaldehyde Tank for the Onion Drill

The formaldehyde solution is applied to the row from a tank attached to the seeder. Various kinds of tanks and methods of regulating the flow of the solution from them have been used and described by previous investigators (5:161).

In order that the control of smut be effective and injury reduced to the minimum it is important (1) that the rate of flow be uniform and (2) that the operator have some means of knowing just how much solution he is applying. These two requirements were doubly important for our experimental work.

In order that the data obtained might be reliable, a machine was needed which would distribute evenly and with a fairly high degree of accuracy any desired quantity of solution on a stated length of row. For this purpose the regulating apparatus on all of the machines which have been described before was found to be worth-

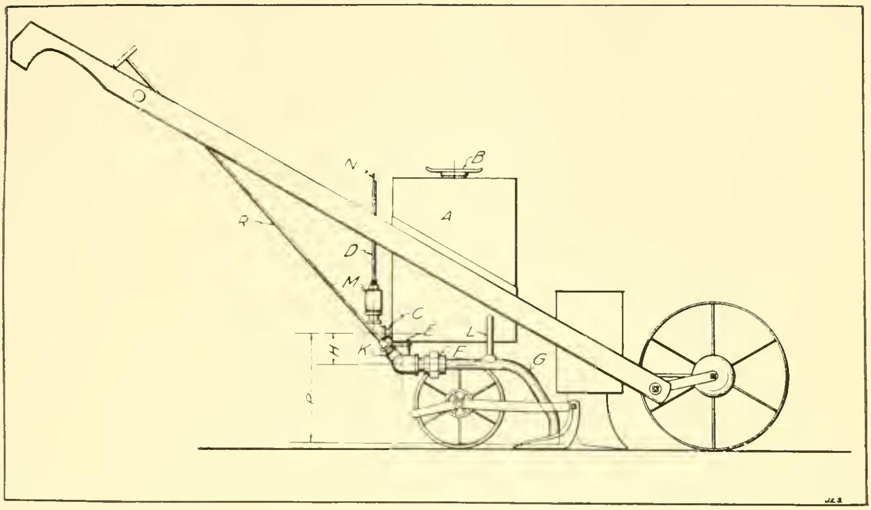

Fig. 5.—Mechanical drawing showing details of formaldehyde tank construction.

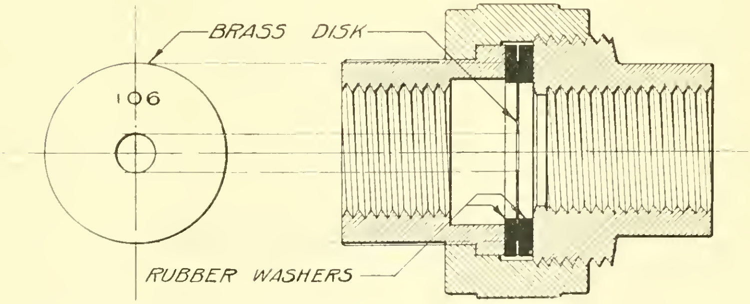

Fig. 6.—Sectional view of union in outlet pipe, with disk and washers in place.

less. None had a valve which could be set so that the operator would know when he started across the field how much solution would be applied per hundred feet. Actual tests of the different types of tanks showed considerable variation in the flow depending on how full the tank was. A 14-quart tank described below required more than twice as long to deliver the last quart as it did the first. The one-gallon copper tank first constructed by Stone (Mass. Agr. Expt. Sta. Circ. 21)—which is still in the possession of the Station—was tested and showed a difference in time of 15 per cent. between the first and last point. None of the tanks previously described has any method of correcting this error. None of them has any provision for eliminating the error due to variation in the speed of the operator. In short, there were so many sources of error and variation in all of the machines described up to the present that they were found to be utterly unsuitable for accurate research studies and a new tank and method of regulation had to be devised. The one which was finally evolved after experimenting with many different modifications is illustrated in Fig. 5 and described below.*

The tank itself (Fig. 5A) is a 14-quart cubical galvanized iron box attached between the handles of the drill just back of the seed box. The bottom of the tank is not flat but has a slight slope to a lowest point at the rear from which the solution is conducted through a ½-inch pipe (E) to the stopcock (K) and to the union (F). From there it is led through a ⅜-inch flexible block tin tube (G) and distributed on the seed and soil just back of the seed spout and in front of the coverers. The valve (K) is operated by a ¼-inch iron rod (R) from the rear end of the handles. It has nothing to do with the regulation of the flow but merely starts or stops the stream at the ends of the row or wherever desired.

The rate of flow from the tank is regulated by a series of brass disks with central apertures of graded sizes. A disk is held in place between rubber washers in the union of the outlet pipe (Fig. 6). Any number of these simple brass disks may be quickly cut out with tin shears from a sheet of brass. A hole is drilled through the center of each disk and this is enlarged with a rat-tail file to the proper size for the delivery of a gallon of solution in the previously calculated number of seconds which the operator wishes to use. The number of seconds required to deliver a gallon of solution is then stamped on the disk (Fig. 6). The size of the aperture needed depends on the formula of application which the operator wishes to use and the rate at which he walks. The number of disks which the experimenter or grower needs depends on the number of formulas he wishes to use, and the number of men, of different speeds of walking, who expect to push his drill. In our own experimental work seven different formulas of application were being tested and the drill was pushed at different times by three operators, the first one walking 4 feet per second, the second one 4½ feet per second and the third one 5 feet per second. Thus before the experiments were completed there were 21 disks. The operator could quickly find the proper disk by reference to a table attached to the side of the tank (Table 1).

TABLE 1.

Indicating the Disks of the Onion Drill to be Used According to the Speed of Workman and Formula Desired

Formula	4 Ft. per Sec.	4½ Ft. per Sec.	5 Ft. per Sec.
1- 50-3000	120	106	96
1- 50-4000	160	142	128
1- 50-5000	200	178	160
1- 32-3000	188	167	150
1- 32-4000	250	222	200
1- 64-3000	94	83	75
1-128-3000	47	42	37.5

*The authors are glad to acknowledge the very helpful cooperation of Professor C. I. Gunness and Professor J. L. Strahan of the Department of Rural Engineering, whose aid in the solving of some of the mechanical difficulties and the preparation of mechanical drawings, has been invaluable.

To illustrate: If the operator found that he walked at the rate of 4½ feet per second and he wished to use the 1–64–3000 formula, a glance at the table would tell him to insert in the union the disk stamped with the figure 83. Such a large number of disks will be needed only by the experimenter. The practical grower would not have occasion to use more than two or three and could make them as desired. This method of regulation was found to be very satisfactory and has the advantages of (1) permanent accuracy; no variation with wear or play; (2) cheapness and ease of construction within the reach of any grower; (3) simplicity; no complicated mechanism to be frequently out of repair; and (4) great elasticity, since a disk may be quickly made to suit any desired rate of flow.

The next modification was made for the purpose of correcting the variation in flow due to difference in head of the liquid as the quantity in the tank diminishes. All of the tanks which the writers have seen described have loose-fitting lids in the top through which the solution is poured to fill the tank. As the solution flows out through the outlet pipe the space which it leaves in the tank is immediately filled with air which comes in around the lid. Such an arrangement makes the rate of flow entirely dependent on the height of the water in the tank and as a result, the flow is much more rapid when the tank is full than when it is nearly empty. In order to determine the extent of such variation, the 14-quart tank just described was filled and the water permitted to run out with the lid loose or removed entirely. The time required for delivering each of the successive quarts was determined with a stop watch and the average of three tests is indicated in Table 2:

TABLE 2.

Rate of Flow of Each Successive Quart of Liquid from 14-Quart Tank (Open)

Quart	Seconds	Quart	Seconds
1	17.7	8	24.3
2	18.8	9	25.2
3	19.2	10	26.9
4	20.0	11	29.3
5	20.5	12	32.3
6	21.6	13	34.6
7	22.8	14	39.4

Thus, the operator who started with a full tank would be putting on the first part of the treated row double the amount which he put on the last part. The resulting control or injury would naturally show a similar variation. Data derived from the use of such a tank cannot be accurate. The variation in even the small tank described by Stone has been noted above. In order to make our control data reliable it was absolutely essential that this variation be eliminated. After considerable experimentation this was finally very successfully accomplished by modifying the tank thus: Instead of a loose-fitting lid, a screw cap (B), of 2-inch diameter (such as is commonly used on an automobile radiator) is used for closing the opening in the top. When screwed down with the shoulder against a rubber washer, this makes the top air-tight. A stand-pipe (D) parallel with and as high as the side of the tank is connected with the air vent (C) by means of an elbow.*

In this way, atmospheric pressure is maintained at the level of the vent (C) and consequently a uniform flow of solution is obtained irrespective of the height of water in the tank. The effective head producing the flow is always equal to (H). In order to prove that the flow is uniform, the outflow of each successive quart was timed just as described above but with the air-tight cap screwed down, and (with the No. 150 disk in the union) every quart from the first to the 14th flowed out in just 37½ seconds.

*In a later model this stand-pipe is built inside the tank and is simpler in construction but the principle is the same.

Two other modifications of minor importance have been added. In the enlarged base of the stand-pipe there is a float (M), which consists of a light hollow brass cylinder which has a "play" up and down of one inch. Attached to the top of this float is a slender brass wire stem (N) passing up through the narrow part of the stand-pipe and projecting an inch above the top of it when the float is up, just even with the top when the float is down. When the stream is running from the tank and everything is in order, the float is down and the stem does not appear above the top. If, however, there is any leak in the top of the tank or the operator has forgotten to screw down the cap, *i.e.*, if the tank for any reason is not air-tight, the water rises in the stand-pipe to the level in the tank, the float remains up and the projecting stem warns the operator that something is wrong. The float is thus a safety device and not an absolutely essential part.

The second modification is a very small pipe (L) about two inches long inserted on the upper side of the outlet pipe. This was added when it was discovered that for each of certain intermediate disks there were two distinct rates of flow. If the pipe below the union became immediately filled with water when the stream was turned on, it continued to come out in a steady stream and we had the faster rate of flow. Under these conditions the effective head would be (P) in the diagram. But at other times, even with the same disk, air gained access to this pipe and the water dribbled out. Then we had the slow rate of flow due to the head (H). Either flow remained constant but one never knew when he opened the valve which speed he would have. This difference in flow was eliminated when air was admitted to the outlet pipe through the small opening and pipe just mentioned.

With this improved tank just described all chances of error due to variation are eliminated except one. Variation in the rate of application might arise from variation in the speed at which the workman pushes the drill; *e.g.*, he might walk more slowly when he was tired or in softer land, etc. Numerous tests of the speed of different workmen at various times have convinced the writers, however, that a man's speed is remarkably constant and the error from this source is small. Nevertheless, it would be a distinct improvement if even this small error could be eliminated and the practical grower would be saved the trouble of measuring his speed and calculating the disk which he should use. This could be done if the apparatus were so constructed that the amount of solution delivered was proportionate to the distance travelled (*i.e.*, to the number of revolutions of the drill wheel) and not dependent on the length of time during which the valve is open. Then the rate of application would be entirely independent of the speed at which the drill was pushed. Such a regulating apparatus, geared to the drill wheel, is mechanically possible and its construction has been planned at various times by the writers. The construction has been abandoned for various reasons but principally because it would be too complicated and expensive and therefore less suitable for the average onion grower. For all practical purposes, and even for a fairly high degree of accuracy for experimental work, the apparatus described above is quite satisfactory.

MATERIALS OTHER THAN FORMALDEHYDE

One objection to the use of formaldehyde is the danger of injury to the seed under certain soil conditions which have been discussed previously. Although this can be largely avoided by changing the formula of application to suit the soil condition, growers cannot always be depended on to attend to this and some losses from this source are inevitable. It would be much better if we had a substitute which would give just as good control as formaldehyde, but without the attendant seed injury. In a search for such a substitute the writers have experimented with a list of chemical preparations, including Kalimat, Pythal, Furfural, Semesan, Uspulun, Germisan and several disinfecting powders manufactured by the Du Pont Company and by the Corona Chemical Division of the Pittsburgh Plate Glass Company. All of these were found to have some merit in decreasing the amount of smut, but for the most part the control was inferior to that secured by formaldehyde. Kalimat, however, is a notable exception. It was tested for two years in the field and in the greenhouse in pots where the soil moisture was controlled. These experiments and the results are described in detail in a separate publication (3). It is sufficient here to present the data on the experiments of 1924 (Table IX, p. 29) and the conclusions from the results of the two years' experiments.

"In all tests during the last two years, kalimat has controlled onion smut just as well as formaldehyde. It is superior to formaldehyde, however, not on account of its fungicidal properties but on account of its comparative safety when used in concentrated solutions or when used in very dry soils. Under these same conditions formaldehyde frequently causes serious injury.

"The claim of the manufacturers that the percentage of germination is increased by the use of kalimat would seem at first to have some support in the data presented. Of the 14 comparisons between treated and check rows, 10 show that there were more seedlings on the treated than on the untreated rows. This does not necessarily mean, however, that kalimat stimulated germination of the seeds; it may have merely killed off some organisms which naturally destroy the seedlings before they reach the surface of the soil.

"The only objection to the use of kalimat is that it is rather expensive at present. It may be obtained for about $1.00 per pint. In larger quantities, however, it could probably be obtained at a lower price. If any considerable demand for it should be developed, the cost of production will be lowered or other substances embodying the same protective principle will appear on the market.

"Of the formulas tried, probably the 1–50–4000 could be recommended as giving excellent control and as being economical of labor and material. This would require about five quarts of kalimat per acre of onions when the rows are thirteen inches apart. In extremely dry soil the same amount applied in greater dilution might have some advantage."

Uspulun. This is a patented German chemical preparation marketed in the form of a purplish gray powder, readily soluble in water to form a purple solution. The active fungicidal principle is orthochlorphenol. In preliminary greenhouse experiments 1 per cent. and 2 per cent. were tried in the formulas 1–50–3000, 1–50–4000, 1–50–5000, 1–100–3000, 1–100–4000 and 1–100–5000. Fair control was secured with all formulas but the best with 1–100–3000. In the field experiments of 1924 the formulas of 1–50–3000 and 1–100–3000 were each used on one row 70 feet long. The percentage of control was just as high as that secured by kalimat or formaldehyde. There was no evidence of seed injury or stunting and the percentage of germination was higher than on the check rows. The results were sufficiently promising to warrant the further testing of this substance. The results will be described more in detail after further tests under different conditions.

Germisan. This is also a German patented disinfectant marketed in the form of a powder but to be used in solution. It has been tried only in our field experiments of 1924 and in the formulas 1–50–3000, 1–50–4000 and 1–50–5000. All formulas gave increased germination and good control of smut. The weakest formula gave just as good control as the others. These results look promising, but we hesitate to make any recommendations until the material has been tried under other conditions.

The other chemical solutions tried gave a percentage of control much lower than formaldehyde.

Dry Chemicals. If some effective and comparatively cheap substance could be found which could be applied as a dry powder it would present certain advantages over solutions: (1) it would eliminate the labor of drawing barrels of water to the field, (2) it would make the drill easier to push because of elimination of the weight of the water, (3) it would eliminate the danger of clogging the seed spout and packing wheel with mud, and (4) machinery for application would probably be simpler and cheaper.

A number of these dry preparations have been tried by the writers but only one up to the present has given a high enough percentage of control to encourage further trials. This is a powder prepared especially for this kind of work by the Corona Chemical Division of the Pittsburgh Plate Glass Company and furnished to the writers under the label "Corona 640." In the preliminary greenhouse tests, this gave better control than any of the others and was, therefore, selected for the field tests of 1924. This was in badly infested soil but at the end of the season the row to which this material was applied contained as many healthy onions as any of the rows treated with the other preparations. There was also an increase in the number of seedlings which came up. Further investigations are now in progress to determine whether the results will be repeated under different conditions and to perfect simple machinery for application.

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TABLE I.

Cowls Farm Experiment, 1919

Treatment Formula	100 Ft. of Row on June 2			100 Ft. Harvested September 15				Gain in Pounds per Acre
	Standing Onions	Per Cent. Smut	Total Gain in Healthy Plants	Number Onions Harvested	Gain in Bulbs	Weight in Pounds	Gain in Lbs.	
1- 64-3200	2120	11.3	1222	773	596	105	66	26,400
1- 96-3200	2256	12.8	1308	844	667	116	77	30,800
1-128-3200	1923	17.7	825	936	759	112	73	29,200
Untreated	1325	50.4		177		39		

TABLE II.

C. A. Clark Experiment, 1920

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Ft.				Gain in Pounds per Acre
		No. of Bulbs Harvested	Gain Over Check	Weight of Bulbs Harvested (Pounds)	Gain in Pounds Over Check	
1-128-3000	1068	736	301	120	42	18,295
1- 96-3000	1068	769	334	121	43	18,731
1- 64-3000	1068	782	347	122	44	19,166
1- 48-3000	1068	686	251	117	39	16,988
1- 32-3000	534	758	323	125	47	20,473
1- 50-4000	534	694	259	114	36	15,682
1- 50-5000	534	615	180	108	30	13,068
Untreated	2136	435		78		

TABLE III.

Kuzmeski Farm Experiment, 1920

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Ft.		Percentage of Increase
		Number of Bulbs Harvested	Gain in Bulbs Over Check	
1-96-3000	3488	849	493	137
1-50-5000	3488	610	254	72
Untreated	1744	356		

TABLE IV.

C. A. Clark Experiment, 1922

Treatment Formula	Percentage Methyl Alcohol	Feet of Row Treated	Average of 100 Feet		Percentage of Increase
			No. Bulbs Harvested	Gain in Bulbs Over Check	
1- 50-3000	6-14	2000	230	54	30
1- 50-3000	.4	1000	288	112	64
1- 50-3000	16.	1000	234	58	33
1- 50-4000	6-14	2000	238	62	35
1- 50-5000	6-14	2000	285	109	62
1- 64-3000	6-14	1000	268	92	53
1-128-3000	6-14	1000	303	127	72
Untreated		3000	176		

TABLE V.

Kuzmeski Farm Experiment, 1922

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Feet		Percentage of Gain
		No. of Sound Bulbs	Gain in Bulbs Over Check	
1-50-3000	880	580	203	53
1-50-4000	880	576	199	53
1-50-5000	880	699	322	85
Untreated	880	377		

TABLE VI.

Allen Clark Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Feet		Percentage of Gain
		No. of Sound Bulbs	Gain Over Check	
1- 64-3000	1132	737	611	485
1- 75-3000	1132	733	607	482
1- 50-3000	1132	565	439	350
1-100-3000	1132	677	551	437
1- 50-4000	1132	721	595	472
1- 50-5000	566	339	213	169
Untreated	1698	126		

TABLE VII.

Kuzmeski Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Per Cent. Chemical Loss	Average Harvest on 100 Feet		
			No. of Sound Bulbs	Gain Over Check	Per Cent. Shrinkage June 1 to Sept. 3
1- 50-3000	1744	57	299	- 8	29
1- 50-4000	1744	51	262	-45	33
1- 50-5000	1744	20	338	31	38
1- 64-3000	872	41	285	-22	40
1- 75-3000	872	32	356	49	35
1-100-3000	872	36	314	7	36
Untreated	2616		307		62

TABLE VIII.

College Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Per Cent. Chemical Loss	Per Cent. Shrinkage June 1—Aug. 30	Final Gain Over Check per 100 Feet
1- 50-3000	300	70	25	-31
1- 50-4000	300	49	39	23
1- 50-5000	300	30	33	95
1- 64-3000	300	72	28	63
1- 75-3000	150	60	31	7
1-100-3000	300	48	40	22
Untreated	975		73	

TABLE IX.

Comparison of Kalimat and Formaldehyde in the Field Tests of 1924 Each Row 70 Feet Long

Chemical	Formula	Number of Rows Treated	Average Number of Seedlings Which Came up per Row	Average Sound Onions Harvested per Row
Check		12	539	122
Kalimat	1- 50-5000	8	544	340
Formaldehyde	1- 50-5000	8	538	309
Kalimat	1- 50-4000	8	625	432
Formaldehyde	1- 50-4000	8	525	331
Kalimat	1- 50-3000	4	516	380
Formaldehyde	1- 50-3000	4	469	285
Kalimat	1-100-3000	4	593	331
Formaldehyde	1-100-3000	4	416	293

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

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EXPERIMENTS ON THE CONTROL OF APPLE SCAB AND BLACK ROT AND SPRAY INJURY IN 1924

By W. L. Doran

This bulletin reports the results obtained, during the past season, in the study of the control of apple scab and black-rot. Incident to the main problems there have been comparisons of spraying and dusting, and observations on many related subjects. The difficulty which led to such widespread injury from apple scab, previous to the initiation of this work in 1921, was in the spray calendar, particularly with reference to the prepink and pink sprays or dusts. Greater care in these applications seems to be absolutely essential in any thoroughgoing attempt to control this destructive disease.

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EXPERIMENTS ON THE CONTROL OF APPLE SCAB AND BLACK ROT AND SPRAY INJURY IN 1924.*

By W. L. Doran

The experiments of 1924† were planned with the object of securing further data on the comparative efficiency of several materials and schedules in controlling apple scab caused by *Venturia inaequalis.* In addition to this, some attention was given to black-rot caused by *Physalospora cydoniae,* with a view to increasing our knowledge of its economic importance, seasonal occurrence, and control in Massachusetts. Data were also secured which, it is believed, will assist orchardists in reducing the severity of spray injury on fruit and foliage.

Materials and Methods.

At Middlesex Fruit Farm, Gravensteins having a spread of about 35 feet and a height of about 25 feet were sprayed, and Baldwins having a spread of about 30 feet and a height of about 25 feet were dusted. At both Harvard Fruit Farm and Pine Crest Orchard only McIntosh trees were used. At the former orchard these trees are eight years old and about 15 feet in height and diameter, and at the latter orchard they are 11 years old and larger in proportion.

At Harvard Fruit Farm and Pine Crest Orchard, Friend sprayers were used with a pressure of about 200 pounds. At Middlesex Fruit Farm an Arlington X L Sprayer was used with a pressure of about 150 pounds. At Middlesex Fruit Farm two spray rods were used. Spray guns were used at Pine Crest Orchard and at Harvard Fruit Farm, two at the former and one at the latter.

At Middlesex Fruit Farm liquid lime-sulfur, 1 gallon in 50 gallons, was used; and in the other orchards dry lime-sulfur, 4 pounds in 50 gallons, was used.

Lead arsenate was present in all sprays or dusts in the usual proportions for the pink and calyx applications and for the application about two weeks after the calyx.

The Bordeaux mixture used was of the 3-10-50 formula.

Dry-mix sulfur-lime was made up to contain 8 pounds of sulfur, 4 pounds of hydrated lime, and ½ pound of calcium caseinate in 50 gallons of spray, as described by Farley.**

The copper dust used contained 11 per cent monohydrate copper sulfate. The sulfur dust used contained 90 parts or 85 parts sulfur, and 10 parts or 15 parts lead arsenate in 100 parts. Niagara Sulfo-dust without arsenic was used for all applications except those specified above as receiving an arsenical.

The dusting was done with Niagara power dusters. In dusting, the halves of the application were not "split," that is, at each application each tree was dusted from two sides. The dusting was done either early in the morning or in the evening, in order to have the foliage moist and to avoid wind.

Two McIntosh orchards were dusted and two McIntosh orchards were sprayed. An orchard of Gravensteins was sprayed and an orchard of Baldwins was dusted.

All plots were sprayed or dusted at least four times. The dates of applications were as follows in the McIntosh orchards: prepink, May 5-7; pink, May 14-17; calyx, May 31—June 2; fourth, June 11-16; fifth spray, July 14; fifth dust, June 30—July 1; sixth dust, July 14-15; seventh dust, August 9-11. On the other varieties, the applications were made at about the same time, although in the case of the preblossom and calyx applications, the Gravenstein orchard received treatment a few days before the McIntosh, and the Baldwins a few days after the McIntosh.

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* *Acknowledgment.* This work was done with the co-operation of the Nashoba Fruit Producers' Association, in the following orchards: Mr. Albert Jenks' Middlesex Fruit Farm, West Acton; Mr. Stephen W. Sabine's Pine Crest Orchard, Groton; and Mr. Philip H. Babcock's Harvard Fruit Farm, Harvard. In scoring the fruit, assistance was given by Professors A. I. Bourne, B. D. Drain, J. S. Bailey, and W. H. Thies of Massachusetts Agricultural College. Mr. W. P. Wharton furnished rainfall records.

† For results of earlier experiments in Massachusetts, see: Mass. Agr. Expt. Sta. Bulletins 214 and 219.

** Farley, Arthur J. Dry-mix sulfur lime. New Jersey Agr. Expt. Sta. Bul. 379. 1923.

Relation of the Weather to Infection and to Disease Severity.

There was rain on nineteen days in May, and ascospores were ejected on each of these days. The combination of rain, viable ascospores, and susceptible host tissue resulted in a condition most favorable to scab infection. In 1924, ascospores were mature and beginning to be discharged earlier with reference to the condition of apple bud development than in 1923. In Baldwin orchards where no spray was applied before the pink application considerable primary infection was permitted.

The precipitations for June and July were below the normals for these months. Rain fell on eleven days in June and on seven days in July. As a result of the dry summer, scab control was not difficult, and the year was characterized by scab infestation of average rather than exceptional severity. This would seem to indicate that rainy weather before and during the period of flowering may not have any greater influence on the percentage of scabby apples at picking time than has the rainfall of the summer.

Not more than 7.0 per cent of the fruit on any check plot developed black-rot. The rarity of black-rot and frog-eye leaf spot was presumably the result of the relative dryness of the weather in June and July, for the rainfall was abundant in May and was not below normal in August.

Scab Infection on Leaves.

On June 9, after the trees had received prepink, pink and calyx applications, accessible leaves were scored for scab lesions. This was only ten days after the first scab infection of the season was found, and the count therefore gives us a very fair indication of the relative success of the several treatments in preventing the primary infection. The results are given in Table I.

In all orchards there was somewhat less scab on trees dusted with copper-lime-arsenic dusts at the prepink and pink applications than on trees dusted with sulfur. This difference, it should be added, practically disappeared later in the season.

There was at this time less scab infection on the leaves of sprayed trees than on the leaves of dusted trees, due probably to the more rapid removal of the dust by the frequent rains in May.

Lime-sulfur solution (with or without spreader), Bordeaux mixture and dry-mix sulfur-lime were practically equally successful in preventing the primary infection.

Set of Fruit as Affected by Scab and by Fungicides.

Scab infection on pedicels resulted in the early fall of many flowers and young fruits on check trees at the Harvard Fruit Farm. Flowers were counted on marked limbs in each plot at this orchard, and on June 30 the fruits which had set on these limbs were counted. In sprayed or dusted plots from 3.0 to 5.0 per cent of the flowers had set fruit and on check trees from 0.9 to 1.5 per cent of the flowers had set fruit. The fungicides, by preventing pedicel infection, increased the set of the fruit.

Control of Scab on the Fruit.

These results are given in Table II. In considering scab control, it is first of all necessary to take into account the degree of scabbiness of fruit on check trees. The percentages of scabby fruits on check trees in the several orchards were as follows:

Pine Crest Orchard	(check for sprayed plots)	69.4
Pine Crest Orchard	(check for dusted plots)	45.8
Harvard Fruit Farm	(check for sprayed plots)	81.0
Harvard Fruit Farm	(check for dusted plots)	84.2
Middlesex Fruit Farm	(check for dusted plots)	50.2

Results in the sprayed plots.—Four applications of lime-sulfur solution without spreader may be regarded as the standard treatment. With this treatment at Pine Crest Orchard there was 1.2 per cent scabby fruit, and at Harvard Fruit Farm, 0.2 per cent scabby fruit. This adds to the evidence, already abundant, that lime-sulfur is a dependable fungicide against apple scab.

The protection afforded by lime-sulfur without the calcium caseinate spreader is so nearly complete that it is not surprising to find the use of the spreader without benefit in scab control. In fact, at both Harvard Fruit Farm and Pine Crest Orchard there was slightly less scab where no spreader was used than on plots where it was used. It is certain that the addition of the spreader to lime-sulfur-lead arsenate does not increase the efficiency of the fungicide in preventing apple scab.

A fifth application of lime-sulfur solution was applied to certain plots the middle of July because black-rot as well as scab was under observation, although neither the weather conditions nor the prevalence of scab indicated any necessity for it. This application followed six weeks of dry weather, and there was less than 2.0 per cent scabby fruit on the trees. The fifth application did not prove necessary since the protection given by four applications, as revealed at picking time, could hardly be excelled. In August, 1924, there was rain on a greater number of days than is normal for the month, and we may conclude that the necessity for a late application for scab control is affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab as thoroughly as did lime-sulfur. In one orchard, in the plot sprayed with dry-mix sulfur-lime 8.8 per cent of the apples were scabby, and in the plot sprayed with lime-sulfur there were 0.2 per cent scabby apples. In another orchard there was 3.5 per cent scabby fruit in the dry-mix sulfur-lime plot, and 0.2 per cent scabby fruit in the lime-sulfur plot. Evidently on varieties as susceptible to scab as McIntosh, dry-mix sulfur-lime is not equal to lime-sulfur in protecting against scab.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection essentially as good. Since, as is brought out elsewhere in this report, Bordeaux mixture costs somewhat more than lime-sulfur, and since Bordeaux mixture, even when used only for the prepink and pink applications, is more likely to cause fruit russeting than is lime-sulfur, the use of Bordeaux mixture at all seems to be a practice of rather doubtful value.

Results in the dusted plots.—In both McIntosh orchards the percentage of scabby apples was slightly less in the plots on which copper dust was substituted for sulfur dust for the first two applications, than in the plots dusted with sulfur at all applications. But this difference was too small to be important.

In each orchard there were four plots dusted with sulfur four, five, six and seven times respectively. The increase in the number of applications beyond four or five did not result in any consistent increase in protection against scab. The average percentage of scabby apples on plots dusted with sulfur four, five, six or seven times was as follows: Baldwins 6.9, McIntosh (Pine Crest Orchard) 3.2, McIntosh (Harvard Fruit Farm) 3.8. When the fifth application was made, about June 30, 10.0 to 15.0 per cent of the leaves were scabby. The infrequency of rains thereafter made later applications unnecessary.

Injury to Leaf and Fruit by Sprays and Dusts.

Leaf Injury.—Leaf injury was more pronounced on McIntosh than on Gravenstein or Baldwin. Leaves on check trees, which of course received no spray or dust except arsenate, were all large, flat, and uniformly green with no pale margins. Leaves on trees dusted with sulfur had practically the same appearance as leaves on check trees, that is, they were entirely uninjured and showed no tendency to curl or for the leaf margin to become pale. Leaves on trees sprayed with lime-sulphur-lead arsenate were somewhat curled, spoonshaped, or cupped. Many had pale yellowish-green margins, with some marginal burning.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not reduce the injury to the leaves.

The foliage of trees sprayed with dry-mix sulfur-lime was not injured as much as that on trees sprayed with lime-sulfur. In fact, there was practically no visible injury on leaves sprayed with dry-mix sulfur-lime.

A fifth application of lime-sulfur resulted in no more leaf injury than was present on plots sprayed four times. Injury occurred when the calyx and fourth summer sprays were applied. When these applications were made, the spray dried on the foliage in about twenty minutes and the temperature was between 55° and 67° F. These conditions are not such as are popularly regarded as conducive to spray injury. Nevertheless, spray injury as above described did occur when lime-sulfur-lead arsenate spray was applied.

Another type of spray injury, also practically confined to trees sprayed with lime-sulfur, consisted in the killing of leaf tissue under and around scab lesions.

Spray injury to the fruit as revealed at picking time.—Fruit russeting was much more severe on Gravenstein than on McIntosh or Baldwin. (See Table III.)

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted, in the case of Gravenstein, in a reduction of about 50 per cent in the amount of russet. When this spray was used without spreader, 16.0 per cent of the apples were russeted; when used with spreader, 8.4 per cent of the apples were russeted. The addition of the spreader was evidently of very considerable benefit but by no means did it prevent all russeting; for there was nearly four times as much injury, even where the spreader was used, as there was on the check plot. On McIntosh plots sprayed with lime-sulfur there was so little russeting, either with or without the spreader, that no benefit from the use of the spreader was evident.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications resulted in more russeted fruit than when lime-sulfur was used for all applications. In the Gravenstein orchard there was 13.1 per cent russeted fruit where Bordeaux mixture was used and 8.4 per cent on the plot on which lime-sulfur was used for all four applications. Similarly, in the two McIntosh orchards there were 14.7 and 13.5 per cent russeted apples on plots receiving the preblossom applications of Bordeaux mixture, and 0.2 and 0.4 per cent russeted apples, respectively, on plots where lime-sulfur was used for all applications.

With the substitution of copper dust for sulfur dust for the preblossom applications in the two McIntosh orchards, there were 11.1 per cent and 5.0 per cent russeted fruit. The percentages of russeted fruit in these two orchards in plots dusted with sulfur for all applications were 0.8 per cent and 0.6 per cent respectively. In the Baldwin orchard the difference was not as great: there was 2.2 per cent russet where sulfur dust was used, and 4.0 per cent russet where copper dust was substituted for the prepink and pink applications But on McIntosh, especially, there is evidence that even for preblossom applications copper dust is more likely to result in russeted fruit than is sulfur dust.

There was practically the same percentage of russeted fruits on plots sprayed four times with lime-sulfur as on plots which received a fifth application of lime-sulfur (about the middle of July).

Apparently, late applications of sulfur dust are as safe as the earlier ones, for there were no consistent or significant differences in the amount of russeting of fruit on plots dusted four, five, six or seven times.

Black-Rot and Frog-Eye Leaf-Spot.

In April and May large numbers of the pycnospores of the causal fungus were found on the surface of the bark of cankered limbs. Such limbs were sprayed in the laboratory with Bordeaux mixture or with lime-sulfur, and spores so treated would not germinate although 95 to 100 per cent of spores from limbs not sprayed germinated. This means that the preblossom applications must have disinfecting values, in that they kill such of the spores of this fungus as are at that time exposed on the surface of the bark of cankered twigs and limbs.

The first frog-eye leaf-spot was observed June 9. There was a slight increase in the number of these leaf-spots up to July 25, but there was no increase after that, at least on the marked branches used for earlier counts. On July 21, in the Baldwin orchard, 9.0 per cent of the accessible leaves on check trees, and an average of 3.0 per cent of the accessible leaves on all dusted plots had frog-eye leaf-spot.

In neither of the McIntosh orchards or in the Gravenstein orchard was there more than 0.5 per cent black-rot on fruits in check plots at picking time. Only in the Baldwin orchard was there enough black-rot to enable us to secure any information as to relative efficiency of the several treatments in controlling this disease. In this orchard 7.2 per cent of the fruit on check trees, 2.0 per cent of the fruit on the plot dusted with copper dust followed by sulfur dust, and an average of 0.9 per cent of the fruit on all plots dusted with sulfur dust showed black-rot infection. The infection on the check was of course light, but we have some indication of the protection against black-rot given by the dust treatment.

Cost of Dusting and Spraying.

This includes the cost of materials and the cost of labor, but not the cost of equipment. The cost of treatment for one tree for the season is given in Table IV.

The labor involved was performed by two men and two horses at each orchard, except Middlesex Fruit Farm where but one horse was used. Further details as to size of trees and labor are given under the section on "Methods and Materials."

On the Gravensteins of the Middlesex Fruit Farm, 690 gallons of liquid and seven hours of labor were required to spray 100 trees. To dust 100 Baldwins here required 50 minutes and 127 pounds of sulfur dust. At Harvard Fruit Farm, 100 trees were sprayed in two hours, using 160 gallons of liquid. One hundred trees of this size were dusted in 33 minutes, using 75 pounds of sulfur dust. At Pine Crest Orchard, 100 trees were sprayed in two and three-fourths hours, using 360 gallons of liquid. One hundred trees at this orchard were dusted in 35 minutes, using 110 pounds of sulfur dust.

Although liquid lime-sulfur was not used at Harvard Fruit Farm or Pine Crest Orchard, it is also included in the record of costs for purposes of comparison.

A study of Table IV makes it evident that our cheapest method of protection is to spray with liquid lime-sulfur. Dry-mix sulfur-lime is more expensive, although the difference is not so great if dry rather than liquid lime-sulfur is considered. Bordeaux mixture is intermediate in cost between dry and liquid lime-sulfur. Use of the spreader necessarily increases the cost.

As to whether spraying or dusting is cheaper depends on the facilities for spraying, the distance from the water supply, the size of the spray tank, the size of the trees, and how many applications of dust are considered necessary. Five applications of dust were enough in 1924. This being the case, it was as cheap to protect by dusting as by spraying at Middlesex Fruit Farm. At the other two orchards, with smaller trees and less time spent in going for water, protection proved somewhat cheaper by spraying than by dusting, provided that our cheapest spray material is considered.

In most orchards where dry lime-sulfur and spreader is to be used, it is probable that the cost will not be far from that of dusting.

Summary.

The primary infection of the leaves was prevented equally well by lime-sulfur, Bordeaux mixture, and dry-mix sulfur-lime. The primary infection of the leaves was prevented more completely by spraying with lime-sulfur than by dusting with sulfur.

The prevention of pedicel infection by the fungicides improved the set of fruit.

On McIntosh plots sprayed with lime-sulfur four times, there were 1.2 per cent and 0.2 per cent scabby apples; while on their respective check plots there were 69.4 per cent and 81.0 per cent scabby apples.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not result in increased protection against scab.

A fifth application of lime-sulfur did not increase the protection against scab afforded by four applications. The necessity for a late application for scab control is probably affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab on McIntosh as completely as did lime-sulfur.

The substitution of Bordeaux mixture for lime-sulfur for the preblossom

applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection which was essentially as good.

Sulfur dust gave satisfactory control of scab. In McIntosh orchards there was an average of 3.5 per cent scabby apples on plots dusted with sulfur, while on the check plots there was an average of 65.0 per cent scabby apples. No proof was secured that it is necessary to substitute copper dust for sulfur dust for the preblossom applications.

Lime-sulfur-lead arsenate spray caused foliage injury, and this was not prevented by the addition of calcium caseinate spreader. Leaves on trees dusted with sulfur or sprayed with dry-mix sulfur-lime were not visibly injured.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted in a reduction of about 50 per cent in the amount of russeted fruits on Gravensteins.

There was a larger percentage of russeted apples on plots on which Bordeaux mixture or copper dust was used for preblossom applications than on plots sprayed with lime-sulfur or dusted with sulfur at all applications.

In the Baldwin orchard, there were three times as many leaves with frog-eye leaf-spot on check trees as on trees dusted with sulfur. In this orchard, 7.2 per cent of the fruit on check trees became infected with black-rot and the disease was present on 0.9 per cent of the fruit dusted with sulfur.

The costs of various treatments are recorded and compared. The costs of spraying and of dusting are not very far apart.

TABLE 1.—SCAB ON LEAVES

Variety*	† Treatment	Per cent Scab
Baldwins	Check	24
	Copper dust, prepink and pink; sulfur dust at calyx application	7
	Sulfur dust	11
McIntosh	Check	27
	Copper dust, prepink and pink; sulfur dust at calyx application	8
	Sulfur dust	14
McIntosh	Check	45
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	2
McIntosh	Check	30
	Copper dust, prepink and pink; sulfur dust at calyx application	4
	Sulfur dust	7
McIntosh	Check	34
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	3

* Separate orchards indicated by brackets.

† Up to June 9, through calyx application.

Table II.—Scab Control.

(Fruit counts in August, September and October, at picking time.)

Treatment	Number of Applications	Per cent Scabby Fruit		
		Baldwins	McIntosh	
		Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Check for sprayed orchards	None		69.4	81.0
Lime-sulfur without spreader	Four		1.2	0.2
Lime-sulfur with spreader	Four		2.4	
Lime-sulfur without spreader	Five		0.2	0.0
Lime-sulfur with spreader	Five			2.4
Dry-mix sulfur-lime	Four			3.5
Dry-mix sulfur-lime	Five		8.8	
Bordeaux, prepink and pink; followed by lime-sulfur	Four			0.0
Bordeaux, prepink and pink; followed by lime-sulfur	Five		0.1	
Check for dusted orchards	None	50.2	45.8	84.2
Sulfur dust	Four	9.2	1.5	5.4
Sulfur dust	Five	4.7	2.3	3.3
Sulfur dust	Six	8.5	3.1	3.8
Sulfur dust	Seven	5.3	6.0	2.8
Sulfur dust (average of plots)	Four to Seven	6.9	3.2	3.8
Copper dust, prepink and pink; followed by sulfur dust	Five	7.3	1.2	2.4

TABLE III.—SPRAY INJURY.

Russeting of Fruit.

Treatment	Number of Applications	Per cent of Fruit Russeted			
		Middlesex Fruit Farm		Pine Crest Orchard	Harvard Fruit Farm
		Gravenstein	Baldwin	McIntosh	McIntosh
Check for sprayed orchards	None	2.7		0	0
Lime-sulfur-lead arsenate spray:					
Without spreader	Four	16.0		0.8	0.4
With spreader	Four	8.4		0.9	
Without spreader	Five			0.6	0.8
With spreader	Five	9.0			0.9
Dry-mix sulfur-lime-lead arsenate spray	Four				0.9
Dry-mix sulfur-lime-lead arsenate spray	Five	4.6		0.3	
Bordeaux mixture, prepink and pink; followed by lime-sulfur-lead arsenate spray:					
With spreader	Four	13.1			13.5
Without spreader	Five			14.7	
Check for dusted orchards	None		0.4	0.5	0
Sulfur dust	Four		2.3	1.6	0
Sulfur dust	Five		2.2	0.9	0.8
Sulfur dust	Six		1.3	0.5	1.0
Sulfur dust	Seven		4.8	0.3	0.6
Sulfur dust (average of plots)	Four to Seven		2.2	0.8	0.6
Copper-lime-arsenic dust, prepink and pink; followed by sulfur dust	Five		4.0	11.1	5.0

Table IV.—Cost per Tree.

Treatment	Number of Applications	Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Lime-sulfur without spreader	Four		$.33* .26†	$.19* .16†
Lime-sulfur with spreader	Four	$.56†	.35* .29†	
Lime-sulfur without spreader	Five	.60†	.39* .31†	.19†
Lime-sulfur with spreader	Five	.67†		.20†
Dry-mix sulfur-lime	Four		.38	.20
Dry-mix sulfur-lime	Five	.81		
Bordeaux mixture, prepink and pink; followed by lime-sulfur with spreader	Four	.63†		
Bordeaux mixture, prepink and pink; followed by lime-sulfur without spreader	Four		.31†	.17†
Sulfur dust	Four	.48	.30	.25
Sulfur dust	Five	.56	.35	.29
Sulfur dust	Six	.64	.39	.33
Sulfur dust	Seven	.72	.44	.37
Copper dust, prepink and pink; followed by sulfur dust	Four	.50		
Copper dust, prepink and pink; followed by sulfur dust	Five		.36	.33

* Dry lime-sulfur. † Liquid lime-sulfur.

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MILK SUBSTITUTES IN THE REARING OF YOUNG CALVES

By J. B. Lindsey and J. G. Archibald

Dairy farms located adjacent to their market, as are most of those in Massachusetts, usually find it more profitable to sell fluid milk than to sell cream and use the skim milk in growing young stock. The relatively high price of fluid milk has been an incentive to better the grade of stock kept on our dairy farms, while the same cause has made it unprofitable to rear calves from this high grade stock. Unless a substitute for milk, to be used in rearing calves, can be found, one of the great advantages of high grade producing stock on our dairy farms cannot be realized. It was to meet this need that the work here reported was initiated. The bulletin presents the report of seven different feeding trials with forty-five different animals.

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AGRICULTURAL EXPERIMENT STATION
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MILK SUBSTITUTES IN THE REARING OF YOUNG CALVES.

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Introduction.

The problem of rearing calves for the first four to six months of their lives without the liberal use of whole or skim milk has been studied by many agricultural investigators. Where plenty of whole and skim milk are available it is a relatively simple matter, provided one understands the technique of calf rearing, which includes cleanliness in care and feeding and close observation to prevent overfeeding. Much depends on the calf itself; some are thrifty and require but little attention, while others are delicate and finicky, and require constant attention and considerable skill to bring them through their babyhood.

In the three southern New England states most of the product of the dairy herd is sold as whole milk, hence very little of either whole or skim milk is available for feeding purposes. In northern New England, where creameries are still in operation and skim milk and pasture are available, large numbers of dairy cows should be raised to supply the needs of the dairymen farther south. Even were this practice followed to a greater extent than it is at present, dairymen could still be found throughout southern New England desirous of raising more or less of their own stock. They have been and are still confronted with the difficulty of finding a suitable substitute for the relatively expensive milk.

It is not the intention in this publication to review in detail the work of the many investigators who have studied the problem, but rather to state briefly the different types of substitutes that have been fed and the results secured, and in addition to give a brief summary of our own more recent study of the subject.

In most of the older investigations reported, skim milk was used extensively, supplemented with numerous substances such as cod liver oil, coconut oil, flaxseed jelly, starch, rolled oats, etc. Some form of oats, either crushed, rolled, whole, or oat meal, seems to have been the most universal supplement and to have given the best results. The problem, however, with skim milk unavailable is to find some substitute that will take its place and produce thrifty calves.

The substitutes used in more recent studies can be grouped under four general heads:

1. Calf meals compounded from cereal grains, oil seeds and oil cakes, and leguminous seeds.
2. Meals similar to those in (1) supplemented with such animal proteins as blood flour and skim-milk powder.
3. Manufactured milk by-products, such as skim-milk powder, malted milk residue, semi-solid buttermilk and buttermilk powder.
4. Infusions of clover hay, of flaxseed, and of such meals as bean meal and linseed oil meal.

The feeding trials with these various mixtures have been carried on at widely separated points, under varying conditions and in many cases with an insufficient number of animals; so that it is not possible to state positively which type of substitute has given the most satisfactory results. The success of the different types as measured by daily gain in weight of the calves has varied from fair to excellent, largely due, no doubt, in most instances, to differences in the vigor of the individual calves. In general fair growth has been produced, the average being about a pound to a pound and a quarter daily. The few trials that have been made with the materials in Group 3 indicate that they are more suitable for calves up to six or eight weeks of age than are meals made from grains. Considering their source this is what would naturally be expected. In Groups 1 and 2 linseed meal and some form of oats seem to have been universally used. Obviously no statement as to comparative costs can be made. That depends on current prices and materials locally available.

Recent Experiments at this Station.

Our own more recent investigation of the problem commenced in the fall of 1921, and is still in progress. This article reports results up to June, 1924, at which time seven different substitutes had been given a trial and forty-five calves had been more or less successfully raised.

In formulating our substitutes the following essentials have been taken into consideration:

1. Variety and completeness of protein.
2. Sufficient carbohydrate to balance the ration satisfactorily.
3. Plenty of vitamines.
4. Sufficient mineral matter.

Method of Feeding.

Our method of feeding has been planned so as to have the calves weaned from whole and skim milk as early as possible. The calves are left with their dams only twenty-four hours, at the end of which time they are taught to drink whole milk from a pail. The milk fed to them is always from one of the lowest testing Holstein cows in the herd, and the maximum fed is six quarts daily. When the calf is a week to ten days old the whole milk is gradually replaced by skim milk. If it is a vigorous animal it will be receiving skim milk entirely by the end of the second week. When the calf is from two to three weeks old the skim milk is gradually replaced, a quart at a time, by a gruel made from the meal which it is desired to give a trial. The gruel is made by mixing the meal with water in the proportion of 3½ ounces of meal to each quart of water. It is stirred up with a little cold water first so lumps will not form, and then the correct amount of warm water is added, and the gruel fed at blood heat, never cold or very hot. Skim milk, while it continues to be fed, is mixed with the gruel at feeding time. By the time the calf is a month old it is receiving only two or three quarts of skim milk daily and this is gradually withdrawn so that before it is two months old it is weaned from milk entirely. Ten quarts of liquid is the average maximum fed.

This schedule cannot be blindly adhered to, because calves differ greatly in their individual appetites and ability to stand the changes in feed, but it serves as a general guide. The calves have been taught to eat rowen and dry grain as early as possible. Most of them have learned to eat these feeds at about four to five weeks of age.

The feeding trials have in every instance been discontinued at four months of age as it is considered that by that time the critical period of the calf's existence has been passed. All calves have been weighed weekly and their progress carefully noted.

The calf meals have been mixed as needed in one hundred pound lots and carefully sifted to remove all lumps and foreign material. A detailed account of the nature of the various substitutes and the results obtained with each, is given in the following pages. A summary of the work appears on page 49 .

Calf Meal No. 1, composed of:

Ground rolled oats	45 lbs.
Soluble blood flour	20 "
Linseed meal	10 "
Corn starch	14 "
Corn sugar	5 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

The chief source of protein in this meal was soluble blood flour, a high grade product, readily soluble in water, specially prepared for animal feeding by the United Chemical and Organic Products Company of Chicago. The rolled oats and linseed meal were used because experience has shown that they are of great value in calf feeding. The starch and sugar furnished a large part of the carbohydrate of the ration, and in addition the sugar gave the meal a sweet taste. Alfalfa flour was included as a desirable source of vitamines and protein. Calcium chloride furnished additional calcium in a readily soluble form.

Seven calves were raised on this meal, a group of four during the winter of 1921-22, and another group of three in 1924. The first group made an average daily gain of 1.25 pounds, and required 284 pounds of dry feed for 100 pounds of gain. Strangely enough the second group did not do nearly so well, making an average daily gain of 0.57 pound and requiring 494 pounds of dry feed for 100 pounds of gain. Two of them (Nos. 73 and 74) made so little growth and were so unthrifty that at three months of age they were changed over to Meal No. 6 (see page 47 for composition of this meal) to see if it would produce any more favorable results. No. 73 responded at once and made an average daily gain of 1.28 pounds during the fourth month of his life, as compared with 0.42 pound daily gain previous to the change. No. 74 did not respond at all and had to be put on a skim-milk diet to save him. No reason other than individual vigor of the calves can be assigned for the great difference in the two groups. With one possible exception all of them were strong and hearty when dropped. The figures for the whole lot are: average daily gain—0.96 pound; dry feed required for 100 pounds of gain, 374 pounds.

Calf Meal No. 2 consisted of:

Ground rolled oats	45 lbs.
Skim-milk powder	20 "
Linseed meal	10 "
Corn starch	14 "
Corn sugar	5 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

This meal was similar to Meal No. 1 except that its chief source of protein was third grade skim-milk powder obtained from the Merrell-Soule Company, Syracuse, New York. Four calves were raised on it and all made good growth, the average daily gain being 1.19 pounds; dry feed required for 100 pounds of gain—316 pounds.

Calf Meal No. 3, composed of:

Ground rolled oats	35 lbs.
Soluble blood flour	5 "
Skim-milk powder	15 "
Linseed meal	10 "
Corn starch	19 "
Corn sugar	5 "
Alfalfa flour	10 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

This meal combined the chief protein sources of Meals 1 and 2; also the starch and alfalfa flour were increased five pounds each, the rolled oats being reduced ten pounds. This change was made for two reasons, (1) it was thought that the alfalfa flour constituted an excellent source of vegetable protein, of vitamines, and of ash, and (2) for the sake of economy. At the time the meal was formulated rolled oats was selling for four cents a pound while starch was less than two cents a pound and alfalfa flour was two and a half cents.

Four calves were raised on this meal; two others did not thrive on it at all and it was deemed best to dispose of them. Of the four raised, two did reasonably well and the other two made very poor growth. The average daily gain was 0.77 pound and the dry feed required for 100 pounds of gain was 349 pounds. It is evident that this meal was not suitable as a skim-milk substitute. Thinking that the trouble might have been due to the increase in amount of alfalfa flour, this ingredient was cut down to five pounds, the amount used in Meals 1 and 2, and the rolled oats increased to forty pounds. The corn sugar was discontinued and five more pounds of corn starch substituted for it. The meal, which was designated as Calf Meal No. 3 (modified), then consisted of:

Ground rolled oats	40 lbs.
Soluble blood flour	5 "
Skim-milk powder	15 "
Linseed meal	10 "
Corn starch	24 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

Three calves were raised on this modification of Meal No. 3. They made slightly better growth than did those on the original meal, but required considerably more food for an equal amount of gain. The average daily gain was 0.89 pound, and the dry feed required for 100 pounds of gain was 381 pounds.

Calf Meal No. 4 was composed of:

Ground rolled oats	14 lbs.
Soluble blood flour	10 "
Skim-milk powder	10 "
Linseed meal	10 "
Coconut meal	10 "
Peanut meal	10 "
Milk sugar	30 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

The principal difference between this meal and the preceding ones is in the source of the carbohydrates. In an attempt to more closely resemble milk, milk sugar was substituted for all of the starch and part of the rolled oats. Also ten pounds each of coconut and peanut meal were included to give a higher fat content and in the case of coconut meal to supply more of Vitamines "A" and "D."

Four calves were raised on this meal and, taking into consideration the fact that three of them were delicate to begin with, they made very fair growth, the average daily gain being 0.99 pound, and the dry feed required for 100 pounds of gain being 303 pounds. At prevailing prices of milk sugar this meal was too expensive, but it indicated possibilities which should not be disregarded.

Calf Meal No. 5:

This meal was not prepared to feed as a gruel, but as a dry grain for the control lot of calves which received skim milk, and was not consumed in any quantity until they were 5 to 6 weeks old. It was also fed as dry grain for two lots of calves that received modified skim milk as the liquid portion of their diet. It was composed of:

Ground whole oats (not rolled)	30 lbs.
Flour middlings	20 "
Corn meal	19½ "
Linseed meal	10 "
Coconut meal	10 "
Peanut meal	10 "
Salt	½ "
Total	100 lbs.

Results secured in feeding this meal will be discussed under the heading of skim milk and modifications of skim milk.

Calf Meal No. 6:

This meal was formulated as a result of our experience with the other meals over a period of two years. It consisted of:

Ground rolled oats	20 lbs.
Soluble blood flour	10 "
Skim-milk powder	10 "
Corn starch	19 "
Red dog flour	15 "
Linseed meal	10 "
Coconut meal	10 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

It is in many respects similar to Nos. 1, 2 and 3. Red Dog flour was substituted for a portion of the rolled oats for considerations of economy and to make a little more variety. Coconut meal was included for the same reason as in Meal No. 4. Peanut meal was not included because of difficulty in obtaining it.

Six calves were raised on this meal. None of them made very good growth at first. Later four of them did very well, but two of them (67 and 68) continued to do so poorly and refused so much of their feed that it was decided to remove from the meal for these two, the coconut meal, which it was thought might be the particular ingredient they objected to. After this change they made somewhat better growth. The average daily gain for all six was 1.02

pounds, and the dry feed required for 100 pounds of gain averaged 326 pounds. As already noted (p. 45) Calf No. 73 when changed from Meal No. 1 to this meal showed a marked improvement in growth.

Skim Milk.

As a standard with which to compare results from our numerous substitutes skim milk was fed to six calves. The maximum amount fed to any one calf was 12 quarts daily. The calves were all weaned to skim milk during the second week of their lives, except that two quarts of whole milk were given daily until eight weeks of age in order to supply a little milk fat. Additional mineral matter was supplied in the form of mineral mixture No. 1 (one part, by weight, salt, to two parts calcium carbonate), three grams of this mixture being added to each quart of skim milk fed. The calves were taught to eat dry grain in the form of Meal No. 5 when about 4 to 5 weeks of age.

All six calves made excellent, some of them phenomenal growth, which was to be expected. The average daily gain was 1.68 pounds; one calf made daily gains of over two pounds. The amount of dry feed required for 100 pounds of gain was 251 pounds.

Skim-milk powder and corn starch.

The dried milk industry has of recent years developed very rapidly. According to Hunziker* there were forty-seven concerns producing skim-milk powder in the United States in the year 1919, and their total output was over thirty-three million pounds. A considerable quantity of the output is so-called "third grade," unsuited for domestic or bakers' consumption but suitable for animal feeding. This can be had at a reasonable price and as it solves the transportation and storage problems of liquid skim milk its value for calf feeding is worthy of thorough study. As already noted we have used more or less of it in all our formulae, as high as 20 per cent in Meal No. 2. During the summer of 1923 a somewhat different method of feeding it was given a trial.

A gruel consisting of two parts of skim-milk powder to one part of corn starch was fed to seven calves, the maximum amount to any one calf being nine quarts of the gruel. The corn starch was added to the milk in order to widen the nutritive ratio, and thus protect the protein from being used as a source of energy.

The weaning procedure and other details were identical with those followed for the calves raised on Meals 1 to 6 except that two quarts of whole milk were fed daily until the calves were eight weeks old. The dry grain for this lot and the next one was Meal No. 5. The gruel was prepared in the following manner:

3½ ounces skim-milk powder
1¾ ounces corn starch
1/10 ounce mineral mixture No. 2 (equal parts by weight salt and calcium carbonate)
1 quart water.

The skim-milk powder and starch having been weighed out beforehand, the necessary amount of cold water was measured out and the starch stirred into it slowly and carefully, care being taken to have all lumps broken up. The starch and water mixture was then heated slowly and with constant stirring to a temperature about 170°-175° Fahrenheit, but not higher than 175° Fahrenheit. The mixture was then cooled to 140° Fahrenheit and the skim-milk powder and mineral mixture slowly stirred in. When the gruel had cooled to blood heat it was ready to feed. This method of preparation insured a uniform gruel free from lumps, and the solids did not settle out on standing. Several gallons of the mixture were made up at one time and it kept well, being quite sweet twenty-four hours after mixing if kept cool. The calves

*Otto F. Hunziker, Condensed Milk and Milk Powder, 3d edition, 1920, p. 278.

drank the gruel readily and although they had some digestive disturbance in the form of scours this was not any more marked, nor as much so as in the case of many of those raised on the different meals. All of them made good growth, notwithstanding the fact that four of them were delicate at birth. The average daily gain was 1.34 pounds and the dry food required for 100 pounds of gain was 280 pounds.

Liquid skim milk and starch.

In order to check the skim-milk powder against liquid skim milk, a second lot of four calves was fed on a gruel prepared in a manner similar to the above except that liquid skim milk was used, the starch and mineral mixture being stirred into the skim milk which was then heated to about 150° Fahrenheit, not higher. All the calves made very good growth, the average daily gain being 1.35 pounds, and the dry feed required for 100 pounds of gain was 277 pounds, results almost identical with those obtained in feeding the skim-milk powder and starch. This would indicate that skim-milk powder can be successfully substituted for the liquid article.

The question was raised as to whether the calves could readily assimilate the starch added to the skim milk. The good growth secured with both lots of calves (eleven in all) indicates that they were able to utilize it quite well. Tests for starch were made on their droppings. In only two instances was any found, and both of these were delicate calves at birth.

The accompanying table summarizes the results which have been given in detail in the foregoing pages.

SUMMARY OF GAINS PRODUCED ON VARIOUS SKIM-MILK SUBSTITUTES

Material	Number of calves	Average daily gain in live weight	Average amount dry feed for 100 lbs. gain	Cost of food per 100 lbs. of gain	Food cost to 4 months of age	Cost of one quart of gruel	Cost of 100 lbs. of dry calf meal	Remarks
		Lb.	Lbs.			Cts.		
Calf Meal No. 1....	7	0.96	374	$15.39	$22.56	1.6	$6.30	{ 1st lot did well 2d lot did very poorly
Calf Meal No. 2....	4	1.19	316	14.39	20.58	1.3	5.10	Made good growth
Calf Meal No. 3....	4	0.77	349	16.55	15.72	1.4	5.40	Did not grow very well
Calf Meal No. 3, modified	3	0.89	381	18.17	19.80	1.4	5.40	Slightly better gains than those on Meal 3
Calf Meal No. 4....	4	0.99	303	22.67	27.19	2.4	9.90	Made very fair gains
Calf Meal No. 6....	6	1.02	326	15.62	19.32	1.3	5.10	Made very fair gains
Skim milk (check lot)	6	1.68	251	(14.29* (16.91†	28.54	1.6‡	....	Excellent growth
Skim milk and starch	4	1.35	277	17.67	29.25	2.0‡	....	Very good growth
Skim milk powder and starch	7	1.34	280	20.32	33.38	2.5‡	....	Very good growth

*With skim milk at 1½ cents a quart.
†With skim milk at 2 cents a quart.
‡The dry grain fed to these three lots was Meal No. 5, which cost at current prices approximately $2.50 a hundred. All costs are figured from prices current in September, 1924.

Discussion of the Results.

In the first place the results of the several trials, as summarized in the preceding table, confirm our previous knowledge relative to the superior value for growth of skim milk for young calves, providing it can be had at a reasonable price (1.5-2.5 cents a quart). Even at 1.5 cents a quart, the food cost of growing calves to four months of age is considerably above that of the calf meals; but *on the basis of growth produced*, the food cost is about the same as for the several meals. Only, however, when liquid skim milk is not available at such prices should calf meals or skim milk powder be substituted.

In the second place our studies show that calves can be raised on various skim milk substitutes together with a minimum of skim milk, and fairly good growth secured. Care has to be taken not to overfeed. Many of the calves thus grown are apt to look rather rough and not as smooth as skim milk calves. After they have reached the age of 6-8 months this difference generally disappears. The average amount of skim milk consumed by the calves raised on the various meals was 211 quarts, as compared with an average consumption of 1046 quarts by the calves in the check lot which were raised on skim milk and dry grain and hay. Those fed skim milk and starch consumed on an average 912 quarts of skim milk. The calves reared on Meal No. 6 received an average of only 108 quarts of skim milk each.

It must be admitted that the dairyman who raises a few calves at a time, if he does not have skim milk available, will have to depend upon the manufacturer for his calf meal mixtures. The manufacturer can secure and blend the different ingredients more cheaply than the small feeder; hence the results of station studies along this line are likely to be passed to the dairy farmer through the manufacturer.

The work has shown quite conclusively that skim-milk powder is a promising substitute. This material is fairly easily obtained, can be readily prepared for feeding, and at present prices costs very little more than liquid skim milk. The addition of starch spares the amount of milk powder, but slightly increases the cost of the gain. Because in the processes of drying the skim milk, it is heated to 140° Fahrenheit or above for a considerable time, it would appear that the danger from disease germs is likely to be remote.

Finally it may be remarked that success in calf rearing is dependent not only on the feed used but on several other factors which are:

(a) A vigorous calf at birth.
(b) Clean pens and clean feeding utensils.
(c) Regular feeding hours.
(d) Special attention to the individual peculiarities of each calf.
(e) Milk or gruel always fed at the same temperature—blood heat or thereabouts.
(f) Care to prevent overfeeding. If the calf refuses part of his allowance let him go hungry at the next meal, or if he starts to scour cut his ration in half for the next twenty-four to thirty-six hours.
(g) Sunshine, fresh air and exercise. Access to pasture if possible after the calf is six months of age; at least an open yard to run in, except in severe winter weather.

The above bulletin is a report of progress only. The study of skim-milk powder and of milk substitutes for young calves is being continued along somewhat different lines and any pronounced progress will be reported.

Practical Suggestions.

On the basis of the work reported in this bulletin, we are not prepared to recommend any particular combination of ingredients going to make up a calf meal mixture. Combinations No. 2 (see page 45) and No. 6 (see page 47) have done fairly well. As already stated, the most promising substitute investigated has been skim-milk powder and a combination of the powder with corn starch.

If skim-milk powder is used as a substitute for liquid skim milk, it is suggested that one pound of the powder and a scant even teaspoonful of salt be fed to each gallon of water. The milk powder and salt should first be stirred with a small quantity of cold water to avoid lumping and after a creamy consistency has been secured the necessary amount of lukewarm water should be added, the mixture well stirred and thus fed. Do not feed the solution cold.

If skim-milk powder and starch are fed, mix as follows:

1 lb. of dry skim milk
½ lb. of corn starch
Level teaspoonful of salt.

Five ounces of this mixture should be added to each quart of water. The method of mixing consists in adding to the powder a small quantity of cold water and thoroughly stirring in order to avoid lumping. After a creamy consistency is secured, add the necessary water, stir and heat the mixture to 150° Fahrenheit and allow it to cool to blood heat before feeding. An amount sufficient for one or two days can be mixed at one time, but before feeding, it should be well stirred and heated until it is lukewarm.

COMPOSITION OF CALF MEALS

Material	Water	Dry Matter Basis*				
		Ash	Protein	Fiber	Nitrogen-free Extract	Fat
Calf Meal No. 1	9.92	4.27	32.24	2.61	56.62	4.28
Calf Meal No. 2	8.93	4.75	18.12	2.51	70.10	4.52
Calf Meal No. 3	8.56	4.98	21.87	2.68	67.00	3.46
Calf Meal No. 3, modified	9.76	4.67	22.40	2.42	65.98	4.52
Calf Meal No. 4	6.49	4.68	27.35	3.84	59.40	4.73
Calf Meal No. 5	10.18	4.40	21.02	6.71	61.07	6.79
Calf Meal No. 6	10.71	5.22	24.64	3.54	61.88	4.72
Skim-milk powder and starch gruel	88.90	8.05	20.72	none	71.26	trace
Skim milk and starch gruel	88.70	6.99	18.58	none	74.42	trace

*In case of the dry meals to reduce roughly to normal water basis, deduct 10 per cent. and for the skim milk and starch gruels, deduct 90 per cent.

A study of the chemical composition of the several meals shows that they contain, when ready to feed, about 10 per cent of moisture, 4-5 per cent of mineral matter, 2-3 per cent of fiber, 60-70 per cent of extract matter (largely starch), and 4-6 per cent of fat. The protein percentage in the several meals varies widely—from 18 per cent in case of Meal No. 2 to 32 per cent in case of No. 1. We have no positive knowledge as to the best percentage of this ingredient, but on the basis of our experience believe that 18-24 per cent should prove satisfactory. The fiber percentage should be kept as low as possible, especially in a meal that is to be used in the gruel form during the first few months of the life of the calf. A reasonable amount of fat is desirable. It is doubtful if 5 to 7 per cent is at all excessive.

6000. 4-7-'25. Order No. 1473.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 224 March, 1925

THE COSTS OF MARKETING THE APPLE CROP OF 1923

By Lorian P. Jefferson

Knowledge of costs is a necessary antecedent to control over them. Increasing competition from other producing regions makes it necessary that Massachusetts orchardists know their costs, and be prepared to reduce them, or to give better marketing service, in order to maintain the strategic position which is and should continue to be theirs. The study which this bulletin reports was initiated, therefore, as an attempt to determine the factors of cost which Massachusetts orchardists must meet in getting their product from the tree to the market which they serve.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

5,000. 4-24-'25 Order No. 1620.

THE COSTS OF MARKETING THE APPLE CROP OF 1923

By Lorian P. Jefferson

This study was undertaken in order to determine the costs of putting apples on the market, what grades may be marketed with profit, the margin over costs of marketing returned to the grower from sales by various methods, and the type of container most desirable.

Information was collected by personal visits to growers, 65 individual reports being obtained beside that from the Nashoba packing house.

No attempt was made to secure data from all growers in any section, but those growers visited were representative. Data were obtained in four sections of the state—Franklin County; Granville, a small and comparatively new area near the Connecticut line in Berkshire County; the Newbury section in the northeastern corner of the state; and an extensive area centering about Littleton, but including many widely scattered growers of Middlesex and Worcester Counties.

The data used were sometimes taken from records, bills of sale, etc., kept by the grower, and sometimes—more often indeed—they were thoughtful estimates of the producer. Most of those visited gave such estimates for at least a part of the information sought, although many had some sort of record on which the figures were based. These figures were carefully tabulated, omitting the few questionable returns.

It was found that, owing to wide ranges in the reports, averages were not always representative of the expenditures for various items. In these cases the most common cost was used as typical. Hence the tabulation summarizing the costs must be considered merely as a fairly representative list of costs. All averages are weighted except when otherwise stated.

No attempt was made to discover the cost of growing the fruit. It must therefore be recognized that the "margins" or "returns" considered throughout the study are to be regarded as profits only after the costs of growing are deducted from the "margin over cost of marketing."

One grower said that apples could not be sold at a profit unless the price obtained was more than $3.50 a barrel. Another said that it cost $2.00 to grow and market a bushel of apples. Obviously a wide range exists in the individual costs of production as well as in the costs of marketing. A difference of 83 cents a bushel appears between the two cases cited.

Grades.

The law of the state provides for three grades of apples—Fancy, A and B —and an ungraded class. In reality, the apples known as ungraded are of two kinds: those which are sold as they come from the trees, culls only having been removed; and the inferior grade which remains after Fancy, A and B grades—any or all of them—are taken out. The term "ungraded" as applied to this inferior lot of apples is a misnomer, and some other designation should be devised.

The growers visited reported 214,153 bushels of apples sold from the crop of 1923. Seventy-five per cent of these were sorted and graded. The grades appeared in the following proportions:

Grade	*Bushels*	*Per Cent*
Fancy	17,640	8.1
A	68,816	32.1
B	29,273	13.7
Ungraded	90,062	42.0
True	52,007	24.3
Inferior	38,055	17.7
Cider	8,362	3.8

Of the apples which were graded, 13 per cent were Fancy; 51 per cent were A's; 22 per cent were B's; while 14 per cent were the inferior stock, called "ungraded," left after the higher grades were sorted out. Some few of the growers graded into all grades, but most of them did not. Sixteen per cent report apples of the Fancy grade; 41 per cent sold apples of A grade; 27 per cent sold B grade; and 17 per cent sold ungraded stock which remained after the higher grades had been sorted out.

Methods of Sale.

Probably the most important single factor in determining the price received for apples is the method of sale. Obviously, whether the highest price means also the greatest profits depends upon costs of production and costs of marketing.

Several methods of sale were found in current use among the growers visited:

1. To the buyer, who comes to the orchard or packing shed, usually provides his own containers, and may be a huckster, a jobber or a wholesaler. This method is common throughout the state.
2. To the wholesaler, to whom the apples are usually delivered by the grower.
3. On commission, the rate of commission varying from 7 per cent of the selling price for apples which are exported, to 12 per cent which is the common rate on the Worcester market.
4. To the retailer, the grower generally paying the delivery charges, although in at least one instance the retailer buys the entire crop of the grower and hauls it away on his own trucks, a distance of 30 miles.
5. Cooperatively, there being one cooperative packing association and one cooperative roadside market selling apples.
6. At retail, at the door or at a roadside market maintained by the grower.
7. From door to door, probably the most expensive method of sale.
8. At a farmers' market. One grower only reports sales by this method and his fruit is sold chiefly to retailers and hucksters.

Sale to buyers who come to the door is probably the most common way of selling throughout the state, 55 per cent of the growers visited selling all or part of their crop to buyers at the door. Some of the buyers are hucksters and sell in various cities throughout the state. Some are wholesalers and some few are retailers. Frequently the fruit is bought "orchard run" at the farm and the grower has no responsibility for it after it is picked and hauled from the orchard. Most of these buyers seem to make the best bargain possible with each individual grower, having neither fixed price nor fixed terms of purchase, and these terms may differ widely in any community. Particularly is this true in the western part of the state. One grower sells his apples on the trees, the buyer picking, sorting and packing them and hauling them to the station. Another grower picks his apples, hauls them to the packing shed, supplies one packer, while the buyer supplies one or two. Sometimes the grower furnishes two or three packers and boards another who is hired by the buyer. The grower may or may not deliver the apples f.o.b. his loading station.

The same variations appear in the prices paid by these buyers, who sometimes request the growers not to reveal the price paid. The range of prices for the different grades of the crop of 1923 varied as follows:

A	\$3.00 to \$5.00, per bbl. with eight different prices.
B	\$2.75 to \$3.60, per bbl. with five different prices.
Ungraded	\$1.00 to \$4.00, per bbl. with twelve different prices.

More than half the apples reported for this study by Franklin County growers are sold absolutely ungraded; while but 6 per cent are sold as the inferior lot, misnamed "ungraded," remaining after the better grades are sorted out.

With the exception of those who sold their apples on the tree, the growers who sold to these buyers always paid two items in the cost of marketing—picking and hauling from the orchard to the packing shed. From this point, varying bargains were made by the buyers. They did all or any part, commonly one-half, of the sorting, grading and packing; they furnished the container in some cases, while in others it was furnished by the grower; either the buyer or the grower hauled to the station, as was agreed. The freight was generally paid by the buyer.

The reasons for this undesirable situation seem to be:

1. The distance from market. Most of the orchards lie at a considerable distance from the large markets in the western part of the state, and the small markets are soon over-stocked. The haul to Holyoke or Springfield is long—40 miles at the least, and for some of the growers it is 50 miles or more. On account of the hills this haul is more difficult than one of the same mileage in a more level section. It is more convenient and less expensive to sell to a buyer at the door, or at least at the nearest shipping point.

2. Custom undoubtedly has some influence in the matter. For years these buyers have come to Franklin County for the apples they handle, and the growers have formed the habit of selling by this method.

3. The size of the individual crop probably influences to some extent the method of sale. The average crop in Franklin County is about 2200 bushels, and 45 per cent of the growers reporting sell yearly less than 1700 bushels each. The average crop in the eastern section of the state is nearly twice as large as that in the Franklin County area.

In Worcester and Middlesex Counties the methods of sale are various, but chiefly apples are sold to buyers at the farm, cooperatively, to retailers, and on commission. The most interesting method is the cooperative sale by the Nashoba Apple Packing Association, which maintains two packing houses, one in Littleton and one in Bolton.

The apples were picked and hauled from the orchard by the grower. They were hauled to the packing house by the Association at a flat rate of 5 cents a bushel, regardless of distance. Sorting, grading and packing costs were reported as 30 cents a bushel, but this included some items which should have been charged to supplies. The actual cost of the labor of sorting, grading and packing was possibly not more than 25 cents a bushel.

The packed box was then hauled to Boston for 12 cents and delivered to one commission merchant who handled the entire output of the Association.

There was a very small charge for labels and advertising. With commissions the total costs of the Association amounted to an average of \$1.08 per box.

Over half, 51 per cent, of the growers report that they sell by one method only; 27 per cent sell by two methods; 18 per cent use three methods, while four, five and six methods are used by one grower each.

Two growers sell their crops on the tree and have no further responsibility.

Buyers who come to the orchard purchase the entire crop of 30 growers reporting. Nine growers sell to wholesalers, 20 on commission, 23 to retailers, 7 to hucksters, 7 cooperatively, 9 at retail at the door or at roadside stands, 6 sell from door to door, and one at public market.

Total Costs.

The items of cost which appear in the marketing of apples may be listed as follows, but it is obvious that very few growers would incur each of these expenditures:

- Picking
- Sorting
- Grading
- Packing
- Container
    - Boxes, with risers
    - Barrels
    - Baskets
- Cooperage

Heading of barrels
Nailing of boxes
Paper
Hauling container to orchard
Hauling container to packing shed
Hauling from farm to market
Hauling from farm to station
Hauling to storage
Hauling from storage
Freight
Storage
Selling

It will be noted that the costs of marketing are here considered as beginning with the cost of picking and including all actual expenditures till the fruit is in the hands of the first purchaser, whether he be buyer, wholesaler, retailer or consumer. These costs vary greatly with different growers and to a certain extent with the locality.

Picking.

The most common cost of picking a bushel of apples, as reported by the producers visited, was about 8 cents in 1923. The range of costs for this operation was from 3 cents to 20 cents. Of the 62 reporting, 31 paid less than 10 cents a bushel for picking, 14 paid from 10 to 14 cents, and 17 paid from 15 to 20 cents. The average cost was between 10 and 11 cents a bushel.

Sorting.

Sorting, grading and packing costs vary even more widely than the picking costs, the range being from 3 cents to 42 cents a bushel. The average cost was 13 cents; 43 per cent of the growers report this charge as less than 10 cents, 31 per cent paid between 10 and 14 cents, 11 per cent paid between 15 and 20 cents, while 13 per cent report that it cost more than 20 cents a bushel. The most common cost was 8 1/3 cents.

It must be recognized that these figures include all types of sorting, grading and packing; those that are merely put into the container as well as those that are sorted, graded, wrapped and packed, the utmost attention being given to each detail. Obviously there must be wide differences between costs. Fourteen per cent of the apples sold (ungraded) were reported as having cost an average of 5 cents a bushel for such sorting and packing as was done. This is 37 cents less than the highest charge reported.

Storage.

Comparatively few growers stored apples and only 15 of these were able to give costs of storage. The range of this charge was from 3 cents to 32 cents a bushel, but includes farm storage as well as hired cold storage, the farm storage being estimated on the basis of interest on the cost of the storage. The average cost of storage per bushel of apples stored was 23 cents. This average is much increased by the costs of a few growers, as one-third of those reporting storage costs paid less than 10 cents a bushel.

Containers.

More than half the costs of marketing apples in Massachusetts may often be charged to the container. The average price of barrels to 45 growers, who sell in this way, amounts to 23 cents per bushel sold. The prices reported ranged as high as 85 cents a barrel including cooperage and delivery. Some growers buy second-hand barrels when these are obtainable, and some report that the barrels are returned by the retailer or the consumer.

Boxes cost an average of 21 2/3 cents as reported by 30 growers, and the most common price is 22 cents. Baskets are reported in several sizes, holding

2 quarts, 4 quarts, 8 quarts, 14 quarts, 28 quarts, a half-bushel and a bushel. The cost of baskets averages, for the 23 growers who report their use, about 26 cents a bushel.

The one grower who reported sales in 2-quart baskets paid at the rate of 48 cents a bushel for these containers. Four-quart baskets cost an average of 32½ cents a bushel. Selling in baskets containing 14 quarts meant an average expenditure of 23 cents a bushel for containers, while baskets holding 28 quarts cost an average of 17 cents a bushel. Baskets containing a bushel cost an average of 13 cents.

One instance was found where the containers, "barrel crates," were the property of the buyer, who charged the grower 25 cents each for their use. The grower had, however, provided storage space for these crates between seasons, and for this service the buyer allowed him 12½ cents per crate. This amounted to nearly 3 cents a bushel cash outlay for containers.

The type of container most desirable seems to depend upon the grading done. Ungraded apples are probably more suitably packed in barrels, while graded fruit may better be packed in boxes. Baskets seem to be used for retail trade particularly.

Selling Costs.

The cost of selling varies greatly with the method of sale. The most expensive methods being, apparently, from door to door and at roadside markets, but accurate data as to these methods are very difficult to obtain. Quantities thus sold vary from day to day with a consequent change in selling costs per unit.

Selling on commission is most commonly at a rate of 10 per cent of the selling price, although exported apples are sold for 7 per cent commission, and rates here run as high as 15 per cent. Sales in Worcester are reported at 12½ per cent. The average cost of selling on commission was 19 cents a bushel.

The selling costs of 106 lots of apples sold varied from 4 cents to 90 cents a bushel. The most common cost was 10 cents a bushel, 11 per cent of the lots reported showing this selling cost. The average cost of all these lots was 18 cents a bushel.

There were in addition 36 lots, most often the entire crop, sold to buyers who came to the door, relieving the grower of all selling costs except for the time required to bargain with the buyer. For the purpose of this study, there is no cost of selling included for the lots of apples so sold.

The average selling costs on all lots reported, 142 in number, was nearly 14 cents a bushel, but this figure has little significance in view of the wide variation in individual costs. The weighted average selling cost was 18.6 cents per bushel.

Transportation.

The cost of hauling from orchard to packing shed is most commonly about 2 cents a bushel, 34 per cent of the growers reporting this cost, while 77 per cent report a charge of less than 5 cents a bushel for this item. The highest cost reported is 12½ cents a bushel.

More of the crop is hauled to market by truck and wagon than is shipped by freight. The cost of hauling to market ranges from 3 cents to 33 1/3 cents. The most common cost is 15 cents; 42 per cent of the growers report this cost to be either 15 or 16 cents, while 39 per cent haul their apples to market for less than 15 cents a bushel.

The most common cost of delivery at the station is 5 cents a bushel, the range being from 5 to 11 cents.

Two-thirds of the growers use motor trucks, mostly privately owned, but a few are hired. The average length of haul by truck is 20 miles, practically always to market, though a few haul by truck to their railroad stations, delivery being thence made by freight. Wagons are used by the remainder of the growers, and three report that they use both, depending upon the weather. The average wagon haul is 4 miles and the haul is commonly to the station.

A few, however, report that apples are hauled by wagon to nearby markets. Wagons are used almost entirely in the western part of the state where the hills sometimes render hauling by truck a difficult matter.

The average haul for all vehicles is about 15½ miles, while the most common haul is less than 10 miles. The average haul by wagon is about 4 miles at an average cost of \$.0169 for hauling one bushel one mile. The average haul by truck is 20 miles, at an average cost of \$.0092 a mile for each bushel hauled.

The mileage cost per bushel hauled by truck less than 10 miles is \$.0136, nearly ¼ cent less than by wagon.

For distances varying from 10 to 24 miles, the trucking cost per bushel averages \$.009 per mile, while for distances of 25 to 43 miles (the greatest reported) the average cost is \$.0053 per bushel per mile.

The most common cost for trucks lies between ½ cent and 1 cent per mile for a bushel, while the most common cost for wagons lies between 1 cent and 1½ cents. One-fifth of the trucks carry a bushel a mile for less than ½ cent, while 8½ per cent report cost exceeding 1½ cents a mile for each bushel hauled. The highest cost reported was slightly more than 5½ cents, which appears in both truck and wagon costs. The lowest cost was reported for a truck hauling a distance of 30 miles for 15 cents a barrel, \$.0016 a bushel per mile. The most common length of haul by truck was 30 miles at an average cost of \$.0058 per bushel per mile. The average cost for all vehicles is practically one cent a mile for each bushel handled.

Transportation costs for trucks amounting to nearly the same figure are reported from the eastern and western parts of the state. Few wagons are used in the eastern section, except for hauling from the orchard to the packing shed.

Cider Apples.

Cider apples included culls and apples from wild trees unfit for other use. These were sold mainly at local cider mills, although some few growers make and sell their own cider. Cider apples brought an average price of about 17 cents a bushel, but they are sold mostly by the hundredweight.

Prices and Margins.

Following is a comparison of the prices and margins over costs of marketing received for the various grades by different methods of sale. The three methods most commonly employed among the growers visited are here presented, since the great part of the apples reported were sold by these methods.

It is notable that in every case sales to country buyers showed the lowest prices and lowest margins over costs of marketing. Sales of Fancy apples to retailers brought the highest margins over costs of marketing. Sales of A's on commission brought the highest price for this grade, and sales on commission averaged the highest prices and the highest margins.

The true ungraded apples brought the highest prices for this grade when sold on commission, but a small quantity of inferior ungraded sold to a retailer brought the highest margin over costs for this grade. This was due to the fact that the retailer supplied the container and hauled the apples from the farm, making the actual expenditures of the grower very small. However, the price received was not as high as for those of the same grade sold on commission. Ungraded apples returned lower prices and margins over costs of marketing by all methods of sale than did graded fruit.

The influence of low grades of a product upon the prices received for the higher grades is difficult to calculate, but it is the opinion of many growers and dealers that the low grade apples might be kept off the market with profit to the grower. It is doubtful, for example, if the margins over the costs of marketing ungraded apples, when sold to country buyers particularly, cover costs of production. In 1923 it is certain that some growers lost on B grade apples, and others made little or nothing by selling this grade. Some few growers made their low grade apples into cider which was sold at a roadside market.

Average Prices, Costs of Marketing, and Margins over Costs of Marketing.

	Bushels	Average Price	Cost of Marketing	Margin over Cost of Marketing
		FANCY		
To country buyer	1,224	$1.67	$ .53	$1.14
To retailer	180	2.12	.38	1.74
Commission	9,636	2.07	.45	1.62
		A GRADE		
To country buyer	14,697	1.23	.49	.74
To retailer	13,824	1.93	.81	1.12
Commission	18,495	2.20	.98	1.22
		B GRADE		
To country buyer	3,594	1.34	.60	.74
To retailer	5,280	1.51	.63	.88
Commission	9,201	1.56	.88	.68
		UNGRADED—INFERIOR		
To country buyer	12,535	.91	.41	.48
To retailer	225	1.08	.10*	.98
Commission	19,414	1.90	1.06	.84
		UNGRADED—TRUE		
To country buyer	27,980	.88	.39	.49
To retailer	8,300	1.10	.40	.70
Commission	2,000	1.92	.84	1.08

*Sold at door, buyer furnishing container and hauling away.

A comparison of the prices and margins over costs of marketing for all graded apples and for those ungraded which are merely picked, sorted and packed is of interest. All graded apples, including the so-called ungraded remaining after other grades are removed, brought an average price of $1.79 per bushel, with an average margin of $1.03. The true ungraded apples brought an average price of $1.03 with a margin over costs of marketing of 57 cents a bushel, practically half the margin on all graded apples. Omitting the inferior grade, the graded apples brought an average price of $1.88 with an average margin of $1.08 per bushel.

According to the data tabulated, B grade apples sold to country buyers brought a higher average price than did A's sold by the same method. This may be explained by the fact that comparatively few apples of B grade were sold by this method, tending to give undue weight to any unusual instances; and that some lots of apples brought the same price for A and B grades.

In the case of ungraded apples, it is noticeable that the country buyer paid more for the inferior class than for the true ungraded. This may, perhaps, be explained by the probability that the growers who grade their apples carefully do so because they are better acquainted with market conditions and are therefore in a position to make a better bargain with the buyer.

Information secured with reference to the expenditure of labor necessary to pick, sort, grade and pack showed that there is a wide variation in labor as in money costs. The average number of bushels reported picked in a day is about 48, although orchard conditions have a marked influence in the matter. Sorting, grading and packing, which are usually considered as one item, average a little higher, one worker packing about 54 bushels a day. Many growers, however, estimated that the labor costs of this item are about the same as for picking.

It is almost impossible to give the cost in labor of other items, such as hauling and storing, because the work is done so intermittently that the amount of time required per bushel or the amount of work done in a day is difficult to estimate.

A tabulation of the average or most common expenditures for the various items entering into the costs of marketing will serve as a summary.

Operations	*Cost per Bushel*
Picking	$ .10
Sorting, grading and packing	.13
Container	.23
Hauling from orchard	.02
Hauling to station	.05
Hauling to market	.15
Selling	.19
Typical costs of marketing apples hauled to market	$ .87
Storage	.23
Hauling from storage	.05
Typical costs	$1.15

The study leads to certain definite conclusions.

1. Sale to country buyers is the least profitable method of sale.

2. It pays the grower to grade his apples. How closely this may profitably be done depends, obviously, upon the character of the crop.

3. Sales on commission returned, to the growers reporting, the highest average prices and the highest average margins over costs of marketing. These sales were made in some cases throughout the season, thereby taking advantage of the season of highest prices. The 10,000 bushels sold cooperatively were in this group. Some other methods, *e.g.,* sale to country buyer, dispose of the crop early in the season, when prices are likely to be low.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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YELLOW PICKLE IN GREENHOUSE CUCUMBERS

By VICTOR A. TIEDJENS

Contribution from the

MARKET GARDEN FIELD STATION

of the

MASSACHUSETTS AGRICULTURAL COLLEGE

Yellow pickles on greenhouse cucumber plants are due to a physiological disorder causing the fertilized pickles to ripen prematurely. Any environmental factor that reduces the amount of food material in the plant may result in a condition favorable to the formation of yellow pickles. Inadequate light, insufficient nitrates, excessive set, surplus water, poor drainage, or a serious attack of animal or plant parasites may all contribute to a premature ripening of cucumbers. The remedy is primarily the prevention, elimination, or correction of those conditions that tend to devitalize the plant.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

YELLOW PICKLE IN GREENHOUSE CUCUMBERS

By VICTOR A. TIEDJENS

Perhaps no other problem causes greenhouse cucumber growers more concern than the appearance of a large number of yellow pickles when the vines should be yielding at their maximum. Whenever plants are weakened from disease, poor growing conditions, or a heavy set, yellow pickle[1] is always present. Some growers attribute it to degenerated seed, some regard it as mosaic, while others ascribe the condition to lack of pollination by bees. Observations on self and cross-fertilized cucumbers for two generations lead to the conclusion that these assumptions are to a certain extent correct, but the condition is due to many more causes than any one group is usually willing to admit.

Yellow pickles may be the result of one or more causes such as too heavy a set, poor pollination, the method of growing (whether string or A trellis is used), insufficient soil nutrients, animal or plant parasites, or conditions that weaken growth and stunt the plant.

The Condition Called Yellow Pickle

Reference is made to yellow pickle as a condition because it is usually secondary and is brought on by one or more causes. As a rule yellow pickle manifests itself on small cucumbers on old diseased vines, or heavily set vines which are in the first set. Occasionally the condition is found in cucumbers from six to eight inches long if the plant has experienced a sudden shock or "set back." Ordinarily, in the condition known as yellow pickle, the cucumber does not grow beyond a length of four inches. After growth is stopped the cucumber becomes yellow near the stem end, the yellow color gradually spreading toward the tip if decay does not set in first. Some make sufficient growth to mature a few viable seeds. If sufficient growth has not been made to develop viable seed, the cucumber wilts and gradually dries up.

If it has been fertilized, the yellow pickle may remain on the vine from four to six weeks before it drops off. This condition has been called premature ripening, but differs from that of a normally maturing cucumber in that the yellowing of the mature cucumber becomes visible over the entire surface, the stem end being less pronounced in color than the remainder of the cucumber, a condition directly opposite to that found in yellow pickle. Plants may have from one to six or more of these yellow pickles at one time, depending on the set of the plant. A plant having a heavy set may develop only half of the pistillate flowers into marketable cucumbers, in which case the other half becomes yellow, the proportion of yellow pickles to normal cucumbers depending on the vigor of the plant. A weak plant may mature only one of many pickles fertilized, in which case the percentage of yellow pickle will be very high; whereas, although a strong plant under the best growing conditions may not mature all its pickles if the set has been exceptionally large, the percentage of yellow pickle will be relatively small.

1. There is some confusion in the use of the two terms "yellow" and "white" pickle. The condition here referred to as yellow pickle may result from any one of several physiological causes and manifest itself in a premature yellowing of the pickle.

THE RELATION OF FRUIT SET TO THE DEVELOPMENT OF YELLOW PICKLE

A cucumber plant grows in cycles with reference to producing pistillate flowers. After a large number of pistillate flowers have been produced, that is, one on each node up to the first ten nodes of the stem, only staminate flowers are produced for a number of new nodes higher up, followed by another group of pistillate flowers. Thus a "set" usually follows the removal of a number of large cucumbers from the vine. Usually more pistillate flowers are produced in one set than the plant will mature, and some of them must be sacrificed. Under greenhouse conditions, where all the flowers are in a favorable position to be visited by bees, a very large percentage of the female flowers set fruit. If conditions are ideal for good growth, the plant may be able to mature a complete set. Usually, however, a few of the cucumbers formed on the first few nodes of the plant are a day or two ahead of the others and develop normally, while the later pollinated pistillate flowers make very little growth until the first formed cucumbers have been picked. If growing conditions are unfavorable so that several weeks are required to grow the market size cucumber, the pickle becomes stunted and, even though conditions later become favorable, it does not grow. Instead a newly pollinated flower may start and as a result the small pickle is prematurely ripened. It may have a few viable seeds or it may not have grown sufficiently to develop any seed. The pickle turns yellow, a condition which many growers have attributed to a parasitic disease. An infection of a plant by an organism is probably the most important cause of yellow pickle on normal plants.

The condition cited above very definitely manifested itself in self-pollinating work on old plants which had set a number of fruits. A study was undertaken of certain characters existing in a mixed lot of cucumbers grown in the station greenhouse. Self-pollinated flowers, on plants already having a number of pickles set, invariably developed yellow pickle; and not until every pollinated flower and developing cucumber were removed from the plant was it possible to get the plant to produce any self-fertilized fruit. On the other hand, when the first flowers of the plant were self-pollinated the fruit developed and matured, indicating that self-pollination was not the determining factor.

Yellow pickle was very much in evidence on plants used for seed production in breeding work. As many as eight pistillate flowers on a plant were selfed, but only three or four matured while the others remained for several weeks without growing, and then turned yellow. It was not uncommon to find five or six yellow pickles on these plants because of the time required to mature the early pollinated fruit.

Since, in the production of seed, the mature cucumber must remain on the vine much longer than that which is picked for market, much more food material is required and the plant is not able to carry as much maturing fruit as if all were picked green. Under such conditions yellow pickle is very much in evidence.

Generally yellow pickle is associated with old vines, but the plants in the above experiment were in their first set. This brought out the fact that yellow pickle is a premature ripening of pollinated flowers at a time when the plant is carrying a heavy load. The second set came along after the mature seed cucumbers were removed. The fruits from this set produced good marketable cucumbers while the yellow pickles were still hanging on the vines. A few that had not turned yellow failed to grow after standing still for such a long time, and finally dried up without becoming yellow. The flowers from which these yellow pickles developed were self-pollinated on June 21, 1925. The pickles did not begin to turn yellow until August 8, 1925, 48 days later. Some of them were three to four inches long and a few had some viable seeds.

Relation of Pollination to the Development of Yellow Pickle

Many cases of yellow pickle can be attributed to lack of pollination. However, with certain varieties, when a pistillate flower is not pollinated, its growing period is much shorter, and the pickle very seldom grows over two inches. Often it does not have the characteristic yellow color found on the larger pickles. In the case of the English variety it is possible to mature large cucumbers without pollination, but this is not the case in the ordinary varieties used in a study of this problem. Yellow pickles were found, however, on English vines which already had three or four mature cucumbers.

Interest in the yellow pickle problem prompted the bagging of a large number of pistillate flowers to prevent visitation by insects. None of these flowers developed pickles over two inches long. The color was a grayish yellow and in some cases almost white. Some of these decayed in a short time, while others dried up and dropped off, a condition differing from that described above.

The Relation of Method of Growing to Yellow Pickle

Two methods of growing cucumbers in greenhouses are generally practiced; namely, the "A" trellis method, and the string method. Where the "A" trellis is used, fewer plants are necessary and these develop more normally than with the string method. With the string method the plants are closer together, and are pruned so that each branch has only one or two nodes, the main stem being twined around the string which extends from a wire near the top of the house to the base of each plant. The prevalence of yellow pickle depends somewhat on the method that is used.

The number of pistillate flowers formed is largely determined by hereditary factors. Thus, there will be as many pistillate flowers on the main stem and first two nodes of the branches whether the plants are grown on strings or trellises. In the string method, a large amount of leaf surface is removed in pruning, thus curtailing the amount of food the plant can manufacture and store. Such plants cannot develop as many of the pistillate flowers as those on the "A" trellis where very little pruning is done. Also, the plants are crowded more in the string method and less soil nutrients are available to each plant. This means that there are likely to be more yellow pickles on the string plants under uniform conditions of growth. This has been commonly observed, but not proved by tests under controlled conditions.

Relation of Parasitic Diseases to Yellow Pickle

As was stated in the introduction, yellow or white pickle resembles symptoms of mosaic. It is also common to find yellow pickles associated with diseases produced by animal or plant parasites, but the yellow pickle with which we are here concerned does not come within the category of any of these diseases. When plants are affected with disease their health is impaired to the extent that they cannot mature their fruit and grow new foliage as normally growing plants can and consequently the fruit is prematurely ripened. As cucumber plants grow older, especially with the string method, they shade each other more, and for that reason the lower leaves either drop off naturally or succumb to disease. Under such conditions the plants are unable to carry to maturity the fruit which was pollinated when they were in a fairly healthy condition, and consequently many yellow pickles appear.

Soil Conditions and Yellow Pickle

Ordinarily the soil in a greenhouse is so well manured that if it is handled properly there will be sufficient soil nutrients present to carry a crop of cucumbers from nine months to a year, or as long as the vines are able to produce a paying crop. There are, however, certain conditions caused by poor drainage which tend to shorten the growing period of a plant, and materially cut down the yield. After cucumbers are transplanted, a period of soil saturation with water follows so that the plants are continually growing in a wet soil, which is usually too wet for healthy growth. If good drainage is provided, as in benches, little damage will result. If no drainage is provided, the soil becomes water-logged, oxygen is excluded and practically no nitrification takes place. The plant does not receive sufficient nitrates to make a healthy growth and a large number of yellow pickles results. Even if compost manure or fertilizer is applied on the top of the ground and kept moist, the plant will not function properly as long as the soil is in a water-logged condition. This undoubtedly has much to do with the longer growing period of cucumbers when grown in benches.

The cucumber plant needs a large quantity of water, but it will not thrive if the roots do not receive sufficient air in the presence of too much water in the soil. Greenhouse growers claim that plants wilt if the soil is not thoroughly wet down. This is true, but they will wilt even though more than the necessary amount of water is added, the reason being that the plants have received so much water from the time they were set in the beds that the root system is not large enough to balance the upper part of the plant. The roots remain near the surface and will not branch out and down for water and food. They are near the surface where there is air. It is the same condition found in a poorly drained field. If plants wilt during hot dry weather, growth is interrupted to the extent that many cucumbers become stunted and produce either nubbins or yellow pickles. Proper watering after transplanting will prevent much of this trouble. An excess of water from the time the seed germinates makes a soft plant which requires a large amount of water. It is impossible to give such a plant sufficient water during hot dry weather to prevent it from wilting, because the root system is not large enough to replace the water that is given off by the leaves. Undoubtedly, cucumbers grown with less water from the start are more lignified (less soft), have stiffer cell walls, and do not droop as readily even when there is a slight water deficit.

This condition of the soil has considerable influence on the health of the plant. The number of yellow pickles will be influenced by the condition of the plant.

The Relation of Deformed Cucumbers to Conditions Causing Yellow Pickle

The cause of nubbins and deformed cucumbers is usually attributed to the fact that the flower was improperly fertilized or that the seed is degenerating. Both answers seem improbable in the light of certain observations on both healthy and diseased plants. There are plants so genetically constituted that they produce only nubbins or deformed cucumbers. But many plants later in life produce nubbins and deformed cucumbers which earlier produced number one cucumbers only. In this case we cannot attribute the condition to heredity. When nubbins are produced on greenhouse grown cucumber plants that are as freely visited by bees as plants producing number one cucumbers, we hesitate to attribute the result to a lack of pollination. It would be supposed that hand pollination should overcome the trouble, but experience has shown that resorting to such a method is no assurance that the cucumbers will be normally formed. Therefore we are led to think that the physiological balance of the plant is upset to the extent that fertilization is abnormal. This assumption, however, cannot be proven at the present time. When a plant is weak and an insufficient supply of food is available to nourish the newly pollinated flowers, the time when any given flower is pollinated may have some influence on the shape of the fruit developing from it. The number of growing cucumbers on a plant is undoubtedly a contributing cause of the production of nubbins and deformed cucumbers. By observation it has been noted that the condition of the fruit indicates the conditions under which it was produced. That is to say, if a plant is in good health and sets six cucumbers on six succeeding days, they may all start to grow. If something tends to cut down the food supply, four of the cucumbers, depending on time of pollination and position on the plant, may continue to grow uninterruptedly, while the other two stop growing until more food material is available. If two of the four cucumbers are picked the remaining two may resume growth. However, the plant is producing new foliage and new flower buds while cucumbers are maturing. If no new pistillate flowers have been formed, the two small cucumbers may grow and form cucumbers, the upper half of which will be small, while the tip half will be quite bulgy and will contain a large number of viable seeds.[1] However, if new pistillate flowers have been pollinated on the plant, they may receive the support of the plant and grow while the two small cucumbers either ripen into nubbins with a few viable seeds or become yellow pickles. This condition applies only to plants which under normal conditions produce cucumbers of good shape.

The Application to Practice

Growers ask as to what can be done to avoid yellow pickle. The better control is, obviously, prevention. When all the yellow pickles and mature cucumbers are removed the plants put forth new growth and develop pistillate flowers, providing abundant supply of required nutrients and foods manufactured by the leaves is available. If the plants are kept healthy and vigorous at all times they will carry more pistillate flowers to maturity. Growth must be continuous and rapid. The presence of a number of

1 The seeds from a number of self-fertilized cucumbers of this shape have produced plants which bore perfect normally shaped cucumbers.

maturing fruits suppresses many of the newly pollinated pistillate flowers and causes their fruit to become yellow when there are insufficient nutrients or food materials to allow rapid development of fruits present. Uniform night temperatures with moderate watering and an occasional light application of a nitrogen fertilizer to keep the plants growing, reduces yellow pickle to a minimum.

All cucumber houses should be well drained to prevent the soil from becoming water-logged. The young plants should be lightly watered to make them send out a good root system. The soil should be watered in such a way that the water will not stand on top of the ground. A sprinkler system is better than a hose without a nozzle, because not so much water is applied and it soaks into the soil better. The plants should be watered when it is necessary. They should not be watered as a matter of daily routine. The objective should be to get a good vigorous, healthy, fast-growing plant that will mature a large number of fertilized flowers.

Nubbins and deformed cucumbers should be removed from the vine as soon as it is apparent that they will not be well shaped cucumbers, since if once deformed they can never develop into a salable form. If they are left on the vine in the hope that they will develop into good cucumbers, they merely drain the strength of the plant and prevent it from developing normal fruit. Much less vitality is needed to produce a normal cucumber of salable size than is used to carry a nubbin to maturity, since in the former the seeds are small and undeveloped while in the latter the fruit ripens and seeds are fully developed. The removal of a maturing cucumber results in further production of pistillate flowers, and consequently further fruit production. It is a slight task to remove the nubbins when the vines are being trained or pruned.

Pruning should be a daily rather than a monthly practice. Much less damage is done if the growing tips of branches are pinched off than if seven or eight nodes are allowed to form on the branches and are then cut off with a knife. A large amount of sugar is made by the leaves of these branches and if they are cut off suddenly a starvation effect is brought about, the physiological balance of the plant is upset, and a large number of nubbins or yellow pickles will be produced.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 226 — JANUARY, 1926

RESEARCH SERVICE

TO THE

MASSACHUSETTS APPLE INDUSTRY

PROGRESS REPORTS

This bulletin contains ten papers summarizing the more practical aspects of some of the experimental work of the Station that is of interest to fruit growers. More complete reports of some of this work may appear later in separate publications. The subjects reported upon are as follows:

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

THE APPLE SITUATION

BY LORIAN P. JEFFERSON AND HUBERT W. YOUNT

During the summer of 1925 a study of the Massachusetts apple industry was conducted as a part of an all New England study under the auspices of the agricultural experiment stations. The purposes were to discover the numbers and varieties of non-bearing and bearing trees by ages; to learn certain facts with regard to orchards and orchard practice; to determine the quantities and grades sold of each variety, and the methods of sale and the prices received.

The data were collected through personal visits to commercial orchard owners throughout the state. A tentative minimum of 100 bearing trees was fixed as determining a commercial orchard, but smaller orchards were considered if evidently of commercial importance. Approximately 1750 growers were visited, complete information on both trees and production being secured from about 1700.

The results of the study can not be fully stated here, but the following facts and figures give a summary of the situation as shown by the survey, so far as number of trees and plantings are concerned. It should be borne in mind that these figures relate only to orchards of commercial importance and do not include the trees in thousands of small farm orchards.

The owners of the orchards visited reported a total of 967,000 trees, over 600,000 of which were in bearing. More than seventy-five varieties were reported, but the principal ones together with the number of trees in each table are shown in Table 1. The Baldwin is by far the most important variety, having 45 per cent of the bearing trees and over 50 per cent of the commercial crop.

The McIntosh ranks second with 117,000 bearing trees or 20 per cent of the total, and 13 per cent of the apples grown. Nearly 85 per cent of the bearing McIntosh are under fifteen years of age, which accounts for the relatively low yield. In view of this fact and the large number of trees not yet bearing, the production of McIntosh apples may reasonably be expected to increase 100 per cent within the next ten years. Only 28 per cent of bearing Baldwin trees are under fifteen years of age, but there will probably be an increase of about 20 per cent in Baldwin production within the next decade. The early varieties such as the Transparent and Duchess are relatively unimportant both as to number of trees and production. Only about 5 per cent of all bearing trees fall within this class.

The Wealthy is third in importance so far as bearing trees are concerned, but the Gravenstein, with nearly the same number of trees, produces almost twice the crop. Coupled with the fact that many Wealthy trees are fillers, this gives the Gravenstein third place as a commercial variety.

New Plantings

The past ten years have been years of very heavy plantings, over 460,000 trees being set during this period. The plantings of Baldwins and McIntosh have been about equal. Since 1920, however, there has been a decrease in the rate of planting. From 1914 to 1919 approximately 95,000 McIntosh and 70,000 Baldwin trees were planted. During the period since 1920, there have been only 61,000 McIntosh and 55,000 Baldwins planted, a relative decline in planting, for the five-year period, of 35 per cent for the McIntosh and 20 per cent for the Baldwins. Plantings of all varieties have declined 20 per cent in the same period.

Of the winter varieties, the Delicious shows the greatest percentual increase in plantings, some 36,000 trees of this variety having been set in the last ten years, practically all being permanent. Other winter varieties have been planted in considerable numbers, the Wagener being a favorite. The older varieties, such as Greening, Spy and Russet, are rapidly disappearing, few new plantings being reported.

Fillers

The Wealthy is the variety most commonly planted as fillers. Out of a total of 34,000 bearing Wealthy trees, 15,000 were reported as fillers to be cut within the next five to eight years. In the younger plantings over two-thirds of the Wealthy are fillers. Relatively few McIntosh have been set as fillers, and where this was done some years ago, growers are cutting out the permanents and leaving the McIntosh. Wagener is also popular as a filler, nearly all the Wageners planted being used for that purpose. Duchess and Transparent have also been used in some quantities, about one-third of the bearing trees of these varieties being fillers.

Table 1. Number of Bearing and Non-Bearing Trees of Leading Varieties, 1925.

Variety	Non-Bearing			Bearing		
	Perm'ent	Filler	Total	Perm'ent	Filler	Total
Summer Varieties:						
Transparent....	5,095	1,648	6,743	6,673	2,811	9,484
Astrachan......	5,458	631	6,089	7,003	398	7,401
Williams.......	2,141	108	2,249	4,567	590	5,157
Duchess.......	5,148	3,898	9,046	7,149	3,836	10,985
Other.........	971	79	1,050	1,795	64	1,859
Total........	18,813	6,364	25,177	27,187	7,699	34,886
Fall Varieties:						
Gravenstein....	20,447	392	20,839	28,525	60	28,585
Wealthy.......	11,356	18,059	29,415	19,987	15,147	35,134
McIntosh......	111,656	5,188	116,844	112,980	4,432	117,412
Other.........	7,381	481	7,862	15,029	2,643	17,672
Total........	150,840	24,120	174,960	176,521	22,282	198,803
Winter Varieties:						
Baldwin.......	108,085	200	108,285	277,338	1,228	278,566
Spy..........	3,161	5	3,166	7,608	145	7,753
Delicious......	31,457	1,228	32,685	9,325	45	9,370
Greening......	2,116	....	2,116	11,304	242	11,546
Other.........	18,773	1,391	20,164	67,844	2,181	70,025
Total........	163,592	2,824	166,416	373,419	3,841	377,260
Grand Total.....	333,245	33,308	366,553	577,127	33,822	610,949

TABLE 2. Number of Trees by Age Group, 1925

Age—Years	Perm'ent	Filler	Total
Non-Bearing:			
Under 5	180,482	21,545	202,027
5–9	150,470	11,763	162,233
Old	2,293	..	2,293
Total	333,245	33,308	366,553
Bearing:			
Under 10	85,883	11,256	97,139
10–14	164,993	19,997	184,990
15–19	60,351	2,114	62,465
20–29	55,991	391	56,382
30 or over	133,133	15	133,148
Unclassified	76,776	49	76,825
Total	577,127	33,822	610,949

TABLE 3. Number and Age of Trees in Summer, Fall and Winter Variety Groups.

Age—Years	Summer	Fall	Winter	Total
Non-Bearing:				
Under 5	15,141	93,490	93,396	202,027
5–9	9,987	81,363	70,883	162,233
Old	49	107	2,137	2,293
Total	25,177	174,960	166,416	366,553
Bearing:				
Under 10	9,602	55,970	31,567	97,139
10–14	13,215	89,206	82,569	184,990
15–19	3,964	20,448	38,053	62,465
20–29	2,433	11,306	42,643	56,382
30 or over	3,658	9,023	120,467	133,148
Unclassified	2,014	12,850	61,961	76,825
Total	34,886	198,803	377,260	610,949

THE VALUE FOR MASSACHUSETTS OF SOME OF THE NEWER VARIETIES OF APPLES

BY J. K. SHAW

The question of the best varieties of apples for planting will never be settled. While it is true that we have too many varieties and that nearly every fruit grower has in his orchard varieties that never should have been planted, yet no variety is perfect and the alert grower is constantly on the watch for something better. Then too, conditions are constantly changing and a variety that is quite satisfactory now may not meet the demands of the situation a few years hence. The man who anticipates the opportunity of a new variety and plants it early will receive the largest rewards; but on the other hand one who plants largely of a new variety that does not fulfill its early promise may suffer material losses. The choice of varieties is a most important question, for mistakes are not easily corrected.

Several varieties are now on trial in Massachusetts, and the following comments based on observations in the Experiment Station orchards and on the experience of others in this and other states is offered for the information of orchardists.

Cortland

The Cortland is a cross of Ben Davis and McIntosh originated at the New York Experiment Station. It has been considerably planted in New York where it seems to be meeting increasing favor. The supply of nursery trees has been limited, but nurserymen are now propagating them in greatly increasing numbers and liberal supplies of yearling trees are now available. More than 35,000 trees of this variety were certified by the Massachusetts Fruit Growers' Association in 1925.

Cortland is naturally compared with its parent McIntosh. Our experience indicates that in Massachusetts it will hang to the tree much better than McIntosh and need not be picked until at least two weeks later. It matures in storage later and will keep from one to two months longer. It stands handling distinctly better. Its susceptibility to Scab is no greater and may be a little less. The hardiness, vigor and growth habit of the tree are very satisfactory. It comes in bearing early and bears annually while young, and the fact that both parents tend to be annual bearers encourages the belief that it will keep up this habit very well with age.

It has the same white tender flesh as the McIntosh but is distinctly inferior in flavor. It lacks the spicy richness of its parent variety. It is, however, a good apple, probably equal and possibly superior to Baldwin. In appearance, while a handsome well colored apple, it is hardly equal to McIntosh and it appears to be less uniform in size and shape. Our judgment is that it will not replace McIntosh in New England though it will find a place in extending the McIntosh season.

Delicious

The Delicious has enjoyed an increasing favor over wide areas as a high class dessert apple. It is worthless for cooking purposes, unless for pies, so that fruit not attractive for fruit stand trade is good only for cider or similar uses. It has been considerably planted in Massachusetts, and its behavior is variable. In the Experiment Station orchards it tends to run small and of rather poor color after a few years' bearing. It bears heavily biennially. It seems to be more generally successful in Norfolk, Plymouth and Bristol counties than in the rest of the state. In western Massachusetts it does not do very well.

The tree is vigorous, upright spreading in habit and considerably hardier than Baldwin. It makes a rather dense head but after it reaches bearing age it is not objectionable in this way.

Probably the Delicious is more uniformly successful in other sections than it is in New England. If this is true it is doubtful if it ever attains here a place comparable with that of Baldwin and McIntosh. Possibly increased knowledge may lead to better management that will overcome its tendency to run small on mature trees. Thinning and nitrogen applications in midsummer may prove to be means to this end.

It follows that Massachusetts growers should use some caution in planting Delicious, at least until means of attaining uniformly high quality are more certainly known. No one may wisely plant it unless he is prepared to grow it skillfully so as to produce a high quality product that will meet the demand for a fancy dessert fruit. It is not a variety for a careless grower.

Golden Delicious

Much interest has been excited about the Golden Delicious, due to the extensive advertising it receives from the nursery firm introducing it. As grown in the Middle West it is a handsome waxen yellow apple of excellent quality. The tree is vigorous and begins to bear at a remarkably early age. It is apparently very productive. The apple hangs well to the tree and keeps and stands handling very well. In the humid climate of New England it does not seem to attain this clear waxen color, it is a more dull yellow and a little inclined to russet. It is doubtful if it attains the size it does where the growing season is longer.

Most of our New England markets have a distinct prejudice against yellow apples. This may be foolish, but it must be taken into consideration by fruit growers. Probably the extensive advertising this variety is receiving will go far towards overcoming this prejudice, but unless it succeeds better than preliminary observations indicate we cannot compete successfully with Golden Delicious grown in other sections where it attains greater attractiveness and possibly better quality.

Red Bud Sports

Many cases are known where a single branch on a tree normally bearing striped or splashed apples has produced fruit of a distinctly more intense red color, and this character is uniformly transmitted by buds taken from these branches. In other respects it is generally exactly like the parent variety. Many such "bud sports" of the Gravenstein have appeared in this state and elsewhere, and Rome, Twenty Ounce and other varieties show them occasionally. None of these red sports has attained very great favor with growers.

Recently a bud sport of the Delicious has been brought strongly to the attention of fruit men under the name of Starking. It is beyond doubt a true red bud sport of distinctly deeper color than Delicious usually has.

yet well colored Delicious may equal Starking in color. The deeper color of the new variety ought to be an advantage and if it is equal to Delicious in all respects, as may reasonably be expected, it may largely replace the parent variety.

Another red sport is the Red Spy, a solid red variation of the Northern Spy. It is reputed to be exactly like the old variety except in color. There is a question if it is more attractive in appearance than the best of Spies, yet it is well worth a trial by the patient fruit grower who wants to grow Spy.

Many red sports of Gravenstein have appeared, not all alike. One of the most recent ones is distinctly redder than others, being equal to the best colored Williams. As eastern Massachusetts is about the only fruit growing section, outside of California, that grows Gravenstein, this red sport should appeal to our growers who desire higher colored fruit.

DISEASES OF FRUIT IN MASSACHUSETTS IN 1925

BY WILLIAM DORAN

The Department of Botany of the Massachusetts Agricultural Experiment Station receives many requests for information on the identification and control of plant diseases. On such correspondence and on farm visits by the staff, is based this estimate or composite of the occurrence and severity of fruit diseases in 1925. As is developed below, fruit diseases in general probably caused less loss than usual.

Spray Schedule and Spray Materials

In most commercial orchards in Massachusetts the spray schedule on McIntosh consists of the following applications: pre-pink, pink, calyx, first post-calyx, and (in some orchards) a second post-calyx. Baldwins and other varieties considered less susceptible to scab, are given the pink, calyx, and first post-calyx application. In the case of "off-years" when certain varieties are not bearing, the number of applications is much reduced or perhaps none is given.

The favorite material is liquid or dry lime-sulfur. A few orchardists are partial to Bordeaux mixture for the pre-blossom applications. Those who own dusters are using sulfur dust for all applications or for the calyx and post-calyx applications only, depending on the sprayer for pre-blossom applications. Wettable sulfur (such as dry-mix sulfur-lime) is preferred by a few. Calcium caseinate spreader (such as "Kayso" or "Spracein") is generally used in the lime-sulfur-lead arsenate combination.

Scab of Apple

Most orchardists are familiar with the fact that the first infection of apple scab may occur when spores are ejected from the .dead leaves in which the fungus has passed the winter. In 1925, in the Nashoba area, such spores were first ejected between April 29 and May 1. In this same region, this critical date was April 26 in 1921, May 2 in 1922, May 3 in 1923 and May 3 in 1924. It is thus seen that for five successive years this date has occurred about May 1 and within a range of eight days. We would expect it to be slightly earlier in southeastern Massachusetts and somewhat later in the highlands of Worcester County and the counties to the west, exclusive of the Connecticut Valley.

Apple scab this year was on the whole of average, or perhaps slightly less than average, severity, as indicated by the condition of the fruit on unsprayed or poorly sprayed trees. Good spraying gave practically complete protection even on McIntosh and other susceptible varieties. West of the Connecticut Valley there was a light infection on Baldwins. In the Connecticut Valley, the disease became conspicuous later than usual and in some orchards was regarded as severe on McIntosh and Delicious. There was evidence that the second post-calyx application on McIntosh gave some increased protection. In eastern Massachusetts some orchardists had as much scab on Baldwins as on McIntosh, or more. This was, perhaps, due to the fact that in many orchards the Baldwin received only one pre-blossom application while the McIntosh had two, and to the fact that many of the Baldwins are old and tall trees and consequently more difficult to spray well. In most orchards scab became conspicuous on the fruit in July and continued to increase until into September.

Spray Injury

The occurrence of spray injury is affected by the materials used, the manner of application, the susceptibility of varieties, and the weather at the time of and following the application. This being the case, it is not surprising to find that there was serious spray injury this year in some orchards and none at all in others.

In some orchards there was considerable spray injury on the fruit of Baldwin. But the most severe injury was on McIntosh, fruit russeting proceeding so far as to cause the fruit to crack. Leaf injury, in the form of curling, yellowing, or burning of leaf margins was in some cases associated with fruit russeting. This was easily confused with a condition which occurred on the leaves of certain young and unsprayed trees where the leaves showed a brown or blackened margin, probably caused by the high temperatures and drying winds to which these leaves were subjected during their period of development before the tissues hardened.

Spray injury as it occurred this year has been ascribed to the use of the spray gun, to the high temperatures which prevailed during the spraying season, to the use of fungicides containing copper, and to arsenical injury. The worst spray injury brought to our attention occurred in orchards which received pre-blossom applications of Bordeaux mixture or copper dust, with sulfur fungicides used for the calyx and post-calyx applications. Evidence was secured in 1924 that even for pre-blossom applications copper fungicides are less safe than are sulfur fungicides. As recorded by the present writer in Massachusetts Agricultural Experiment Station Bulletin No. 222, there was an average of 14 per cent russeted McIntosh apples on plots which received pre-blossom applications of Bordeaux mixture, and less than 1 per cent on plots which received pre-blossom applications of lime-sulfur. This year, there was of course some spray injury in certain orchards where only sulfur fungicides were used. Some of this may have been due to the use of a spray gun close to the trees and to the unusually high temperatures during the spraying season. During the first ten days of June the temperature was very high, with the maximum above 90° F. for four days in the eastern half of the state. In their study of foliage injury by arsenical sprays, Fernald and Bourne found (Mass. Agr. Exp. Sta. Bul. No. 207) that it is not safe to spray the apple when the temperature is 90° F. and the relative humidity above 67 per cent. It is therefore reasonable to ascribe some of the injury this year to arsenical burning, for this temperature and humidity combination was reached or exceeded during the spraying period in early June.

Black Rot

Black rot of the fruit of the apple was not generally serious this year, although certain individual growers considered it more serious than in 1924. It was reported on Baldwin, Greening, and Yellow Transparent, and was most common on Baldwin. Black rot was not serious even on fruit which showed severe spray injury. This is of interest since in some seasons black rot has been associated with or has followed blossom-end injury due to the calyx spray.

Black rot canker is the most common of the limb cankers, but in most commercial orchards it is not serious. It is often present on old Baldwins, and failure to spray and prune such trees properly results in its rapid increase in severity. Occasionally this disease causes serious loss in young and apparently well cared-for orchards, but such a condition is exceptional in this state.

Cedar Rust of Apple

This disease was practically absent or existed only in traces (and then on Wealthy) in the Nashoba district. Most orchardists have seen to it that red cedars were removed. There was light infection on Wealthy and Banana in western Massachusetts. The sporidia or spores by which this fungus passes from cedar to apple require water for their dissemination, and during that period in spring when this ordinarily occurs the rainfall was deficient.

Sooty-mold and Fly Speck

This disease was of no great importance this year. It was observed in a few instances on Baldwins and Greenings. It occurred more or less throughout the state, but, except on unsprayed and unpruned trees, it was of no consequence. Ordinarily there is more of this disease in the eastern than in the western part of Massachusetts. It may often be seen on drop apples which have remained long on the ground even when not evident on the fruit on the tree.

Baldwin-Spot

This disease, which also goes under the names of stippen or bitter-pit, is well known to orchardists. Unfortunately its cause and control are obscure.

Baldwin-spot was of somewhat more than average severity this year. In many orchards this was the "off-year" for Baldwins, and the disease was generally associated with a light crop and consequently larger fruit. It was not conspicuous in orchards where the fruit was smaller. The occurrence of the disease has an evident relation to alternate bearing and to thinning. Baldwin-spot may occur on other varieties, but this year it was called to our attention only on Baldwin and Stark.

Fire Blight of Apple and Pear

In eastern Massachusetts fire blight occurred about as usual in most orchards, although from a few orchards there were reports of its being on the increase, especially on Gravenstein and Wagener. In well cared-for orchards the removal of the more susceptible hosts has helped to reduce the menace of this disease.

In western Massachusetts, where the disease on the whole was not of great importance, it was present in a few Baldwin and young Wealthy orchards. In a few orchards in the Connecticut Valley it was serious, much more so than in the orchards of eastern Massachusetts with which we are familiar.

Fire blight on pear occurred throughout the state in varying degrees of severity, from serious in some orchards to none at all in others. It was more general on odd or unimportant varieties than on the standard or commercial varieties. It was observed that unnecessary pruning of healthy trees is likely to be followed by an increase in fire blight.

Other Diseases of Pear

Pear scab was severe in some unsprayed orchards, and if the pear increases in commercial importance here, more attention will need to be given to protection against this disease.

Black rot was reported in a few cases on Bosc pears.

Diseases of Peach

Leaf-curl of the peach was not as bad as usual this year. The ordinary dormant spray of lime-sulfur gave practically complete control, but in certain orchards where this application was not given, the disease was severe.

Brown rot of peach (and plum) was generally present although varying in severity in different orchards. In general, severe orchard infection was not apparent, and the ordinary use of sulfur fungicides, either sprays or dusts, gave a good control. But rotting of the fruit in the market due to this disease was often very bad. Brown rot was more severe on early than on late varieties of peaches. In some cases it was very severe on plums.

Miscellaneous Diseases

Downy mildew of grape was more than usually common. If grapes increase in commercial importance in this state, this disease will be one of the principal enemies of the crop. Fortunately, control by copper fungicides is not ordinarily difficult.

Mosaic of raspberry is of general occurrence. Its effects are becoming more conspicuous each year. The most practical action to take against it consists in the purchase of plants known to be free from the disease.

A root-rot of strawberries was rather common on second-year beds in early summer. Various soil fungi were found associated with it, but it is believed that they were only weakly parasitic and that the primary cause was connected with lack of soil moisture.

ORCHARD INSECT PESTS OF 1925

BY A. I. BOURNE

Perhaps the outstanding feature of the first part of the season was the early transition from winter to spring conditions. This was so marked that at the close of March it was estimated we stood fully two weeks in advance of the normal seasonal development. Although this progress was somewhat slowed up by unfavorable weather conditions encountered in April and May, yet this initial advance was not wholly lost throughout the rest of the season. Sensitive as we have found insects to be to varying weather conditions, it was but natural that we should expect them to commence their activities at a correspondingly earlier date. This is what actually happened.

Orchard Plant Lice began hatching during the last week of March, the earliest record since 1921. Reports from all parts of the state showed them present in unusual abundance. In some orchards they were out so early that the dormant oil sprays nearly wiped them out. They remained very abundant until the long-drawn-out period of cold, unfavorable weather the latter part of April, after which they practically disappeared from the orchards. Many growers found so few plant lice that they omitted the nicotine from the pink and calyx sprays. There were occasional small local outbreaks reported late in the season. These were confined chiefly to young trees, and even then were not a serious factor.

Leafhoppers, so prevalent in 1924, were practically absent from orchards this season. In many cases, where a year ago it was possible to find thirty or more young hoppers on a leaf, this season it was almost impossible to find any. In some orchards where for years they have been considered to be one of the worst pests, they were almost entirely absent this season.

One pest which was still rampant, and offers as yet no sign of relief, was the Apple Tent Caterpillar. From all parts of the state, it was reported as at least as abundant as last year. It is certainly true that, from Worcester County west, this insect is still on the increase. While it was in great abundance on roadside trees and on uncared-for apples in pastures, it also had worked into the orchards, and its control often became a real factor to be considered. Careful attention to this pest in the pink spray was found to control it.

The European Red Mite, in the early part of the season, did not appear to be very abundant. The widespread use of oils the previous spring had apparently so reduced it in numbers that many growers did not give it special attention. During the late summer, in the eastern part of the state especially, a rather heavy infestation developed, which increased rapidly so that. by the middle to last of August and into September, considerable bronzing of foliage resulted. This appeared to some extent in other parts of the state, especially where oil sprays had been omitted in the spring. Some growers expressed the opinion that this heavy attack of mites, late in the season, caused an early dropping of fruit.

No reports of any serious abundance of Red Bugs were received, nor did personal visits to the orchards bring to light any cases of severe injury. Apparently, over the state as a whole, it was either considerably below normal in abundance, or else so well controlled by the spray program followed that it was checked almost at the outset.

The Round-headed Apple-tree Borer continued to be a very serious factor especially in some of the orchards in the western part of the state, although found to be present to some extent in orchards in other sections. This insect does not appear to fluctuate as do many of our pests, but holds very regular in abundance year after year. When it offers any real problem, careful and repeated "worming" of the trees over a period of years enables the grower to gradually bring it under control, or at least materially reduce its abundance.

The Apple and Thorn Skeletonizer in its first two broods proved to be slightly less abundant than usual. It has been our experience, in Massachusetts, that the worst trouble has come from the larvae of the brood maturing the last of July and early in August. This season, this brood was much smaller than usual, and little or no injury was noted. The generation of larvae which came to maturity in early September proved, however, to be unusually large, and a considerable amount of late skeletonizing resulted all over the state. Coming so late in the season, this caused very little concern, and few, if any, of the growers deemed control measures to be necessary.

Over the state as a whole, the San José scale appeared to cause little damage. For the last few years, however, complaints of an increasing local abundance have come in from many points in the state. In some orchards it has developed into a real problem for the grower to face. The rapid spread of the Red Mite and consequent increased use of oil sprays in the dormant season have very often automatically solved the problem of the control of this scale. When, as frequently happens, a grower finds scale in any amount on his harvested fruit, he should use prompt measures for control in his orchard. Oyster-shell Scale is very generally present in practically all of our orchards, but seldom, if ever, is found in destructive abundance.

Early indications, borne out as the season developed, were that the Gypsy and Brown Tail Moths, if present at all in the orchards, were in such small numbers that they constituted no real problem for the growers Treatment of the overwintering egg masses of the Gypsy Moth was practically the only real control measure required.

This year the Plum Curculio began to appear in the orchards very close to the time of the calyx application. This was some two weeks earlier than it appeared in 1924. From the first it gave every indication of even greater abundance than in 1924. While in the best cared-for orchards its injury was held within moderate bounds, this insect still stands as one of the most serious of our orchard pests. It occurs with such regularity, year after year, that unless unusually hard hit, the grower has come to take it for granted, and therefore it is difficult to estimate accurately its relative abundance. It is, without any question, everywhere a serious pest; causes a large annual loss to the growers; and as yet is still far beyond successful control.

The Codling Moth was more abundant than usual over the state as a whole. Through the large fruit growing section in the eastern part of the state, it was often reported to have been the worst pest of the season. There was a considerable amount of early "side worm" injury from late hatching larvae of the first brood. In late summer, there was a very general and unusual amount of damage from second brood larvae. A study of the spray program followed by many of the growers showed very clearly that, where the calyx spray is carefully applied, growers are able to eliminate "blossom end" injury almost completely. Where one or two post-calyx applications have been made to cover fruit and foliage at the time the young larvae are hatching and infestation of the fruit taking place, it has been found possible to secure a very large measure of control. This past season an unusually large second brood developed, which caused much late "side worm" trouble. This was undoubtedly due to a very great extent to the fact that the first brood larvae matured and began leaving the fruit to spin cocoons, earlier than usual. Consequently a larger percentage pupated and formed second brood moths. It should be noted that growers who made one or two post-calyx applications of spray or dust, and followed these with an application early in August, suffered very slight loss from "side worms," either early or late. It is increasingly evident that, for the control of this pest, attention to the post-calyx applications is as necessary as to the calyx spray itself.

In late summer there appeared in all parts of the state an unusually heavy attack of the Apple Maggot or Railroad Worm. Others of the northern fruit growing states encountered a similar outbreak. The attack was somewhat uneven in its intensity, although no particular region of the state entirely escaped. It developed to serious proportions rather late in the summer, and, of the chief commercial varieties, the Wealthy appeared to suffer the worst, while McIntosh and even Baldwin in some cases were severely attacked, and one case of severe injury to Ben Davis was reported. This outbreak appeared so suddenly that many growers were unaware of its serious nature until the fruit began to be harvested and moved into the market; one result of which was that the market became rather suspicious, particularly of Wealthies. Whether this insect will be present in such numbers another season, it is impossible at this time to forecast. Growers should keep a sharp lookout in their orchards next season for the appearance of the adults, to determine the danger of attack. Careful disposal of cull fruit after a season of such unusual abundance is particularly stressed, to offer the least opportunity for the concentration of maggots in or near orchards.

The season was not marked by any serious outbreak of what may be classed as lesser fruit pests. Pear Psylla was present to the usual extent, but rarely in serious numbers. The Peach Tree Borer, largely because of the success of the Paradichlorobenzine treatment, has been reduced to a pest of but secondary importance. Fall Webworm was present in about normal abundance. When the fruit came to be harvested and graded, there was found to be an unusual amount of late injury by the Lesser Apple Worm and Red-banded Leaf Roller. This was noticeable on Baldwins especially.

The season was marked, however, by local outbreaks of some insects not usually found in abundance.

Early in the season, from several points in northwestern Worcester County, Climbing Cutworms were found to have been unusually abundant. On young trees especially, their injury was often severe. Young opening buds were devoured by these larvae, which from their habit of feeding at night and hiding by day gave no inkling of their presence until much of their damage was done. Many small, recently set trees were completely denuded of buds; others, not so severely attacked, lost such a proportion of buds that they were able to make but a feeble start, and were checked more or less through the season. Less severely injured trees were usually able to overcome this early setback and make a fairly normal growth. In some cases, not only were the buds completely devoured, but the hungry cutworms gnawed the tender bark just around them, clear in to the wood.

Somewhat later in the season, a few cases were noted of Click Beetles also gouging into buds and opening flowers. This injury, too, was most noticeable on young trees, but in no case as severe as that noted above, caused by Cutworms.

Early in June, reports of an outbreak of Pear Midge were received from points in Plymouth and Barnstable counties. As far as could be learned, this was not general, but was confined to local outbreaks in that region. Where the pest was reported, however, it was found to be causing severe damage. In some cases, over 50 per cent of the crop was estimated to have been attacked. Clapp's Favorite and Beurre Bosc were the two varieties specifically mentioned as being the most severely infested.

During late September and early October, there was discovered some injury to fruit caused by the so-called Dock False Worm. In one orchard, at least, larvae of this Sawfly were found to have bored into the fruit in considerable numbers. This was noted especially on Baldwins. Through the summer this insect feeds mainly on species of dock, sorrel, etc., and attacks fruit only in the fall when it seeks quarters for hibernation. The larvae bore into the fruit, making small round holes which soon show a slightly sunken, discolored ring on the surface of the apple. Inside the fruit these burrows run well toward the core, usually enlarged slightly toward the inner end where the small, light green larvae may be found. These entrance holes in the apples, while somewhat larger than those made by the Codling Moth, are probably often mistaken for those of that insect. As this insect is primarily a pest on different varieties of weeds, clean culture is obviously the best protection against it. In all probability this insect will seldom, if ever, become a serious pest in orchards. It is well for the grower, however, to be aware of its presence.

Taking the season as a whole, without any question the fruit growers' main troubles were caused by mid-season and late Codling Moth injury, the Plum Curculio and the Railroad Worm. Some of the pests commonly found in abundance were this season practically absent. On the other hand, one or two species, not usually found in numbers enough to warrant any attention from the growers, were encountered in considerable local abundance.

A survey of insect conditions made in the main fruit growing section of the state brought out very clearly the emphasis which should be given to careful and properly timed spraying. In spite of the diversity of insect attack which fruit growers encountered, it is significant that those who gave closest attention to spray or dust applications reported their orchards and fruit remarkably free from injury by insects. This was most noticeably true of those who gave particular attention to the post-calyx and mid-season applications.

PRUNING YOUNG APPLE TREES

BY J. K. SHAW

In the spring of 1916 an orchard of 600 one-year-old trees of Baldwin, Northern Spy, Rhode Island Greening, McIntosh and King were set ten feet apart, for an experiment in pruning with especial reference to head formation. Six different methods of pruning were arbitrarily chosen and consistently followed for a period of nine years. It is the purpose of this paper to present some of the conclusions reached from this experiment, that may be of value to the fruit grower. A more detailed report of the technical aspects of the experiment is in preparation.

The pruning methods chosen were as follows:—

1. The whips to be cut back at planting and the new growth cut back about one-half, the cutting back to be less severe in succeeding years. They were to be thinned out each year the same as the other types of pruning. The purpose was to produce a globular shaped tree, headed back annually.

2. Trees to be cut back at planting as in 1, and to be thinned out the same but not headed back. The purpose was to produce a globular headed tree not cut back.

3. The trees to grow without any pruning whatever except the removal of suckers and water sprouts.

4. The trees to be set without cutting back and the leader allowed to grow to a height of 7 to 8 feet and then suppressed if necessary. They were to be thinned out annually the same as the other types of pruning. The purpose was to produce a modified leader tree.

5. The trees to be set without cutting back, but to have all shoots except the leader headed back in later years, but a little less severely than the cut-back globular trees. The purpose was to produce a central leader tree.

6. The trees to be pruned as in 5, but without cutting back. The purpose was to produce a central leader tree without cutting back.

All trees except the unpruned were to be thinned out to about the same density, and two of the lots were to have the new growth cut back each year.

These five types of pruning were expected to produce, more or less successfully, three types of trees:—the globular headed tree generally preferred in Massachusetts, the modified leader type, and the central leader type. In 1922 when the type of tree was pretty well fixed, an estimate of the degree of success reached in securing these types was made, and the results are shown in Table 1.

Table 1. Degree of success in attaining the expected type of tree.

(Number of trees)

	Failure	Rather Unsuccessful	Fairly Successful	Successful	Highly Successful
Globular cut back....	0	0	5	26	68
Globular not cut back.	0	0	6	29	64
Modified leader.......	0	4	17	32	45
Central leader cut back	16	14	19	19	29
Central leader not cut back	24	23	26	17	10

This classification is, of course, wholly arbitrary and another observer might have classified them somewhat differently. Certain generalizations may, however, be quite safely made. It is evident that the globular headed tree may be more certainly secured than the central leader type and that cutting back the branches helps to produce a leader tree. The trees classed as failures were well formed trees and not by any means failures as orchard trees, but they did not have in any degree a dominant central leader. There was some difference in the five varieties used. Spy and McIntosh were rather more tractable than the other varieties, partly owing to winter-killing in the severe winter of 1917-18 which injured many Baldwins and Rhode Island Greenings and a few Kings. Several trees among the Baldwins, Spies and Kings were killed back to the snow line or severely checked by killing the wood while the bark and outer thin shell of wood remained alive. This doubtless interfered with the rise of water and checked growth for a year or two. Where they were killed back to the snow line a strong shoot arose in many cases and a good leader tree resulted.

The unpruned trees generally assumed a modified leader type and have naturally developed rather thick tops with many branches coming out of the central trunk.

Cutting back young trees is generally advocated, one object being to secure low headed trees. In 1919 measurements were made of the height of the lowest branches on these trees. The maximum difference between the average of trees cut back at planting and those not cut back was only about seven inches, a difference that is of no significance in mature trees

An argument for cutting back frequently advanced is that it makes the tree, including the cut back branches, more stocky. It is now generally recognized that any increase in stockiness arises from shortening the branch and not from increased diameter. In the fall of 1923 the four largest branches on each tree of the Baldwins, Rhode Island Greenings and McIntosh trees were measured four inches from the trunk. The relative size of these branches is shown in Table 2, the unpruned trees being taken as 100.

TABLE 2. Relative size of branches of trees receiving different types of pruning.

	Baldwin	Rhode Isl'd Greening	McIntosh	Average
Unpruned	100	100	100	100
Globular cut back	121	123	139	128
Globular not cut back	144	131	139	138
Modified leader	114	103	118	112
Leader cut back	114	91	108	104
Leader not cut back	128	126	113	122

It will be seen that cutting back the side branches has not increased their diameter; but on the contrary, in all except the McIntosh, they are smaller on the cut back trees. The principal factor governing the size of the main branches is their number. The fewer branches there are the larger the four principal branches may grow; that is why all the pruned trees (except the cut back leader Rhode Island Greening) have larger main branches than the unpruned trees. It also explains why the four largest branches on the globular trees are larger than those on the leader trees; there are fewer additional smaller branches to compete.

After the growing season of 1924, when the trees had completed nine seasons growth, the height and spread of the trees were measured, and the average of all varieties for the several methods of pruning is shown in Table 3.

TABLE 3. Average size of trees at nine years old (feet).

	Height	Spread
Globular cut back	15.0	11.8
Globular not cut back	16.1	14.8
Unpruned	16.7	14.7
Modified leader	16.7	15.1
Leader cut back	17.0	12.4
Leader not cut back	16.9	15.5

This table shows that the leader trees are only a little taller than the globular trees. It is perhaps true that there will be more difference when the trees come in bearing, for the scaffold limbs of the globular headed trees may bend down with loads of fruit.

Cutting back the globular headed trees has made them a little shorter and both these and the cut back leader trees have less spread than the trees not cut back. It is now generally considered that pruning dwarfs trees, but these figures indicate that the rather light pruning practiced here has not dwarfed the trees much except where cutting back was practiced. Thinning out the top leaves the remaining foliage better exposed to the light and this may compensate for the reduction in leaf area from pruning.

The practice of cutting back new shoots annually on young trees was formerly quite generally advocated for young trees. Our experience with this orchard would lead us to avoid cutting back except where it is desired to dwarf one or more branches so that they will not outgrow other parts of the tree.

BLOOM AND YIELD

This orchard has not produced much fruit. None has been borne by the Northern Spy trees, and product of the Kings is negligible. The first crop of the other varieties was in 1922 and there has been a light to moderate crop each year since. The McIntosh trees have naturally borne the most, averaging over 4½ bushels per tree for the four years total crop. The average percentage of bloom and the total yield per tree is shown in Table 4. The most significant fact brought out is the effect of annual cutting back. It has decreased bloom in every case and decreased yield in all cases except the globular McIntosh. Probably the differences between the different types of pruning, not involving cutting back, and including the unpruned trees, are of no great significance. While the tops of the unpruned trees are pretty thick, no marked inferiority of the fruit in either size, color or quality has yet appeared.

The one-year whips set without cutting back made a very poor growth the first season. Most of them sent out two or three side branches not over a foot long. The second year these trees sent out additional branches, and, had it not been for the limitation imposed by the plan of the experiment, might all have been developed into strong well formed trees. Indeed, they are more satisfactory than are many commercial orchards.

TABLE 4. Bloom and yield, 1922-25 inclusive.

	Average percentage of bloom			Total yield, pounds per tree			
	Baldwin	R. I. Greening	McIntosh	Baldwin	R. I. Greening	McIntosh	Total, all varieties
Unpruned	4	13	29	48	55	197	300
Globular cut back	1	10	13	17	34	160	211
Globular not cut back	2	17	21	42	51	141	234
Modified leader	4	18	31	41	52	256	349
Leader cut back	1	16	18	9	32	140	181
Leader not cut back	2	24	28	32	34	223	289

The trees cut back at setting sent out three or four strong shoots. Generally one of these might have been developed as a leader had the plan of the experiment allowed. It is felt that a one-year tree may be cut back at planting or not as the planter desires, but if cut back at setting one shoot should be chosen and maintained as a leader for a few following years. In order to do this the other branches will require cutting back. If it is not cut back, growing conditions must be favorable and one should not be discouraged if rather poor growth is made the first season; it may be expected to be as large as, or larger than a cut back tree after two or three years.

During the three or four years while the leader is developing, several permanent scaffold branches should be selected. These may well be a foot apart even if on opposite sides of the trunk, for if too close they will check the growth of the leader. Not more than two or three satisfactory candidates for main scaffold branches can be expected during the first season of growth.

These scaffold branches should not be cut back except as necessary to keep them about the same size. To insure this equality will require some pruning, especially of the older, lower branches. Cutting back will be more effective than thinning out where it is desired to hold back a branch. It will be generally understood that these main branches should be well distributed around the tree as well as along the leader, in order to produce a tree equally developed on all sides.

The remaining branches not desired for permanent scaffold limbs may be cut out where they are too plentiful or cut back if necessary to keep them smaller than the permanent branches. They may then contribute to the growth of the tree and some of them may serve for a few years as fruiting branches, being removed when the growth from the permanent scaffold branches weakens them by stronger growth and consequent shading.

It is probably safe to urge that as little pruning as possible be given the growing tree and that only for the purpose of directing growth. We cannot in any practical way stimulate the growth of one part of the tree beyond the rest. The only way to keep the various parts of the tree symmetrical is to prune the part that is growing too fast. Probably cutting back is more effective than thinning out, when one is forced to check the growth of a branch that is outgrowing its neighbors.

Always one must prevent the development of equal forks. By this is meant forks of two or more branches of approximately equal size. Such unfortunate conditions are frequently found where a young tree is cut back at planting and the several branches that arise from the shortened trunk are allowed to develop equally. Sooner or later one or more of these branches splits off with a load of fruit, seriously damaging the tree. This condition is prevented if the side branches are kept subordinate to the leader by pruning or perhaps removing some of them. Similarly one must deal with equal forks wherever they appear in the tree. One branch should be cut back severely or entirely removed, and the earlier it is done the better.

EFFECT OF THE STOCK ON THE SCION

By J. S. BAILEY

The variability of seedling root stocks for the apple and the desirability of having trees propagated on vigorous roots have been recognized for years. But not until recently has experimental work been started to seek out desirable root stocks and practical methods of propagating them.

This is a report of progress of work being done at the Massachusetts Agricultural Experiment Station to ascertain the effect of several stocks on various scions and to find a hardy, vigorous, uniform stock suitable to be used in the propagation of our common commercial varieties.

To show the extreme variability in yield of apple trees propagated on seedling stocks, the following data have been taken from reports of the Pennsylvania and West Virginia Experiment Stations. Table 1 gives the total yield in bushels from 1908-1918 of individual trees in a York orchard planted in 1888 in Pennsylvania. The orchard was in sod and the trees whose yields are included in the table were all treated alike and had no fertilizer. The arrangement of the figures in the table corresponds to the location of the trees in the orchard.

TABLE 1

13 bu.	4 bu.	16 bu.	5 bu.		7 bu.	
24		41		50 bu.		35 bu.
41	34		20	30		
31		49	37	25	17	
15	25		14	17		

Some Grimes trees in a West Virginia orchard show even more striking contrasts. Of two trees growing side by side and getting exactly the same treatment, one yielded a total of 36 bushels and the other 3 pounds for a ten-year period. Still another pair yielded 38 bushels and 2 bushels for the ten-year period.

The Maine Experiment Station has concluded from data collected over a long period of years that in any one year 35 per cent of the variation in yield is due to seedling stocks and 65 per cent to soil differences.

With the object of eliminating the 35 per cent of variation due to seedling stocks, the Massachusetts Experiment Station started in 1912 an experiment to grow a number of varieties on known roots. That is, trees were started on seedling roots and after roots had been sent out from the scion, the seedling roots were cut off. These scion rooted trees were then used as the stocks in this experiment.

After the stocks had been obtained the orchard now known as the Root and Scion Orchard was planted in 1915. This orchard consists of over 1100 trees. The main part of the orchard, 685 trees, consists of the following top and root varieties:

Top Varieties	Root Varieties
Red Astrachan	Own rooted
McIntosh	Ben Davis
Yellow Transparent	Bough (Sweet)
Baldwin	Northern Spy
Wagener	Red Astrachan
Tolman	Wagener
	Wealthy
	Oldenburg (Duchess)
	Yellow Transparent
	English Paradise

The balance of the orchard consists of various other varieties on a number of different stocks.

The growth of the trees has already given us some striking results. Figure 1 shows the average trunk diameter in 1924 of the six main varieties on ten different stocks.

The first thing noticeable in this figure is the larger growth of the own rooted trees of the more vigorous varieties,—Red Astrachan, McIntosh and Baldwin. Special attention is called to McIntosh on its own roots, which is much superior to McIntosh on any other root. See Fig. 3, Plate I.

In contrast to the good growth of the own rooted trees, notice the very poor growth of all varieties on Oldenburg roots. This poor growth has been consistent throughout the experiment. It is probably due almost entirely to a lack of vigor of the stock although incompatibility of stock and scion may have had some influence also. Fig. 4, Plate I, shows a McIntosh tree on Oldenburg roots. Compare this with Fig. 3, Plate I.

The Northern Spy has always been considered a desirable stock in this country where it has been grown on seedling roots and then used for top-working. In South Africa and Australia where it has been used as a root stock to resist the attacks of woolly aphis, it is considered a dwarfing stock. In Fig. 1 it shows up as being fairly vigorous. Trees on this stock grew much more vigorously in 1923 and 1924 than previously. The weak growth of trees on Northern Spy during the first few years was probably due to Hairy Root, a form of Crown Gall with which most Northern Spy stock was infected. It is probable that the Northern Spy is a vigorous stock after it has grown sufficiently to overcome the effects of Hairy Root.

Crown Gall is not confined to the Spy stocks. Most of the others are infected more or less with some form of it. Data will be collected later to determine how much it has affected the results.

The Bough stocks show up in Fig. 1 rather better than the Northern Spy stocks. This difference will probably be reversed in the next few years, as the Bough stocks have behaved just the reverse of the Northern Spy. They were the easiest to root of any of the stocks and grew so well the first few years that they got a big start over most of the others. But the past two or three years the trees on Bough stocks have been slowing down in their growth as compared with those on most of the other stocks.

Tolman trees on their own roots are really not as poor, after they get

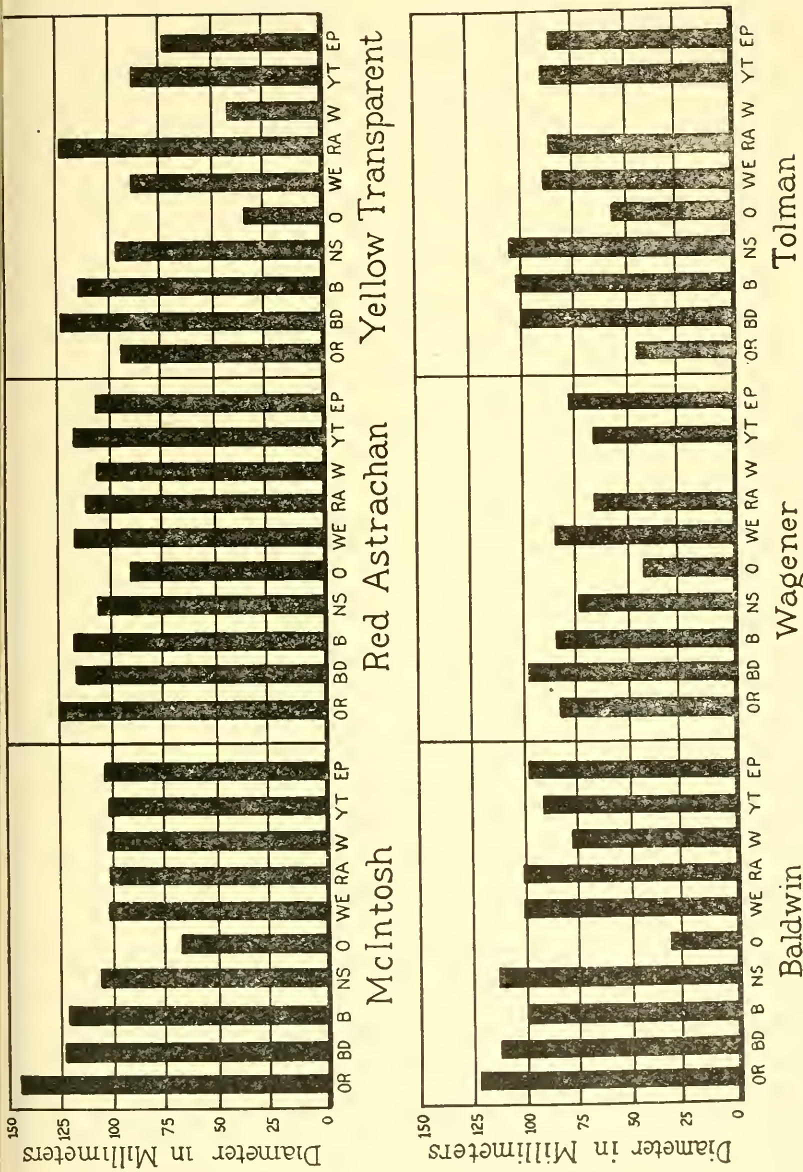

FIG. 1. Average trunk diameter in millimeters of the six top varieties on the several stocks—1921.

O. R. Own rooted
B. D. Ben Davis
N. S. Northern Spy
O. Oldenburg
B. Bough
R. A. Red Astrachan
W. Wagener
WE. Wealthy
Y. T. Yellow Transparent
E. P. English Paradise

started, as Fig. 1 indicates; for during the years 1923 and 1924 they made more growth than Tolman trees on any other roots. The difficulty lies in getting the Tolman roots started. This was the hardest of any of the varieties to root from the scion, and therefore was under a great handicap when the trees were set.

The English Paradise stocks have not done as well as Fig. 1 indicates. They made a fairly rapid growth at the start but slowed down very noticeably during 1923 and 1924. The tops are small and in some cases, such as with Tolman, show a very characteristic shape. (See Fig. 5, Plate II.) Notice the flat spreading character of the top. Compare this with the upright growth of Yellow Transparent on the same stock (Fig. 6, Plate II.)

In regard to the effect of the different stocks on bearing, no conclusions can be drawn at the present time as the trees have not borne enough crops to determine what their actual performance will be. Figure 2 shows the average total yield for the years 1922, 1923, and 1924.

This figure shows four things in regard to earliness of bearing. First, the dwarfing stock, English Paradise, brought most of the varieties into earlier fruiting than any of the other stocks. Second, Oldenburg stocks have not brought any of the varieties into early bearing. This is because the tendency toward late bearing, due to lack of vigor, completely outweighs the tendency toward early bearing, due to the dwarfing effect. Third, McIntosh on its own roots has borne earlier than McIntosh on any other root. This is due to the exceeding vigor of the McIntosh roots which have brought the tree to bearing maturity more quickly than any other roots. Fourth, the Northern Spy root has had the effect of a dwarfing stock on McIntosh and brought it into early bearing. As has already been pointed out, the growth records show that this dwarfing effect is not permanent.

From this work it is concluded that the effect of the stock on the vigor of the scion depends on (1) the vigor of the stock; (2) the readiness of rooting of the stock, though this is only temporary; and (3) "the degree of success of union between the stock and scions."

It follows, then, that a uniform vigorous hardy stock which can be propagated by vegetative means is needed to replace the seedling stock now in use for the propagation of apple trees. This problem has been taken up by the United States Department of Agriculture and the Pennsylvania Experiment Station, as well as by the Massachusetts Experiment Station.

In the spring of 1924 this Station imported from the experiment station at East Malling, England, 800 stocks of 17 types. These types had been selected from apple stocks commonly grown on the European continent. They range from very dwarfing stocks to free growing standard stocks, all of which, it is said, can be vegetatively propagated by means of mound layers. Some of these imported stocks were used for increasing the supply, and others were budded to McIntosh and Wealthy in August, 1924. It is hoped that among these stocks one or more will be found which fills the requirements of a good stock.

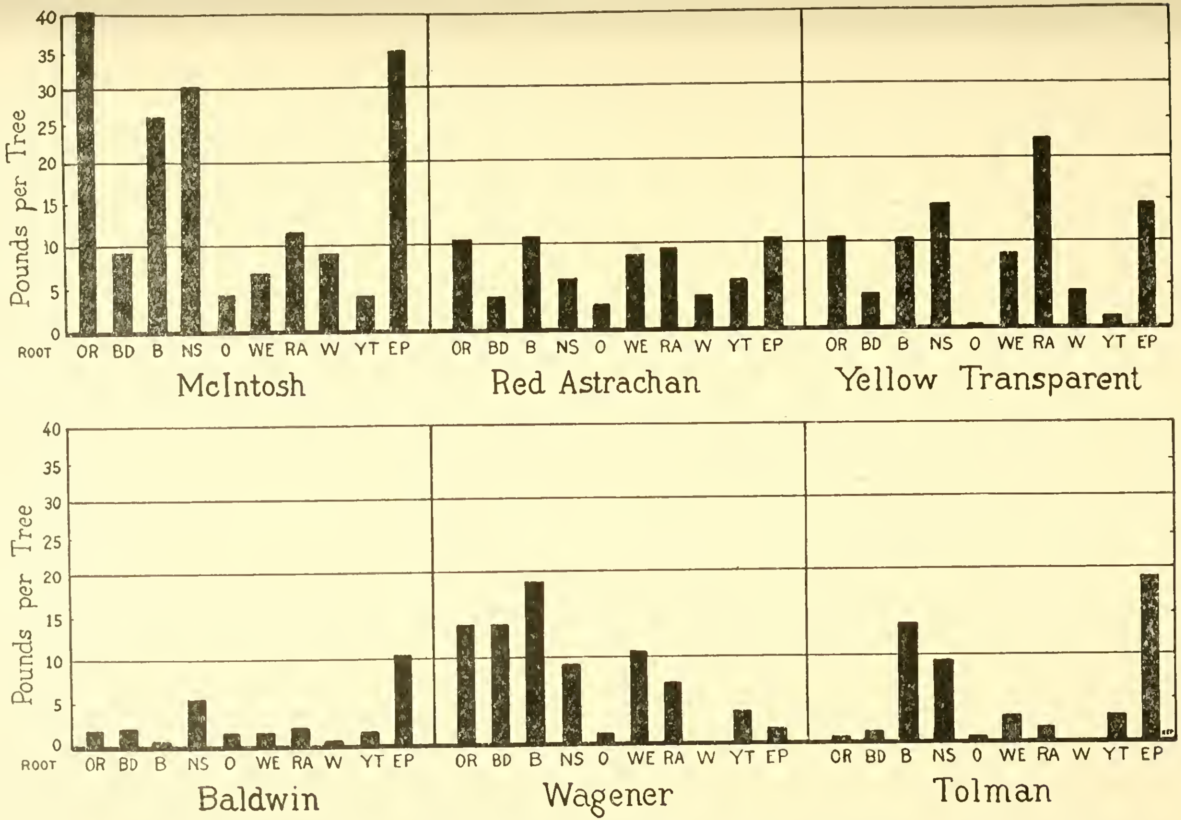

FIG. 2. Average total yield in pounds of the six top varieties on the several stocks—1922-1924, inclusive.

O. R.	Own rooted	N. S.	Northern Spy	R. A.	Red Astrachan	Y. T.	Yellow Transparent
B. D.	Ben Davis	O.	Oldenburg	W.	Wagener	E. P.	English Paradise
B.	Bough	WE.	Wealthy				

THE PROGRESS OF NURSERY TREE CERTIFICATION

BY J. K. SHAW

The certification of varieties of fruit trees for trueness to name rests on the possibility of recognizing varieties by the trees in the nursery row. That varieties could be so recognized has long been more or less well known to nurserymen.

Special studies of varieties of apple trees were begun at this station about 1912, in connection with the project for the study of the Interrelation of Stock and Scion in Apples. By 1920 the writer had become convinced that it was possible to detect misnamed trees in the nursery row with practical certainty. In June, 1921, a meeting was called to consider the possibility of certifying nursery trees and thus minimize or eliminate the misnamed tree that had been a source of considerable loss to fruit growers of Massachusetts and other states, also to nurserymen and tree dealers. At this meeting were representatives of the Department of Pomology of the College and Station, the State Department of Agriculture and the Massachusetts Fruit Growers' Association. The possibilities of certification were discussed and a tentative plan of operations outlined. At a meeting held at Amherst in August, 1921, the Massachusetts Fruit Growers' Association voted to sponsor this plan, and it was first put in operation in September, 1921, and has been continued on a constantly enlarging scale each succeeding year.

For the first two years, work was done in Massachusetts nurseries only. It soon appeared that little progress could be made unless the work was extended to nurseries outside the state, because only an insignificant portion of the trees planted in the state are grown here. Consequently arrangements were made in 1923 to certify trees for a western New York firm that sells a considerable number of trees to Massachusetts growers. In order to avoid a possible charge of favoring any particular nurserymen, certification was offered in 1924 to any nursery desiring it, and this policy has since been followed. The following table shows the development of the work:

Year	Number of Firms	Number of Trees Certified	Number of Trees Refused Certification
1921	1	2580	267
1922	2	8437	435
1923	3	65910	905
1924	6	125609	3505
1925	13	166810	9250
Totals		369346	14362

The nursery firms now cooperating in the certification work sell a large proportion of the trees bought by Massachusetts growers. It is therefore possible for any grower in the state to buy trees with this increased assurance of their being true to name. Too much stress should not be laid on the number of trees refused certification. While it is certain that practically every one of these was not true to the nursery record or label, many of them were known to the nurserymen and would not have been sold under wrong names; in most cases, however, it was a surprise to the nurserymen to learn of these misnamed trees. On the

PLATE I.

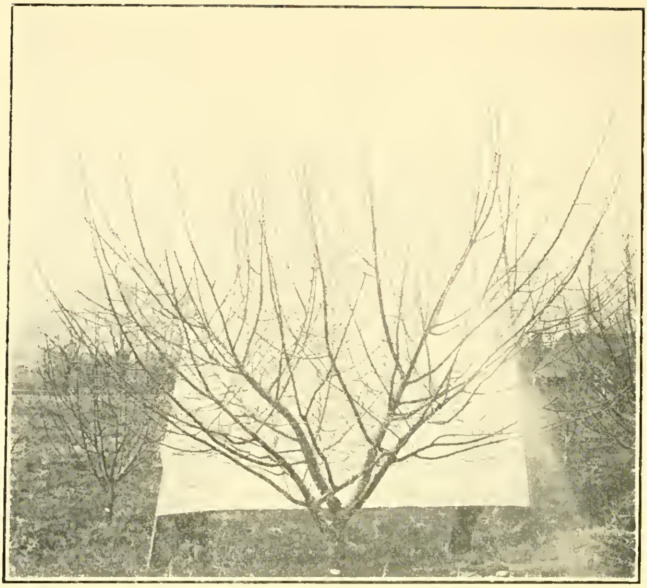

FIG. 3. McIntosh on its own roots.

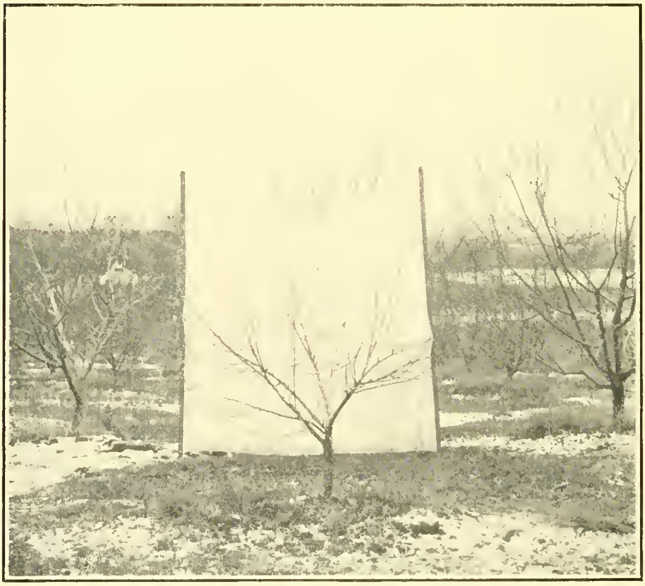

FIG. 4. McIntosh on Oldenburg roots.

(Figures 3 and 4 are on approximately the same scale. The apparent difference in the size of the screen is due to the fact that in Figure 4 the screen was held considerably farther from the tree than in Figure 3.)

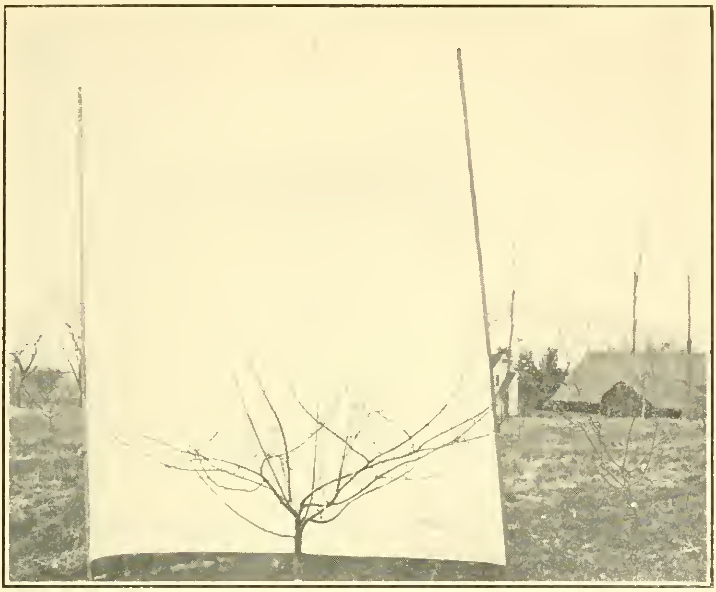

Fig. 5. Tolman on English Paradise roots.

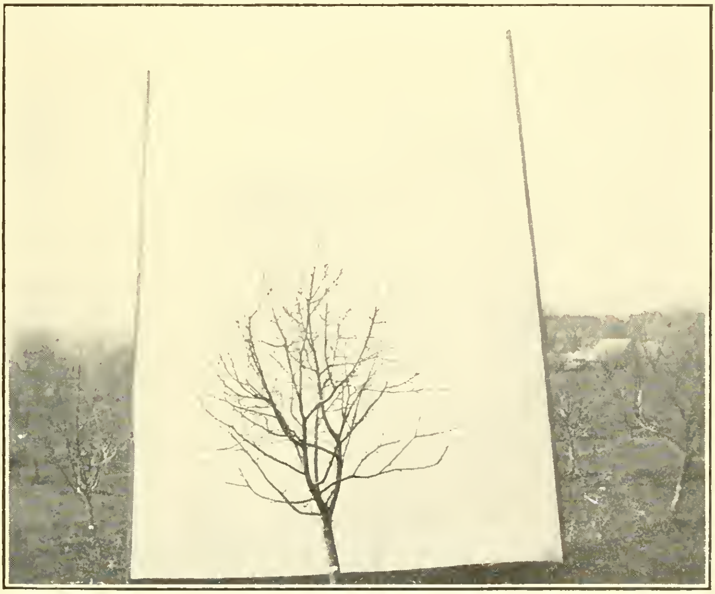

Fig 6. Yellow Transparent on English Paradise roots.

other hand, we have no means of knowing how many mistakes may be made in digging and shipping the trees. Such errors are absolutely eliminated with certified trees. Many more trees have been examined than certified and the misnamed trees among these are included in the above table.

Certification is carried on by the Massachusetts Fruit Growers' Association. The Experiment Station has no official connection with it though it has given moral support and cooperation. Any nurseryman desiring certification may apply to the Association and an agent qualified to distinguish varieties visits the nursery during the late summer or early fall and personally examines the trees. To such as are found to be true to name a lead seal is attached by drilling a one-sixteenth inch hole through a branch, or in case of one-year trees through the trunk. The name of the variety (usually in abbreviated form), the word "certified" and on the reverse side the letters "M. F. G. A." and the year in which the work was done are stamped on the seal with a hand seal press. *All trees certified by the Massachusetts Fruit Growers' Association bear this lead seal.* The work of attaching seals is done by employees of the nursery, working in gangs of four. One gang will seal from 2,000 to 4,000 trees per day. The cost of the work is met by the nurserymen. It has varied greatly with conditions, but with the larger jobs has probably been from $18 to $25 per thousand trees certified, including the cost of attaching seals.

For the first two years only two-year apple trees were certified but later one-year trees were included. The number of varieties has gradually increased until now nearly forty are included. Pear and plum varieties were taken on in 1925 though only a few trees were certified.

All nurseries examined thus far have contained trees not true to name, but the proportion has varied from less than 1 per cent to more than 10 per cent. As the work in any one nursery continues the number of misnamed trees naturally decreases, but new mixtures may appear from year to year.

This plan of certifying trees to be true to name is not infallible. It depends upon the human eye and brain and they are not perfect. The chances of error are, however, slight and it is confidently believed that the number of errors made is insignificant. No such cases have yet been brought to the attention of the Association. Variety certification is in operation in Canada and in California and is under consideration in other states. It is believed that it is the best plan of eliminating the misnamed tree yet brought forward. Every nursery firm starting the work has continued it in succeeding years.

THE CODLING MOTH IN MASSACHUSETTS

BY A. I. BOURNE

The codling moth is one of the worst insect pests with which orchardists of Massachusetts have to contend. In spite of thorough and careful spraying, the annual loss from its ravages continues very high.

The life history of the codling moth in Massachusetts has been approximately known for years, and general methods for its control practiced; yet fruit growers have been annually confronted with very considerable losses which have come mainly from so-called "side worm" injury. Such a condition of affairs led the Station to engage in a study of the insect, with particular reference to determining the proper timing of the "cover" sprays following the calyx spray.

It was at first supposed that this "side worm" injury was due almost altogether, if not entirely, to second brood larvae. Consequently attention was at first directed toward determining the approximate date when this brood appeared, and also its relative size and importance. As the project developed, it became evident that a more accurate knowledge of the entire life history of the insect was necessary, if a satisfactory solution of the problem was to be reached. Beginning with 1923, therefore, the complete seasonal history of the insect has been followed. Some of the more important events in the life history of the insect, as recorded for the three seasons, are summarized in the following table:—

TABLE 1. Development of the Coddling Moth, as recorded in 1923, '24 and '25.

	1923	1924	1925
Beginning of spring pupation	May 3	May 3	April 24
Date of last pupation	June 26	July 11	June 20
Duration of pupa stage	8-24 days	12-23 days	8-24 days
Emergence of first moths	May 27	May 24	May 12
First period of maximum emergence	June 2-4	May 26-30	May 16-18
Second period of maximum emergence	June 20-24	June 22 27	June 3-9
Date of last emergence	July 2	July 24	July 3
Duration of egg stage	5-10 days	4-12 days	4-11 days
Emergence of second brood moths	July 20-Aug. 29	July 21-Sept. 2	July 11-Aug. 28
Period of greater emergence	Aug. 3-6	Aug. 4-9	July 31-Aug. 12
Appearance of second brood larvae	Aug. 1-Sept. 6	Aug. 2-Sept. 17	July 24-Sept. 12

Comparison of the dates of the development of the insect, as shown in Table 1, with the seasonal development of the apple during the three-year period is noted below:—

TABLE 2. Comparison of the seasonal development of the apple with that of the codling moth.

APPLE DEVELOPMENT	CODLING MOTH DEVELOPMENT
Blossom buds showing pink	Beginning of pupation
Pre-pink spray	———
———	Moths appearing (1-6 days before calyx spray)
Calyx spray	First period of maximum appearance of moth
3-4 weeks later (2-3 weeks in 1925)	Second period of maximum emergence of moth

In general the weather conditions prevailing during 1923 and 1924 were very similar, particularly as regards the frequently recurring periods of cold and unfavorable weather in May. These retarded the normal advance of the season and caused a corresponding slowing up of development on the part of the codling moth. In 1925 insect activities commenced fully a week to ten days earlier than in the two previous years, and held this advantage throughout most of the season. This difference is reflected in Table 1 above, where it will be noted that the dates of various steps in seasonal development of the insect for 1923 and 1924 were nearly the same, while in 1925 they were about ten days earlier. It naturally followed that first brood larvae began to mature and leave the fruit that much earlier than usual, so that a larger proportion formed pupae and emerged as second brood moths.

During the last three years it has been possible to follow the seasonal development of the insect in the eastern part of the state, through the assistance of Mr. A. N. Calkins of Harvard. Thus far there has been found to be very slight difference between the two points, a matter of two or three days in either direction being the most thus far noted.

In a survey of the results to date, certain outstanding facts are significant. There have been, each year, two widely separated and distinct periods of abundance in the emergence of first brood moths. The first coincides very closely with the time of the calyx application. By careful spraying at this period, growers have been able to practically eliminate "blossom end" injury, and cut down very largely the danger of a serious second brood.

In the last three seasons there has been a second great peak of abundance which, from our records, may contain the greater part of the total emergence. This second peak in 1923 and 1924 occurred three or four weeks after the first. In 1925 the period was shortened by the extremely hot weather early in June. The main damage caused by the codling moth at the present time appears to be largely due to this irregularity in the emergence of moths and consequent long-drawn-out appearance of first brood larvae. This causes the early "side worm" injury which has been so prevalent in late years.

It is clear that any spray to be effective under such conditions must be timed so as to kill a maximum number of larvae before they enter the apple, and emphasizes the need of the cover or post-calyx spray. This needs to be applied very thoroughly since we have found that young larvae, on their way to enter the fruit, will feed to some extent on the foliage. In the years 1923 and 1924, this would have properly been applied about four weeks after the calyx spray. In 1925, due to the speeding up of development from the hot week in June, this spray would have been timed about three weeks after the calyx spray. It is worthy of note that those growers who sprayed during or just after that week reported very clean fruit in those blocks treated.

As our knowledge of the habits of this insect develops, more than one spray during this period may be found advisable, to give continuous protection during the long period over which infestation of fruit may take place. A survey of some orchards in the main fruit growing sections of the state brought out the fact that growers who made two or more applications of either spray or dust at two-weeks intervals after the calyx application reported early "side worm" injury almost negligible.

Growers have come to believe that the calyx and one or two cover sprays after the calyx will so control the pest that the probability of a serious second brood can be ignored. Ordinarily this may prove true. In 1925, however, there developed a comparatively large second brood, throughout the state, with a serious amount of late "side worm" injury, due very largely to the reasons mentioned earlier in this paper.

From the data at hand, this second brood appears at about the same period every year, regardless of whether the season has been "early" or not. If the grower depends on a single application aimed to control the pest at this stage, dusting or spraying early in August would appear to give him best results. Some growers this season made an application at this time, and succeeded in reducing late "side worm" injury in those blocks very successfully.

For successful control of this pest, from our present knowledge of its life history and habits, certain steps are essential:—

1. A thorough application of the calyx spray. This is very important. Upon it depends freedom from "blossom end" injury, and lessening the danger of a large second brood.

2. The cover or post-calyx spray is almost equally important. It demands even more care from the grower as to the proper time of application. Upon this depends protection over the long period during which larvae are appearing, and relief from early "side worm" injury.

The exact date for this spray, and the number of applications that may be necessary cannot be stated absolutely. These must be determined each season, as they are governed largely by weather conditions From the experience we now have, two applications at intervals of two weeks after the calyx spray have given excellent results. A third application may be advisable should the season be unusually "early."

3. If the season is "early," there will be the probability of a large second brood. The bulk of this brood apparently comes about the first of August each year, whatever the type of season up to that time. With a brood of such size as that of 1925, a special application in early August is necessary to avoid serious late "side worm" injury.

TESTS OF LIME-SULFUR SOLUTION AND SOME OF ITS SUBSTITUTES AGAINST SAN JOSÉ SCALE

BY A. I. BOURNE

While under eastern conditions, at least, lime-sulfur solution has long been recognized as the standard dormant spray for the control of San José scale, yet fruit growers are much interested in the various dry powders now offered as substitutes for the concentrated solution. Transportation charges are less, there is no danger of freezing and no loss from leakage. Used in strengths recommended, these dry powders furnish less polysulfide sulfur than does the concentrated liquid used at standard dilution of one part to eight parts of water.

This situation led the Experiment Station to undertake a test of these different materials with the purpose of finding whether the dry materials are effective, and how dilute the liquid concentrate may be used and still be effective, for scale control.

All the materials used in the tests were of standard brands purchased in the open market. A chemical analysis of each brand was made, as shown in Table 1.

TABLE 1. Polysulfide sulfur and free sulfur in the materials tested.

	Polysulfide Sulfur, Per cent.	Free or Inert Sulfur, Per cent.
Lime-sulfur solution (33°+Beaume)	25+	—
Dry lime-sulfur	55+	6
Sodium sulfur compound	41+	3
Barium sulfur compound	21+	15

The materials were used at the strengths recommended by the manufacturers for scale control, and printed on the label or the container;

and were applied in liberal amounts to insure a thorough covering of all parts of the trees.

The materials were applied each year as "delayed dormant" sprays, and results were determined by microscopic examination of sprayed and unsprayed trees, the number of dead and living scales present being recorded. Counts were made a few weeks after the sprays were applied, but well before the time of appearance of the crawling young. During the course of the tests more than 10,000 scales were counted, this being the basis upon which conclusions were drawn as to the effectiveness of the different materials and dilutions.

Preliminary tests the first season indicated conclusively that dilutions of the liquid concentrate of 1 : 16 or beyond would not give satisfactory control of the scale. Further tests at or beyond this dilution were therefore omitted. The results of the three seasons' tests are summarized as follows:

Table 2. Results of tests with various sulfur sprays for the control of San José scale.

		Scale dead, Per cent.
Lime-sulfur solution	1 : 8	97
	1 : 9	97
	1 :10	97
	1 :11	95
	1 :12	94-95
	1 :14	86-87
Dry lime-sulfur		93
Sodium sulfur compound		92-93
Barium sulfur compound		90-91
Unsprayed check		74-75

It was noted, during the three seasons, that there was considerable variation in the percentage of scale which lived through the winter. This ranged from about 21 to 28 per cent, and seemed closely associated with the type of winter experienced. For the three-year period, the average winter mortality was close to 75 per cent, which figure is doubtless about what we may expect to occur under Massachusetts conditions.

This difference in the percentage of scales which died during the winter caused some variation in the estimates of relative efficiency of the sprays, from one year to another. Over the entire period, the relative control value of the different sprays as compared with the untreated checks i shown in the following table:

Table 3. Relative control value of the different sprays.

		Effective Control, Per cent.
Lime-sulfur solution	1: 8	88
	1: 9	88
	1:10	88
	1:11	80
	1:12	80—
	1:14	50+

Dry lime-sulfur	72
Sodium sulfur compound	70-72
Barium sulfur compound	60-64

From the above, it is evident that in these tests the liquid lime-sulfur concentrate diluted 1:10 proved equally effective to the 1:8 strength. There was a distinct falling off with the 1:11 and 1:12 strengths, and a sharp decline in killing efficiency at the 1:14 dilution. The dry lime-sulfur and sodium sulfur compound proved about equally effective, but did not give quite as good a kill as the 1:12 dilution of the concentrate. The barium sulfur compound fell considerably below the two others in killing efficiency, and proved but little better than the concentrate at 1:14.

In no case did any of the dry sulfides equal the concentrated lime-sulfur solution, 1:8 or even 1:12, in killing the scale. It is evident, therefore, that the dry materials must be used at strengths higher than those recommended, to bring their killing efficiency up to that of lime-sulfur solution. There are two drawbacks to any such plan:

1. Any material increase in dosage will bring the cost of the dry materials to a very high figure as compared to that of the lime-sulfur solution.

2. There is experimental data to show that the efficiency of the dry materials increases as the dosage grows higher, only up to a certain point. Beyond this, the accumulation of insoluble matter is so great as to offer difficulties in application. Straining out this insoluble matter would doubtless relieve this difficulty, but would require an additional step in the preparation of the spray.

There has been for some time a feeling, which has led to considerable discussion, that equal amounts of the liquid lime-sulfur and of some of the dry sulfides, based on the active principles they contain, are not equal in killing efficiency.

On the basis of the polysulfide sulfur content of each of the materials used in these tests, we find the amount of polysulfide sulfur present in 50 gallons of spray to be as follows:

		Polysulfide sulfur in 50 gallons of spray, lbs.
Lime-sulfur solution	1: 8	15
	1:10	12
	1:12	10.5
	1:14	9
Dry lime-sulfur		6.6
Sodium sulfur compound		5
Barium sulfur compound		3

Comparing these figures with the table above showing the effectiveness of the materials in actual field tests, it is evident that the dry materials had a killing power much nearer that of the lime-sulfur solution than their polysulfide sulfur content would lead one to suppose; and further, that any increased dosage should be figured on the actual performance of the different materials in the field, rather than on a comparison of their chemical content alone.

It is along such a line that further work remains to be done.

From the above tests and the information we now have on these materials, certain conclusions are evident:

1. Under Massachusetts conditions, the commercial lime-sulfur solution,

if thoroughly applied, may be used at a 1:10 dilution and still maintain its high efficiency against scale.

2. At the strengths recommended by their manufacturers, none of the dry products has given as satisfactory control of scale as has the concentrated lime-sulfur solution, even when applied weaker than the usual dilution.

3. The dry materials have shown, in actual field tests, a higher degree of effectiveness as compared with the lime-sulfur solution, than a comparison of their chemical content of polysulfide sulfur would lead us to expect.

4. The dry lime-sulfur and the sodium sulfur compound were about equally effective, and greatly superior to the barium sulfur compound.

5. Great concentration of the dry materials is impractical from the standpoint not only of cost, but also of application, owing to the large amount of insoluble matter accumulating in the tank.

It should be clearly understood that the above statements refer to the concentrated lime-sulfur solution and the dry sulfides purely from the standpoint of their efficiency as dormant sprays for the control of San José scale, and have no bearing on any fungicidal value which the materials may possess.

SOME RESULTS FROM SPRAYING WITH SCALECIDE

BY A. I. BOURNE

For many years the question of oils for spray purposes has held the attention of fruit growers everywhere. Because of their effectiveness against San José scale, oil sprays have been used quite extensively, in spite of the fact that, when not properly prepared, severe injury often followed their use. This condition, at first inimical to the use of these sprays, made comprehensive research studies necessary. These have been organized under the sponsorship of the Crop Protection Institute.

The main lines of endeavor in the investigation as conducted in Massachusetts have fallen into two general classes.

1. A study of both immediate and cumulative effects of Scalecide upon various types of fruit trees common to Massachusetts orchards.

2. A study of the effect of Scalecide upon various insect and other pests, primarily those of orchard trees, and necessarily limited to the species common to this region.

The study of the different phases of plant stimulation or other cumulative effects following the continued use of Scalecide has not yet reached the point where definite conclusions can be drawn. Certain results, however, along the line of the insecticidal value of this material, which our tests have brought out to date, can be briefly reported.

Applied as dormant sprays in the spring against the winter eggs of the European red *mite*, with results drawn from counts of 20,000 to 25,000 mites of different stages, Scalecide and other materials showed the following relative control values, as compared with unsprayed checks:

Dormoil (a western type oil)	99 per cent
Scalecide	98-99 per cent
Sunoco	97 per cent
Rex oil emulsion	89 per cent
Lubricating oil emulsion 2%	90 per cent

In every test Scalecide has given very nearly perfect control of the overwintering eggs, when applied as a dormant or delayed dormant spray in the spring. One test made with this material applied in the fall gave a degree of control considerably less than that from spring application.

Against the overwintering egg masses of apple tent caterpillars, while not yielding such striking results as noted above, Scalecide has caused a very substantial reduction in hatch. In view of the increasing abundance of this pest throughout Massachusetts during the past few years, this beneficial effect of Scalecide is of considerable significance.

A study of the effect of this spray upon the early spring infestation of apple aphids has not been as comprehensive as might be desired, due to the scarcity of material thus far available. Results to date have indicated a very definite reduction in the numbers of plant lice, from a spring application very nearly approximating the time of hatching of the eggs; *i. e.*, the so-called "delayed dormant" period. Application as a purely dormant spray yielded very slight control of the subsequent hatch.

Spring application of Scalecide on pears yielded a very material check upon the infestation of pear psylla as based on the comparative number of eggs deposited upon unsprayed and sprayed trees. In one season there was found to be a reduction in infestation amounting to over 90 per cent on trees sprayed with Scalecide as compared with unsprayed rows alongside. The following season favorable weather conditions in early spring allowed early activity on the part of the psylla, and some eggs had been deposited before the spray was applied. Subsequent counts of eggs on sprayed blocks indicated a control of better than 85 per cent. Fall applications did not yield any striking control.

Tests made during one spring, using Scalecide diluted 1 to 20 on a small planting of ornamental spruce, against overwintering stages of the spruce gall louse, resulted in very satisfactory control of the insect and no injury to the trees.

Tests with the oyster-shell scale yielded negative results. Except for causing a possible slight delay in appearance of the newly-hatched young, there was very slight effect noted following the sprays. The difference in amount of hatch between unsprayed trees and those given the oil, if any existed, was not enough to be measurable.

In every instance the material was found to possess excellent physical qualities. It "flowed" from the container without difficulty even when the weather was cold, a feature which favorably impresses any grower who has had experience with oils. In preparation for the spray, the material offered no difficulty, mixed readily with the water, and required only moderate agitation. It formed a very stable solution from which there was little or no oil separation, even upon standing for a considerable period.

It should also be noted that, in all of our tests covering three seasons' work with Scalecide applied to several varieties of apple, pear, cherry, plum and peach, covering over two hundred trees, there has been discovered no instance of injury which was in any way attributable to the spray applied.

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AGRICULTURAL EXPERIMENT STATION

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THE CONNECTICUT VALLEY ONION INDUSTRY

PROGRESS REPORTS OF EXPERIMENTAL WORK

This bulletin contains four papers summarizing the experimental work of the Station which is of special value to onion growers. The subjects reported upon are as follows:

Requests for bulletins should be addressed to

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE PRESENT STATUS OF THE CONNECTICUT VALLEY ONION INDUSTRY

By LORIAN P. JEFFERSON

Three crops of onions are grown in the United States, early, intermediate and late. The chief competitors of Massachusetts in the production of late onions are New York, Ohio and Indiana. The states of Colorado, Idaho and Minnesota are coming into prominence as onion growing states, but as yet they ship comparatively few onions to eastern markets. Acreage in Massachusetts decreased from 4,560 acres in 1922 to 3,190 in 1924, but in 1925 rose again to 3,820 acres. Production, despite reduced acreage remained about the same, practically 1,250,000 bushels; but the crop of 1925 was reported as 1,580,000 bushels. This indicates either an improvement in cultural methods and in care of the crop at harvest time, or an unusually favorable season.

Owing to recent very unfavorable conditions in California, Ohio and Massachusetts particularly, the total acreage of late onions in the United States was reduced some 14 per cent in 1925. The total of 37,450 acres is the lowest planted for several years.

Onion growers have recently been disturbed by the quantities of foreign onions arriving on our markets. Side by side with home-grown onions the foreign product usually commands a higher price. Inquiry among dealers, however, indicates that these onions are mostly used for different purposes. Of milder flavor, the foreign onions are chiefly used raw in salads and sandwiches.

Boston, the chief market for Connecticut Valley onions, receives large quantities from other sources. During the four seasons, 1921-1924, shipments from Spain and other foreign countries constituted an average of 13 per cent of the receipts in Boston.

The Connecticut Valley supplied 47 per cent, and New York shipped an average of 15 per cent of the receipts. However, a significant feature is the fact that New York shipments increased from 3 per cent in 1921 to 36 per cent in 1924. These arrive in quite regular shipments during the same season as Massachusetts onions.

Freight rates on onions are still favorable to Massachusetts onions on the Boston market, as compared with New York and Mid-Western states. The freight rate on 100 pounds of onions from central points in the Mid-Western onion region to Boston, varies from 55 to 69 cents, while from New York points from which onions are shipped probably 35 to 40 cents per 100 pounds is a fair average rate, onion production being widely distributed throughout the state. The rate from the Connecticut Valley is 20½ cents. If, despite the greater freight charges, growers of the Middle West and New York can compete with local onions on the Boston market, it indicates either lower costs of production or onions of superior quality.

Prices received for the 1924-25 crop were practically the same for New York and Massachusetts onions.

The accompanying tabulation presents figures for acreage and production in Massachusetts, and in three states which are her chief competitors in the production of late onions, with totals for the entire late crop in the United States.

Acreage and Production of Onions in Massachusetts and Chief Competing States, 1921-1925.

Acreage.

	1921	1922	1923	1924	1925*
Massachusetts	4,500	4,560	3,360	3,190	3,820
New York	7,280	7,740	7,550	7,600	8,640
Ohio	5,080	5,680	5,760	6,240	2,860
Indiana	4,180	5,620	6,300	6,910	4,580
Total late crop in United States	43,560	47,320	46,720	46,580	37,450

Production (Bushels).

	1921	1922	1923	1924	1925*
Massachusetts	1,250,000	1,254,000	1,284,000	1,244,000	1,528,000
New York	2,184,000	2,090,000	3,156,000	3,192,000	3,300,000
Ohio	1,143,000	2,272,000	1,457,000	2,184,000	698,000
Indiana	1,108,000	2,321,000	2,218,000	1,728,000	1,411,000
Total late crop in United States	9,446,000	12,927,000	12,867,000	12,561,000	12,578,000

* Estimates.

FERTILIZERS FOR CONNECTICUT VALLEY ONIONS

By A. B. BEAUMONT and O. E. STREET

Within the last third of a century the Massachusetts Agricultural Experiment Station has conducted a number of experiments with the onion crop. These studies have dealt with problems of soil fertility, use of fertilizers, plant diseases, insect pests and marketing. In this paper, experiments dealing primarily with soil fertility and fertilizers are reviewed.

Field experiments here reported were conducted on the Station grounds at Amherst. The soils on which onions have been grown vary from fine to very fine sandy loam, contain a small to fair amount of organic matter, are slightly to strongly acid, and occur at elevations of 200 to 250 feet above sea level. The field experiments are divided into two groups for discussion. The first or early group extended over the period 1894 to 1917. This is the larger group. The second group was started in 1925 on the lower portion of the new Station farm known as the Brooks Farm. This second group of experiments is presented first.

After a conference with some of the leading onion growers of the Connecticut Valley, constituting an Advisory Committee on onions, field experiments planned to answer the following questions were laid out:

1. Cover crops: Is it practicable to grow cover crops in onion fields of the Valley? If they can be grown have they any value in respect to hastening maturity of the crop and maintaining fertility? What crops can be grown?

2. Lime: How much lime is necessary for best results with onions? Are large amounts injurious?

3. Fertilizers: (a) What is the best ratio of ammonia, phosphoric acid and potash in mixed fertilizers for onions? (b) Is there any advantage in applying fertilizers at different times within the season instead of all at the beginning?

4. Varieties: What varieties of onions are best suited to the Connecticut Valley? Do varieties run true to name? Can desirable varieties be maintained under Valley conditions? What are the best sources of seeds and sets?

Since the experiments have run only one year, and since the attack of mildew coming August 8 practically ruined most of the crop, only progress and incomplete results can be reported. It can be stated:

(1) That timothy, red and crimson clovers can be grown as cover crops in onions, if seeded immediately after the last shove hoeing and not later than July 26. These crops made considerable growth before the ground froze. Biennial sweet clover made poor growth as a cover crop.

(2) Moderate applications of lime, equivalent to one ton ground limestone, gave small increases in yields of onions. Large applications, up to seven tons per acre, showed no additional advantage.

(3) Complete fertilizers rather high in phosphoric acid and fairly high in potash gave the best results. Rate of application was 2500 pounds per acre. That fertilizer having the ratio of 1:3:2 for ammonia, phosphoric acid and potash gave the best yield. The fertilizer had the grade of 4-12-8.

(4) Concentrated complete fertilizers carrying a total of 32 per cent plant food can be used for onions. The 8-16-8 grade was used.

(5) No advantage was gained by the application of fertilizers at different times throughout the growing season instead of all at the beginning.

(6) Source of seed is an important consideration in the selection of seed stock. This was strikingly brought out by the difference in resistance of certain stocks to the attack of the mildew.

In considering this brief report of progress of this second group of field experiments with onions it should be borne in mind that on some points the results are not conclusive but merely indicative. Further, the land on which the plots are located had received very little cultivation for a number of years. It is probable that several years will be required to put it into a condition that is representative of our typical onion land.

The earlier group of field experiments had for their main objective information as to the kind of fertilizer materials required to grow a good onion crop. This objective was the one common to many field experiments conducted throughout the country during the period of early development of agricultural experiment stations. It was not known at the time the experiments started, whether one needed to feed the onion a single or a mixed ration of fertilizers; or which if any one of the plant food nutrients is the most important; whether lime is necessary for onions; etc. Some of these and other questions of plant feeding were answered by the earlier experiments.

The results are summarized as follows:

(1) On Connecticut Valley soils that have been cropped for a number of years, onions cannot be successfully grown unless a complete fertilizer, or one carrying ammonia, phosphoric acid and potash, at least, is used. There is still unanswered the question as to the necessity of sulfur, but since it is ordinarily present in a complete fertilizer the question is not at present very important.

(2) Fertilizers carrying ammonia entirely in the form of certain chemicals were found to be as good as those carrying ammonia in organic form

only. The significance of this fact may, however, be questioned, and for two reasons: (a) as used, neither treatment produced a large crop; and (b) the usual practice of combining organic with inorganic nitrogen was not included in the experiment.

(3) Nitrate of soda proved to be better than sulfate of ammonia as a carrier of ammonia when there was a deficiency of lime in the soil. Most of our Valley soils are deficient in lime. If lime is supplied in sufficient amounts, ammonium sulfate is as good as nitrate of soda for onions.

(4) Moderate applications of lime in practically all cases were matched by increased yields of onions. This response to lime was particularly marked when ammonium sulfate and muriate of potash were used in combination. Moderate applications (1 to 2 tons) to onions lose most of their effect within four years.

(5) There is little choice between muriate and sulfate of potash as carriers of potash for onions unless there is a great deficiency of lime, when the sulfate is preferable.

(6) Onions have responded well to fertilizers carrying a large proportion of soluble phosphates. A high proportion of phosphoric acid reduces but does not do away with the need of lime.

(7) From the standpoint of fertility, onions can be grown successfully with large (30 tons) applications of manure. Fertilizers used in addition to the manure have no additional advantage.

There are three conclusions common to the groups of experiments worthy of emphasis.

1. For continuous growth of onions on Connecticut Valley soils a complete fertilizer is necessary.

2. Complete fertilizers having a high ratio of phosphoric acid give best results with onions.

3. Moderate and frequent applications of lime are necessary for onions on Valley soils.

There appears to be little if any necessity of a choice of carriers for ammonia, phosphoric acid or potash provided practice is in accordance with these three conclusions.

ONION BLIGHT or DOWNY MILDEW

By A. VINCENT OSMUN

This disease caused widespread damage to the onion crop of the Connecticut Valley in 1924 and 1925. The first authentic report of its occurrence in Massachusetts was in late August, 1924. It is probable, however, that it has been present within the state for a much longer period, as it was reported many years ago from Connecticut, Vermont and New York. Our growers have indeed long been familiar with a disease known to them as "blight," the symptoms of which appear not to be different from those of the disease here under discussion. The disease was first reported in this country from Wisconsin in 1884.

Onion blight is caused by a parasitic fungus known technically as *Peronospora schleideni.* This is one of a group of fungi called Downy Mildews, and hence the name Downy Mildew is often used to designate the disease as well as the fungus which causes it.

Downy mildew attacks the onion tops, starting with a few onions in different parts of a field, and spreading from these centers of infection. In its early stages, even before the tissues are killed by its attack, the mildew may be detected in early morning when the leaves are wet with dew, or during a rain, as small violet colored patches. In the sun these patches dry out and collapse, leaving yellowish or white spots. The mildew quickly spreads over the entire leaf which becomes water-soaked in appearance, collapses and breaks over. The shriveled leaves are soon blackened by mold. Usually, new leaves develop following the first attack, and if weather conditions continue to favor development of the disease, these may also succumb. However, even with the new crop of leaves the bulb seldom attains full size, and the crop is thus reduced.

Downy mildews characteristically thrive best under moist, cool conditions, and downy mildew of onion is no exception. Periods of rain or high humidity with low night temperatures occurring between early July and late September are likely to bring on the disease, and at such times the fields should be closely watched for the first symptoms. With weather conditions favoring the disease its spread is very rapid, often considerable areas becoming affected within a few days and leaves dying within a short time after infection. It was not uncommon last season to find entire fields laid low by the disease.

Control measures for onion blight have been worked out. The various phases of control are based on (1) the ability of the mildew to live over winter in old onion refuse, (2) influence of environmental conditions and (3) susceptibility of the fungus to toxic fungicides.

(1) In order to reduce the possibilities of infection from previous diseased crops, onion refuse should be burned. A three or four year crop rotation also may be helpful in this connection.

(2) As excessive moisture favors development of the mildew, every practicable means should be taken to promote the drying off of the onion tops following periods of high humidity. Under-drainage, clean culture, exposure to prevailing winds, all help in drying off a wet field.

(3) Spraying with 4-4-50 Bordeaux mixture with three pounds of resin fish-oil soap added as a sticker is effective if the applications are sufficiently prompt, thorough, and frequent. If spraying is to be the program, the weather conditions should be closely watched, as the first application must anticipate appearance of the mildew. All tops must be thoroughly covered by the fungicide, and spraying should be repeated at least once a week or every three or four days if weather conditions favoring spread of the disease are prolonged.

Onion growers are not equipped with adequate spraying machinery, if indeed such machinery is in existence. Yet there can be no doubt that downy mildew will continue to attack the onion whenever moisture and temperature conditions suited to its development occur. Growers must face this possibility each season and must decide for themselves whether it will be more profitable to take the loss from possible reduction of yield, or apply the control measures above outlined.

A STUDY OF THE LIFE HISTORY AND CONTROL OF THE ONION THRIPS

By A. I. BOURNE

The onion thrips is, without question, the outstanding insect pest of the onion. In cases of severe outbreaks, the losses it has caused have often been rated as high as 25 to 50 per cent of the crop. The injury, variously termed *blast, white blight,* and *silver top,* results from these minute insects extracting the plant fluids, by means of their rasping and sucking mouth parts.

Throughout the Connecticut Valley, the main onion growing section of Massachusetts, this pest has, during late years, become very generally established and appears in large numbers annually. Previously, its ravages were chiefly confined to occasional outbreaks, many times of only local importance. With the increased acreage devoted to set onions, the thrips has come to be an annually recurring pest, and gives every evidence of increasing abundance.

Relation of Set Onions to Thrips Injury

The very close correlation of the set onion industry to the problem of thrips injury to onions grown from seed is generally recognized. Set onions on the average develop several weeks earlier than the crop of seed onions. Sets, therefore, serve as ideal nurseries for the colonization and multiplication of the thrips. The insects are thus supplied with an abundance of their favorite food plant, and consequently are able to reach large numbers comparatively early in the season. From actual counts made in the field, of the thrips colonized on nearly mature plants of set onions, it was found that two to three hundred thrips per plant were about an average, while five to six hundred were by no means uncommon. The sets themselves do not as a rule suffer severely from the attack of the thrips, since, by the time the insects have developed a heavy infestation, the plants have advanced well toward maturity and accumulated enough leaf surface to withstand the attack.

Areas given over to sets are often located close to, or even alongside, fields later planted to seed onions, so that transfer over onto the younger and smaller plants is easy. This practically assures the later development of a heavy infestation in the fields of seed onions. Observations have shown that while there is more or less of a spread from the sets before they are mature, the great movement takes place when the sets are ready to be pulled. From our studies of the life history of the insect, it was learned that the time of this general transfer usually coincides very closely with the period of greatest reproductive activity of the insect, thus increasing the danger to the fields of seed onions.

There are other sources of possible infestation—refuse and screenings, weeds, grasses, etc. The list of plants upon which the thrips has been found to feed includes many garden and field crops, ornamentals, and greenhouse plants as well as various grasses. While these are of comparatively little importance as compared with set onions, they do offer the insect ample opportunity for hibernation and early spring colonization, and explain why onion fields are often invaded from grass or weedy borders. For this reason, it is recommended to burn over, in late fall or early spring, grass and weedy areas bordering on onion fields.

Dusting for Control of Thrips

In the Experiment Station study on thrips control, various types of commercial nicotine dusts, as well as home prepared dusts, were tested. A study was made of the comparative efficiency of different strengths of nicotine in the dusts; and of the form in which the active principle was present (free nicotine or nicotine sulfate). The influence of weather conditions on the effectivness of the dusts was also studied, to determine the best time to make the applications. Different methods of applying the dusts were tried out, as well as the use of auxiliaries (hoods, curtains, etc.) to confine the dust discharged, prevent drift and so counteract the interference caused by wind.

Nicotine dusts, even those carrying a comparatively small percentage of nicotine, readily kill all the insects reached and are effective early in the season. By applying the nicotine dusts at intervals of about ten days, beginning with the first appearance of the thrips, the insects are held down sufficiently so that the plants can withstand a moderate infestation. The cost of such a practice, however, is almost prohibitive. Later in the season, the nicotine dusts are not satisfactory, since they cannot penetrate the tight crevices in the axils of the inner leaves, where a very large percentage of the thrips congregate.

Study was also made of the recently introduced calcium cyanide dusts. These possess excellent physical qualities, and the gas given off penetrates the tight crevices in the axils of the inner leaves very successfully, overcoming the thrips in practically every portion of the plant. The gas is soon dissipated, however, and a very large percentage of the thrips recover from its effects and resume normal activity. At present the cost of these dusts is high. These difficulties do not appear to be insurmountable. If the manufacturers make as rapid progress in the development of these dusts in the near future as they have in the last two years, calcium cyanide gives promise of becoming a very satisfactory control.

Spraying for Control of Thrips

In a study of the possibilities of sprays for the control of this pest, tests were made of a long list of materials, including almost every type of contact spray. Preliminary tests eliminated very many of these as ineffective or impracticable from one cause or another, and the field soon narrowed down to include the nicotine-soap combinations and certain oil sprays.

One of the greatest problems in thrips control is to reach and kill the insects deep down in the axils of the leaves (chits), where they congregate in large numbers. On account of the peculiar nature of the plant and the smooth, waxy surface of the leaves, any spray to be successful must possess excellent adhesive and spreading properties, as well as insecticidal value. Oil sprays, while very effective against all thrips actually touched, showed a very strong tendency to form into drops and roll off the plants without thoroughly covering all the leaf surface, thus forming "islands" where thrips were untouched by the spray and so escaped. Nicotine sprays used alone do not have the necessary physical qualities. When they are combined with soaps, however, they constitute a spray which possesses all of these qualifications to a very high degree.

Lack of machinery has stood in the way of successful use of sprays. The ordinary types of horse-drawn sprayers cannot be used in onion fields. The common nozzles, delivering a cone spray, have not succeeded in forcing the spray deep down into the narrow space at the base of the inner leaves. The problem was, therefore, to develop a method of driving the liquid well in among the close-standing plants and force it down into the axils of the leaves; also, to find a spray of superior wetting and flowing qualities that is toxic to all stages of the insect and has a killing action rapid enough to overcome the active winged adults.

Nicotine sulfate, the commercial 40 per cent solution, coupled with fish-oil soap, was found to answer the requirements of a spray. A small Skinner System irrigation nozzle, modified to deliver the spray at the desired angle and distribute the pressure evenly, has given good results. This delivers a thin, flat, fan-shaped spray which, with moderate pressure, is broken up into a very fine mist. The full force of the discharge is confined to a comparatively small space, so that the spray may be directed upon the portion of the plant desired, with full advantage of the amount of pressure, and with little waste of material.

This flat spray, directed upon the plants from the side, caused a vibration of the young, limber leaves which, in conjunction with the excellent wetting and flowing qualities of the spray, allowed it to work down into the tight chits and reach the thrips congregated there. From our experiments to date, a steady pressure of 125 to 150 pounds has proven satisfactory, giving a very fine mist and allowing good penetration.

The most satisfactory spray formula used was as follows:
Nicotine sulfate ("Black Leaf 40," Nicotine Sulfate 40 per cent", etc.), ½ pint to 100 gallons (1:1500), Good's No. 3 Potash Fish-oil Soap, 6-8 pounds per 100 gallons of spray.

The soap used in this formula is soft and "pourable", very easily handled and mixed into the spray. This product is of such uniform consistency that proper dilution can be made by measuring the soap as it is drawn from the container, thus allowing a saving of time when refilling the spray tank in the field. The spray made on the above formula had excellent spreading and "flowing" qualities, and covered the smooth, waxy surface of the onion tops very readily. The most promising feature was its tendency to flow down to the base of the stems and into the tight crevices, allowing the nicotine to reach and kill the colonies of thrips clustered there. In addition, the alkali of the soap served as an activator of the nicotine, thus hastening its insecticidal action.

In field tests at North Sunderland, this spray was applied to a section of a large field of onions which had become heavily infested from sets growing alongside. When the sets had been screened and disposed of, this section of the field was sprayed, using a power outfit delivering a steady pressure of 125-150 pounds, with two lines of hose operating. Owing to the heavy, driving rains and the *mildew* which had appeared in the field, some of the plants were broken down, making it difficult to make a thorough application.

Examination of the field the day following the application showed the following:

	Thrips per 100 plants	Average per plant	Control Per cent
Sprayed	165	1- 2	97+
Unsprayed	5230	52-53	—

Despite the very high percentage of control obtained, a second application has been found to be advisable, for restocking takes place very rapidly through the hatching of eggs inserted in the leaf tissues. This second spray should be applied after all the eggs have hatched, and before the first appearing larvae have matured and left the plants. Because the nicotine soap spray cuts down very materially larvae hatching for a period of at least two days after application, the period between the sprays may safely be extended to seven or eight days.

The Critical Period in Thrips Infestation

The data from field observations and life history studies revealed the fact that reproductive activity and consequently the rate of increase vary considerably during the season.

Infestation is comparatively light and shows no marked increase up to about mid-July. From that point there is a steady increase through that month, with a sudden rise to the climax of the season about the first of August. Beyond that point there is a gradual slowing up of reproductive activity for the remainder of the season.

The critical period as regards thrips infestation, therefore, occurs during late July and early August. At this time the insects have transferred in large numbers from sets and are rapidly developing an infestation on the fields of seed onions. This source of danger, coming as it does at the time of greatest reproductive activity on the part of the insect, makes this point in the season a very serious one for seed onions, and emphasizes the need of the follow-up spray to check the pest as thoroughly as possible and give greatest protection to the plants at this particular period.

Conclusion

Our studies to date have shown that the chief source of thrips infestation of seed onions is from nearby fields of set onions, and that the greatest movement of thrips takes place at the time the sets mature and are pulled. This coincides with the period of greatest reproductive activity on the part of the thrips, and comes in late July and early August.

Both from the standpoint of cost and of effectiveness, dusts do not give satisfactory control. This is true both of the nicotine dusts and of the newer calcium cyanide dusts, although the latter show considerable promise.

The usual type of spray nozzles proved unsatisfactory for this purpose, and a nozzle delivering a flat spray has been developed. This delivers the spray where it is needed, and, with a pressure of 125-150 pounds causes it to penetrate the axils of the leaves where the greatest number of thrips congregate.

Nicotine sulfate, 1-1500, with Good's No. 3 Potash Fish-oil Soap added at the rate of 3-4 pounds per 50 gallons of spray was found to give satisfactory control. A second spray application, seven to eight days after the first, has been found advisable to take care of the larvae hatched from eggs laid in the tissues of the plant.

The usual types of spray machinery are not well adapted to operate in large fields of onions. The development or adapation of an outfit which will conform to the particular requirements for the spraying of onions presents the most immediate problem.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 228 MARCH, 1926

AN ECONOMIC STUDY
OF THE
MASSACHUSETTS APPLE INDUSTRY

By HUBERT W. YOUNT and LORIAN P. JEFFERSON

According to the data reported in this bulletin, the task of marketing the Massachusetts apple crop ten years from now may be nearly double what it is today. Existing plantings, with no allowance for new plantings, indicate an increase in the apple crop, in the next ten years, ranging from 240 per cent for McIntosh down to 13 per cent for Wealthy. Were this increase to come suddenly, or without preparation on the part of growers' organizations, it might be impossible to market the crop to advantage. With knowledge as to the probable size of coming crops, growers will have not only a guide to new planting, but opportunity to develop new markets. It was for the purpose of attaining this dual objective, that the work reported in this bulletin was undertaken.

Requests for bulletins should be addressed to
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

AN ECONOMIC STUDY OF THE MASSACHUSETTS APPLE INDUSTRY

By HUBERT W. YOUNT and LORIAN P. JEFFERSON

Introduction

The apple growers of Massachusetts, in common with those of the other New England States, have felt for some time the need of more definite knowledge of the apple industry—the number and ages of trees of different varieties, and the volume of the commercial crop. In order to obtain this information it was determined by a group representing the Experiment Stations, State Departments of Agriculture, the New England Research Council, the Federal Bureau of Agricultural Economics and the New England Crop Reporting Service, that a study should be made of the apple industry of New England. The purposes of this study were, specifically:

1. To secure information as to number and age of trees and the trend of planting.
2. To discover the volume of the apple crop and the amounts put on the market.
3. To discover the relative importance of each commercial variety.
4. To determine the relative importance of orchards of different size.
5. To discover common orchard practices in different producing areas.
6. To learn the relative importance of apple growing as a source of farm income.
7. To determine the relative importance of different methods of marketing.
8. To discover the extent to which grading is done.
9. To learn the prices received and the reasons for price differences.
10. To determine available farm storage space and the quantities stored.
11. To determine probable future production.

Methods and Scope

The method employed in Massachusetts was personal interview with each owner of a commercial orchard. For the purposes of this study a commercial orchard was defined as one which contained a minimum of 100 bearing trees. Exceptions were made in cases where orchards of fewer than 100 bearing trees were of evident commercial importance, or where there were considerable plantings of young trees which gave evidence of future commercial importance.

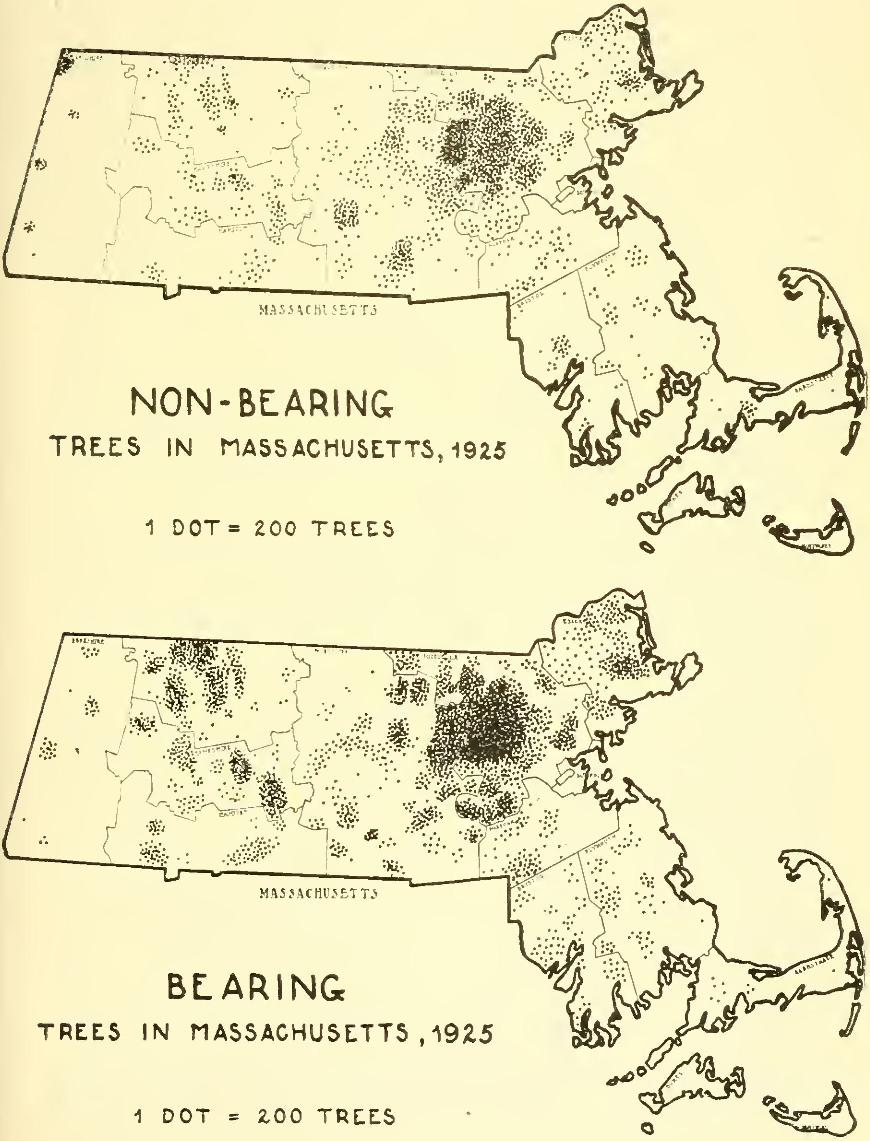
Visits were made to over 2,000 apple growers and complete schedules were secured from 1,754, which is 7 per cent of the whole number who reported apple trees in the Census of 1925. The growers visited reported 45 per cent of the trees and 55 per cent of the production as stated in the Federal Census of 1925. However, a large part of the production reported to the Federal Census is used on the farm or sold for making into cider, and it is estimated that the farms included in this survey grow over 75 per cent of the marketable apples of the state.

Cooperating Agencies

Cooperating with the Department of Agricultural Economics of the Massachusetts Experiment Station in securing this information, was the State

Department of Agriculture which contributed the salary and expenses of two investigators for field work. The New England Research Council acted as a coordinating agency, in order to insure the collection of uniform data throughout the New England states.

CHART 1. Non-bearing and Bearing Trees, 1925



Producing Regions

Apple growing in Massachusetts centers in several rather distinct sections, although apples are grown for home consumption in every part of the state. These are Franklin County, Connecticut Valley, Nashoba area and Essex County.

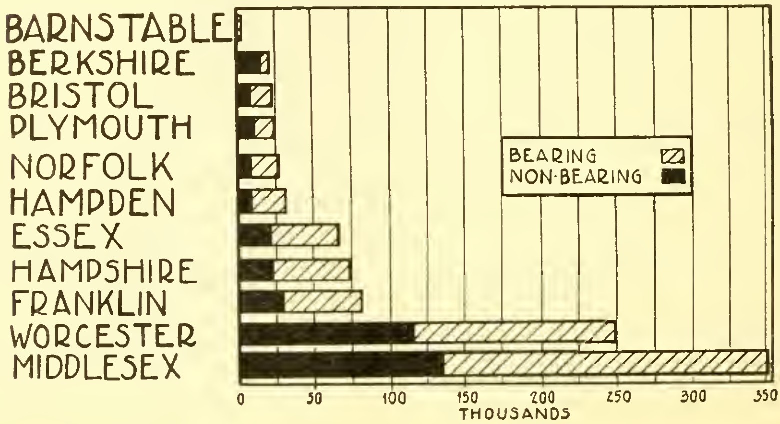
The chief section, lying partly in Middlesex and partly in Worcester counties and known as the Nashoba area, includes the towns of Littleton, Acton, Groton, Harvard, Stow, Sterling, Hudson, Boxborough, Bolton and Westford. Other towns which form a southern continuation of this area are Berlin, Marlborough, Northborough, Westborough and Millbury. Shirley, Lunenburg and Fitchburg form a similar group to the northwest. The topography of this section differs from that in other apple sections of the state, varying from fairly level to very rolling. The outstanding characteristics of this section are numerous small orchards and high production due to good orchard practice.

The Franklin County section, in the western part of the state, is included chiefly in the towns of Colrain, Shelburne, Buckland, Charlemont and Ashfield. Few growers here make apple growing their chief business, as orchards are mostly secondary to other farm enterprises. The varieties commonly grown are Baldwin and McIntosh, with a few Greening and Duchess. This region is hilly, almost mountainous in parts. Most of the orchards are irregular plantings on hillsides, trees being set in blocks in but few orchards.

Similar in many respects is the section in Essex County in the northeastern part of the state. Varieties grown here are chiefly Baldwin, with some McIntosh and small numbers of other kinds. In both Essex and Franklin counties most of the orchards are old and production is declining except in a few towns. It is doubtful if recent plantings in either of these sections have been sufficient to offset the dying of old trees.

The section in Hampden and Hampshire counties is composed of several separate areas lying on the hills along the Connecticut Valley. The towns of Cummington, Williamsburg, Easthampton and Granville form that portion lying west of the Connecticut River, while Amherst, Belchertown, Hampden and Wilbraham are included in the section east of the river.

CHART 2. Non-bearing and Bearing Trees, by Counties, 1925



In the southeastern part of the state are scattered areas consisting of a few specialized towns in Plymouth and Bristol counties. Orchards throughout this section vary greatly as to size, care and varieties. The orchards are, moreover, much scattered, some towns having none, while others grow large quantities of apples in orchards of considerable size.

Number and Age of Trees

A total of nearly a million trees was reported, one-third being not yet in bearing. Forty per cent of the trees are in Middlesex County, which with Franklin and Worcester counties produces about three-fourths of the total crop reported. The ratio of bearing and non-bearing trees varies in different sections. Only 24 per cent of the trees of Franklin County were reported as non-bearing, while in Worcester County 45 per cent are not yet in bearing. The other important counties fall between these extremes.

The estimated average age of trees reported in Massachusetts is seventeen years. There are thousands of trees from thirty to fifty or more years of age, but the great number of trees recently planted reduces the average to this low figure. According to the reports of the growers, about two-thirds of the trees are under fifteen years of age. The following table brings out the pertinent facts concerning age of trees in 1925.

Table 1. Age of Trees in Massachusetts, 1925

Age	Number of Trees	Per cent of Total	Cumulative Per cent
Under 5 years	202,077	20.5	20.5
5 - 9 years	259,804	26.4	46.9
10 - 14 years	188,980	19.2	66.1
15 - 19 years	64,966	6.6	72.7
20 - 29 years	56,382	5.7	78.4
Over 30 years	133,237	13.5	91.9
Unclassified*	79,118	8.1	100.0
Total	984,564	100.0	100.0

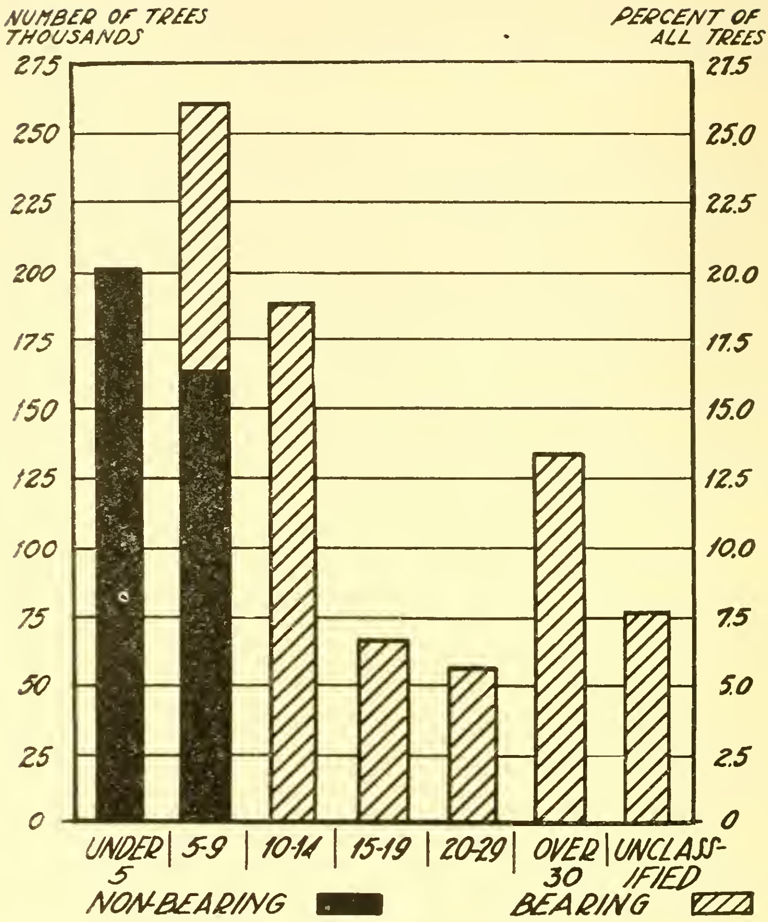
* "Unclassified" means that the age of the trees was not known. Most of these, however, were old trees.

The period of heaviest plantings was between 1915 and 1920. Although there has been a decline of 20 per cent from this high period, new plantings are still being made at the rate of 30,000 to 40,000 trees each year.

Fillers

The number of fillers reported was only 74,000 trees, or about 7 per cent of the total. These were divided equally between bearing and non-bearing, as most of the varieties used for fillers bear at an early age. Fillers are usually cut between the twelfth and fifteenth years, and 95 per cent of those reported are under fifteen years of age. The age grouping is fairly uniform, so that approximately 5,000 trees will be cut each year for the next fifteen years. Several varieties are used as fillers, but about half of those now planted are Wealthy. The McIntosh ranks second in importance, but it is probable that few of the McIntosh fillers will be removed, since already Baldwin and Delicious planted as permanents are being cut instead of McIn-

CHART 3. Age of Trees, 1925



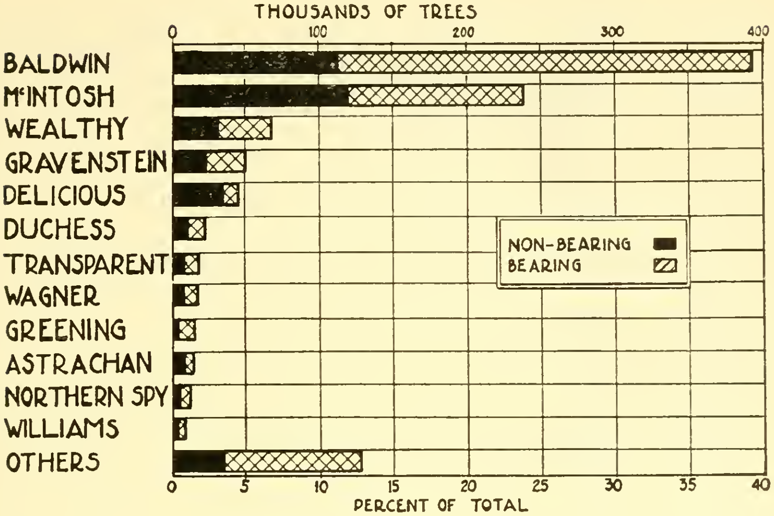
tosh. The Duchess, Wagener and Transparent are all used extensively as fillers and are of about equal importance. Growers expressed considerable dissatisfaction with the filler system and it is not being used on many of the new plantings.

Many growers were unable to state the exact number of fillers, but it is estimated that the figures given are about 75 per cent correct, which would bring the total number of fillers to approximately 100,000 trees.

Principal Varieties

Over 100 varieties were reported by the growers visited, the number of each variety varying from one to several thousand. The number of varieties for which there is a definite market is limited, and there is a strong tendency on the part of the larger growers to limit production to four or five standard varieties. Most of the minor varieties have been planted in small orchards

CHART 4. Non-bearing and Bearing Trees of Leading Varieties, 1925.



for family use or by a few large growers catering to a roadside or other specialized trade.

Baldwin

The Baldwin is the most important commercial variety in Massachusetts, making up 40 per cent of all trees reported. It is found in nine-tenths of the orchards and its continued popularity is indicated by the fact that nearly half of the growers have young trees. Of nearly 400,000 Baldwin trees, over 25 per cent are not yet bearing. The average age, nearly twenty-five years, is

CHART 5. Recent Plantings of Leading Varieties, by Five-Year Periods.

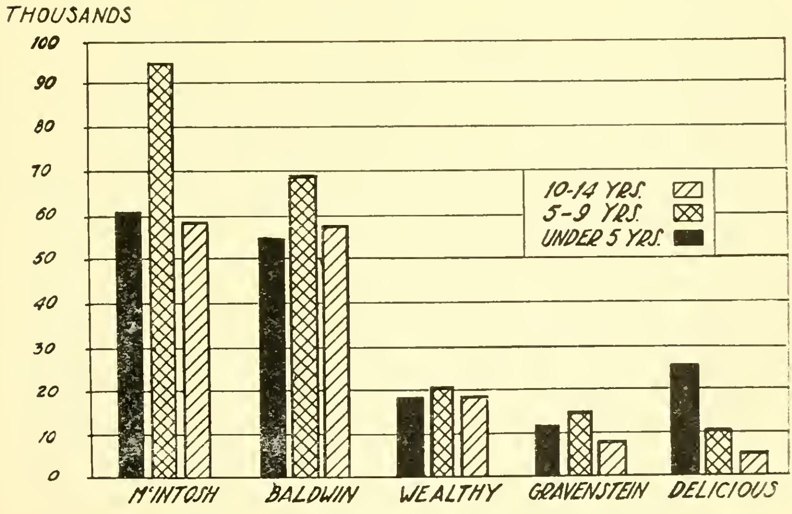
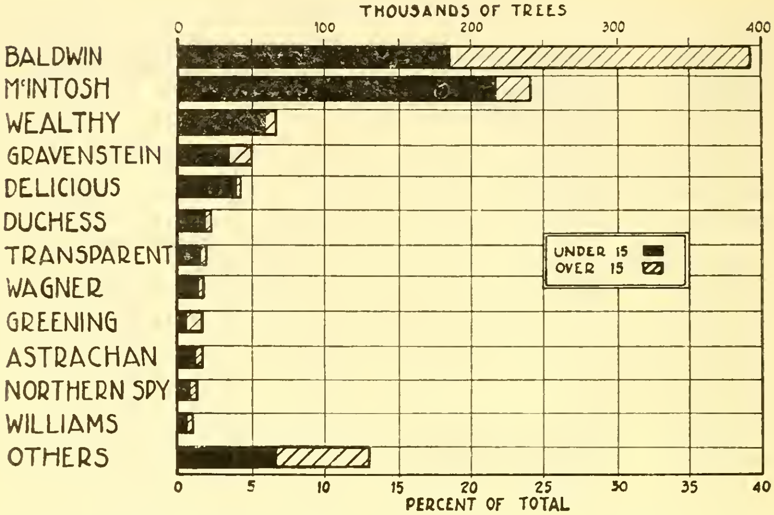


CHART 6. Trees Under and Over Fifteen Years of Age, for Principal Varieties.



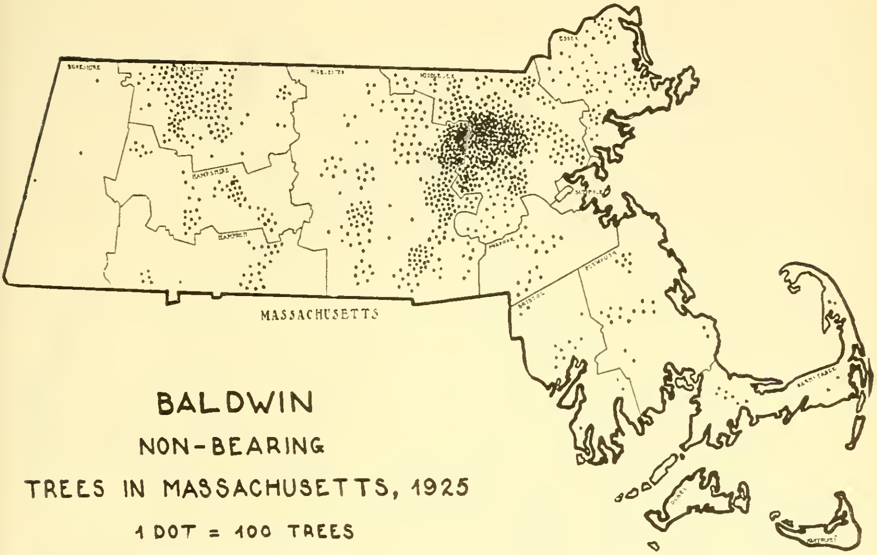
relatively high, one-fourth being over thirty years old. A number of these old trees go out of production each year, but the recent plantings make up for this reduction. Baldwin plantings during the past fifteen years have been almost as heavy as those of McIntosh. Over 50,000 trees have been set during the past five years, and the plantings for the five-year period previous to 1920 were considerably above this figure. Nearly half of the Baldwin trees are under fifteen years of age, and allowing for the loss of old trees, it is reasonable to expect a 50 per cent increase in the crop during the next fifteen years. The popularity of the McIntosh will undoubtedly reduce future plantings of Baldwins. The Baldwin crop in 1924 was over 50 per cent of the entire crop of the State.

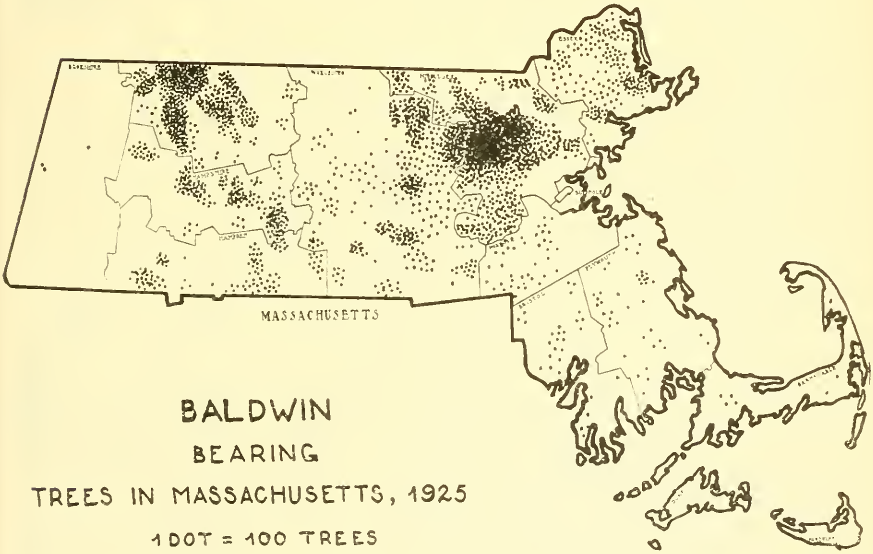
McIntosh

The McIntosh is the second most important variety grown in the State. Nearly 25 per cent of all trees are of this variety and the percentage is increasing each year. Of the 240,000 McIntosh trees reported, about half are not yet in bearing. Over 90 per cent of the McIntosh have been planted during the past fifteen years, which means that only a small number of the trees now bearing have reached full production. The heaviest planting occurred from 1915 to 1920, an average of 18,000 trees being planted per year. The present annual rate of 10,000 trees indicates a 40 per cent decline from that period. The average age of the bearing McIntosh was twelve years in 1925. As these trees mature in the next ten or fifteen years their production will be greatly increased. In addition, about 120,000 young trees will come into full bearing during this period. This estimate includes no new plantings and allows for a loss of 25 per cent of the present young trees. The production of McIntosh in 1924 was slightly over 200,000 bushels, about one-seventh of the total commercial crop. Since the 1924 season was a poor one for McIntosh, this figure is below the average crop.

More grading is done on the McIntosh than on any other variety, approx-

CHART 7. Non-bearing and Bearing Baldwin Trees, 1925.

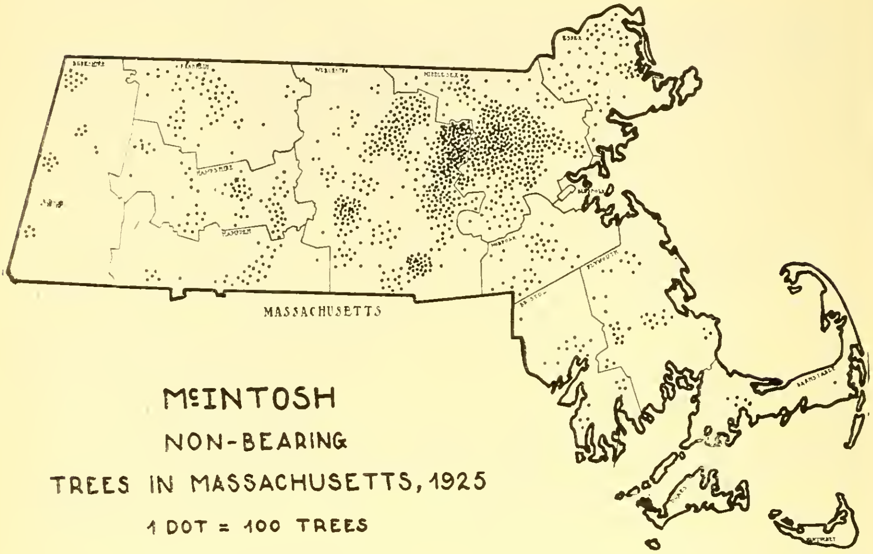


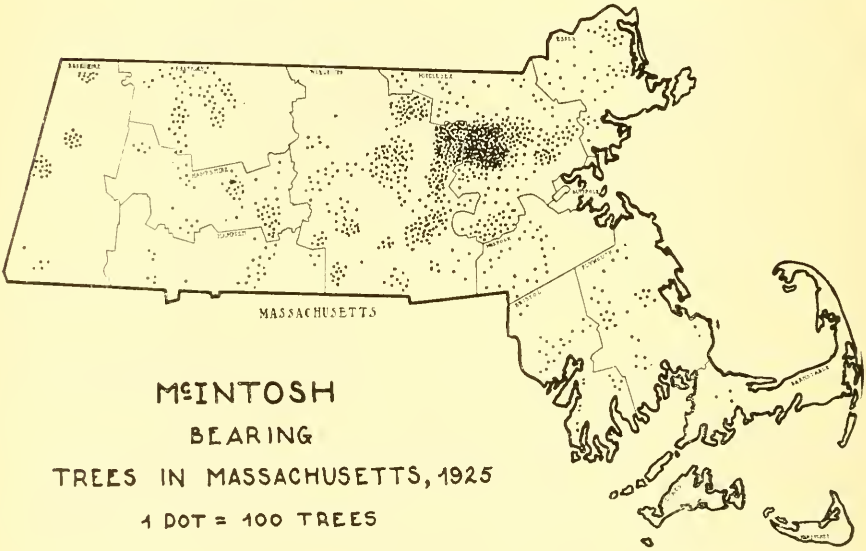


imately half of the 1924 crop being graded. Of this amount, 15 per cent were sold as Fancy. About two-thirds were A's and the remainder B's, many growers reporting as much as 75 per cent of their crop as A grade or Fancy. Prices received for McIntosh averaged almost double those for Baldwin, varying with the section of the state, the amount of grading and the care taken in production.

Ten thousand McIntosh trees were reported as fillers, divided equally be-

CHART 8. Non-bearing and Bearing McIntosh Trees, 1925.





tween bearing and non-bearing. It is probable, as stated above, that many growers who reported McIntosh fillers will not cut them.

Wealthy

The Wealthy is the most important of the minor commercial varieties. Since the Baldwin and McIntosh together make up over two-thirds of the total number of trees, no other single variety appears important when compared with them. There are over 60,000 Wealthy trees in the state, of which nearly half are not yet bearing. The Wealthy is planted primarily as a filler, and nearly 60 per cent of the present number are used for that purpose. Over 80 per cent of the Wealthy plantings are under fifteen years of age, and the production of this variety may be expected to decline very little, even with the removal of fillers. Plantings during each of the five-year periods since 1910 have been about equal and the indications are that the present rate of 3,000 trees per year will continue. Wealthy production amounts to only 5 per cent of the total. About 40 per cent of the Wealthies sold are graded, and 75 per cent of those graded were sold as A's. Disease and insect damage made some difference in this figure during the past season.

Gravenstein

The Gravenstein crop is much larger than the Wealthy crop, although there are fewer trees. Out of nearly 50,000 trees reported, 40 per cent are not yet bearing. The Gravenstein has a higher percentage of non-bearing trees than any other variety except the McIntosh. Plantings during the past five years total over 11,000 trees, a decline of 35 per cent from the preceding five-year period. Two-thirds of the Gravenstein trees are under fifteen years of age, which indicates a substantial increase in production in the future. The total production in 1924 of 115,000 bushels, an average of four bushels per tree, was almost double the Wealthy crop. Two-thirds of the crop was sold ungraded, but of the amount graded, nearly 80 per cent was A grade.

Delicious

The Delicious is a comparative newcomer in Massachusetts, and of the 42,000 trees reported, over three-fourths are not yet bearing. Recent plantings have been very heavy; over 60 per cent of all trees of this variety have been set since 1920. One-fourth of the reporting growers have Delicious trees, usually in small blocks for experimental purposes.

Growers of this variety report sales difficult for the lower grades, but the total volume of production is not sufficient to be a real factor on the market.

Duchess

The Duchess is the favorite of the early varieties, although there are only 20,000 trees, about half of which are not bearing. This variety is principally planted as a filler, 40 per cent of the trees reported being for that purpose. Plantings have fallen off during the past five years, and the present rate of 1,000 per year seems likely to decrease. Most of the Duchess trees are under fifteen years of age, since they are early bearing and short lived. Coming on the market early, production is not an important factor in the general market, except for competition with early Wealthies.

Transparent

The Transparent is another of the early varieties used as a filler. Of the 16,000 Transparent trees reported, three-fourths are bearing. The rate of planting has decreased recently, and many growers express the intention of cutting out these trees. The poor quality of the fruit, its susceptibility to insect injury and small size are some of the reasons advanced for discontinuing the variety.

Wagener

This variety has recently come into favor, particularly in large orchards. Eighty growers reported a total of 15,000 trees in 1925, 60 per cent of which were already bearing. About 50 per cent of the plantings are fillers. Most of the planting has been done during the past ten years, very few trees being more than fifteen years of age. The favor with which this variety is being received by the growers indicates that it will be of more importance in the future.

Greening

The Rhode Island Greening, one of the oldest Massachusetts varieties, is fast passing out. A total of 14,000 trees was reported, of which only 2,000 were non-bearing. Since most of the bearing trees are old, production per tree is high and a total of 26,000 bushels was reported. The poor market for this variety has caused many growers to cut down their trees. The variety is of little commercial importance except in certain sections of the western part of the State.

Astrachan

This variety, formerly a favorite in the farm orchard, is now of little commercial importance. Nearly half of the 13,000 trees reported are non-bearing, and new trees are planted at the rate of nearly 3,000 for each five-year period. The crop is about equal to that of Transparent or Duchess, and comes on the market at about the same time.

Northern Spy

Only 1 per cent of the total number of trees reported were Northern Spy, and plantings are growing less. One-third of the 10,000 trees reported were not bearing, and 70 per cent of the trees are not fifteen years of age. Late bearing and poor market demand account for the lack of popularity of Northern Spy among growers.

Williams

This is one of the older early varieties and is popular in a few sections of the state. Only 7,000 trees were reported, and of this number 2,000 were non-bearing. Recent plantings of over 1,000 trees for each five-year period indicate some increase, which will probably be offset by the cutting of old trees. The production of 17,000 bushels compares favorably with the other early varieties, but is not of sufficient importance to become a factor in the market.

Miscellaneous Varieties

Many other varieties were reported, among them Hubbardston, Wolf River, Grimes Golden, Tolman Sweet, Pippin, etc., none of which is of commercial importance.

Size of Bearing Orchard

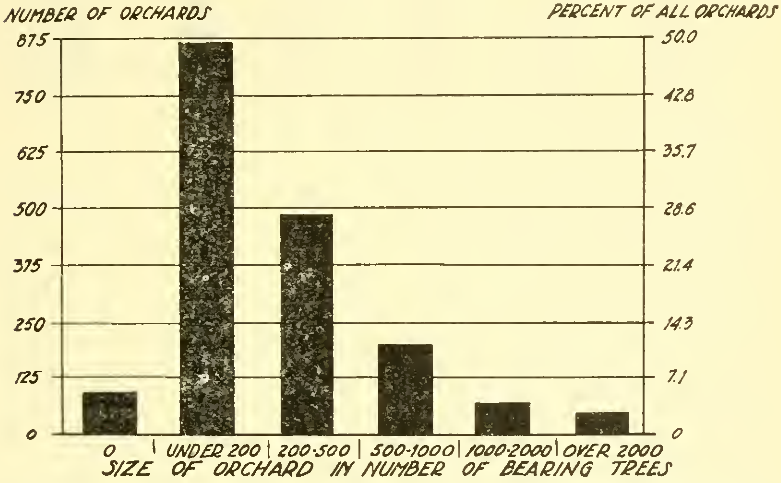
The size of the producing orchard, measured in bearing trees, varies from a few trees to as many as 12,000. The average for all the growers visited is 354 bearing trees. Over half report fewer than 200 bearing trees and the most common size is about 150 trees.

The size of orchard varies with the section of the state. Hampshire County has the highest average with 510 bearing trees. This does not mean that most of the orchards are larger than in other sections, but that there are more large orchards. The most common size is the same for all counties, from 100 to 199 trees. Worcester County ranks second in size with an average of 411 trees, while Hampden County, with 192, is low. Norfolk, Bristol and Plymouth average under 300 trees, indicating few large orchards in those sections.

Ninety-five growers had no bearing trees, but reported young orchards containing nearly one-fourth of the total number of non-bearing trees. This group, comprising only 5 per cent of the growers, averages over 900 young trees per orchard and includes some of the largest single plantings in the state.

Nearly one-fifth of the growers visited own bearing orchards of less than 100 trees. This group of orchards represents blocks of young plantings or old orchards that are well-cared for and commercially important in their section. Many of these growers have maintained a relatively profitable farm orchard

CHART 9. Size of Bearing Orchards, 1925.

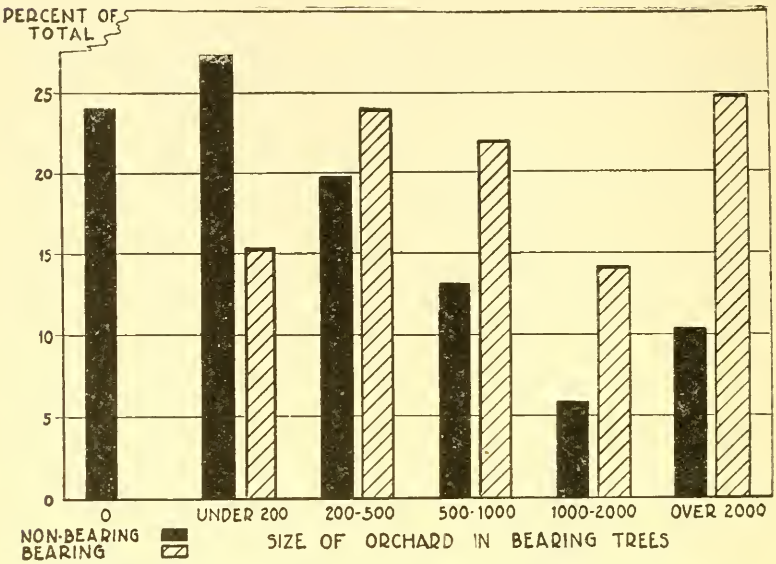


for years and are gradually increasing their plantings. This is indicated by the fact that they reported only 3 per cent of the bearing trees, but nearly 16 per cent of the non-bearing trees.

Recent plantings have been very heavy on small orchards and nearly half the non-bearing trees were reported by men having fewer than 500 trees. Nearly three-fourths of the trees not bearing have been planted by men with comparatively small bearing orchards, or by men just entering the business.

A comparison of the ages of trees in orchards of different sizes shows that those in orchards of 1,000 or more bearing trees are relatively young. Most of them have been set within the past fifteen years. Old trees are found chiefly in the small orchards and the production per bearing tree averages nearly twice that in the large orchards. For this reason the small orchards of the state produce relatively more of the crop than the large orchards. Orchards of fewer than 200 bearing trees produce one-fourth of the crop, and half the commercial production comes from orchards of fewer than 500 bear-

CHART 10. Percentage of all Bearing and all Non-bearing Trees in Orchards of Different Sizes, 1925.



ing trees. It is evident that the small orchard will be a very important factor in the future market.

Preference for the different varieties varies with the size of orchard. The large orchards have fewer varieties, carefully selected with a view to balanced farm organization and market demand. In general, the percentage of McIntosh increases with the size of orchard and the percentage of Baldwin decreases. The large orchards average one-third Baldwin and over one-half McIntosh. There is a tendency for large growers to plant only Baldwin and McIntosh as permanent varieties, at the rate of two McIntosh to one Baldwin. Most of the bearing Wealthy and Wagener trees are in the large orchards as fillers, as are a large proportion of Duchess trees.

Over two-thirds of the trees in small orchards with many varieties are Baldwin. The McIntosh comprises about one-fourth of the average small orchard, although there are many which contain none of this variety. Most of the bearing Gravenstein are also found in small orchards. The conclusion may be drawn that future increases in McIntosh production will come largely from large orchards, while the greater part of the Baldwin crop will be produced on farms with relatively small orchards.

Sources of Income

Most Massachusetts apple growers do not depend solely upon fruit for their income. Specialized fruit farms form only a small percentage of the total number and raise less than 15 per cent of the crop. In many cases fruit growing is a side-line and of secondary importance to the dairy herd. In Middlesex County fruit furnishes 40 per cent of the grower's income; dairying supplies 35 per cent; vegetables, 15 per cent; and poultry, 5 per cent. The remainder comes from a variety of sources. It is significant that in the most highly specialized fruit section of the state dairying is almost as important a source of income as fruit.

In the western part of the state, especially in Franklin County, dairying is more important than fruit, and these two items make up 95 per cent of the income of the average grower. Sales of hay and wages from outside work make up most of the remainder. In Hampshire and Hampden counties dairying is more important than fruit, but poultry, vegetables, hay and other crops furnish a large part of the total farm income.

On most fruit farms there are not more than two principal sources of income. Fruit and dairying are most common in all sections of the state, except in the areas close to Boston. In this section more attention is given to vegetable crops, and fruit and vegetable gardening are the usual combination. This applies to those sections of Essex, Middlesex, Norfolk and Plymouth counties within easy trucking distance of Boston and its suburbs. In other sections, fruit and poultry make a profitable combination on the farm with a moderate size of orchard.

Many specialized growers are combining orchard fruits with small fruits. Raspberries, currants and strawberries are usually planted, and peaches have been successful in a few sections.

Orchard Practice

A part of the survey was concerned with the usual orchard practices common among fruit growers in various sections. The results show to what degree scientific methods have been adopted as well as the practices of successful growers.

Pruning

It was found that 81 per cent of the growers prune every year, although this figure is to some extent misleading, since many growers replied that they "prune some every year". Many orchards are practically untouched and from observation it is estimated that not over two-thirds of the trees are thoroughly pruned every season. Fifteen per cent of the growers stated that they prune only occasionally, while 1 per cent do not prune at all.

Cultivation

Over two-thirds of the orchards are in sod and one-third are handled by clean cultivation or with a cover crop. Many growers reported on more than one orchard, so that the actual number of bearing orchards in cultivation is only about 25 per cent of the total. A wide variety of cover crops was reported, buckwheat, rye and millet being common. The usual practice is to cultivate the young orchard, but leave it in sod after it begins to bear.

Fertilizer

Three growers out of four apply fertilizer in some form every year. A wide variety of materials is used, but nitrate of soda is the most common, 60 per cent of the growers reporting its use. Over half of the growers use barnyard manure. Acid phosphate is used by 7 per cent of the growers, while 4 per cent use a complete fertilizer. Only a few users of sulfate of ammonia were found. Other growers reported the use of bone meal, wood ashes, potash, tankage and wool scourings. Three per cent of the growers use no fertilizer.

Spraying

The number of sprays varies widely. The calyx spray is almost universal. Either the dormant or delayed dormant spray is used by 80 per cent of the growers, the pink by 60 per cent, and the pre-pink by only 32 per cent. Nearly one-fourth of the growers reported the use of sprays in addition to those mentioned. The number varied from one to six, used principally for McIntosh. Dusting is not popular, only thirty growers now using it, and several of them expressed the intention of abandoning it in favor of liquid sprays.

Thinning

Twenty-five per cent of the growers do some thinning, but with many it is not a regular practice. McIntosh is the variety usually thinned, but all of the early varieties are thinned to some extent. Only a few growers reported thinning all varieties. The distance varies with the grower, but one apple to a spur and keeping the fruit from touching are the usual practices. A few growers thin to the recommended distance of six to eight inches. The practice is spreading and many growers are convinced of its value, although unable to do very much thinning on account of lack of time or experienced help.

Production

A total production of 1,712,000 bushels was reported, and of this amount 88 per cent was sold as marketable fruit. The farm consumption is relatively high, due to the large number of small orchards. A small amount of salable fruit is manufactured on the farms, principally for jellies, apple butter and similar products.

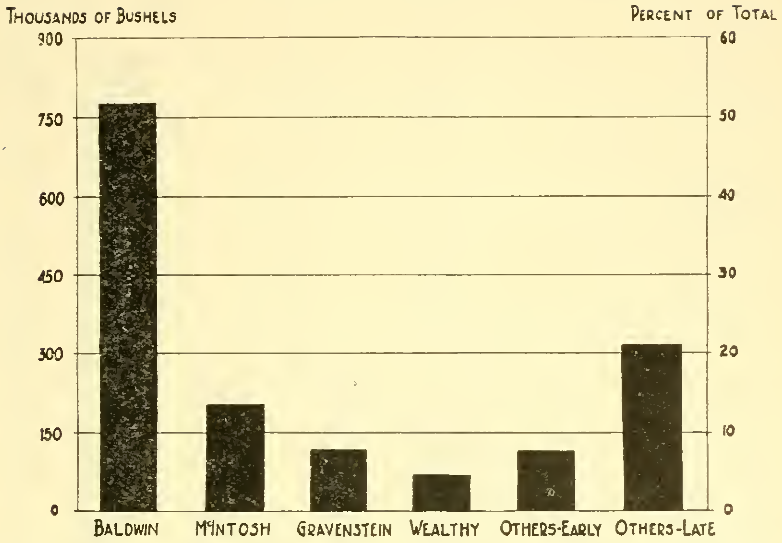
Over 12 per cent of the total production reported was culls or cider apples. In Franklin County 20 per cent of the production was culls, ciders or waste, partly due to poor quality and partly because of the sale of wild apples for cider. In the better commercial sections, the defective and cull fruit averages from 8 to 10 per cent of the total. Two-thirds of the culls are sold for cider, and 13 per cent are made into cider or other apple products on the farm. A few are fed to livestock and apparently about 3 per cent are wasted, most of the waste occurring in the poor fruit sections.

Marketing

Grades

Grading in some form is practiced by two-thirds of the growers. Most of the grading is done by hand, only 80 graders being reported. The favorite graders are the Pease and Cutler with a few machines of each of a half-dozen other makes. The number of grades varies with the grower, the amount and the quality of the crop, the varieties grown, and the custom of the section. Many growers do not distinguish between sorting and grading, and much of the grading reported means nothing more than the removal of small and defective fruit. Three-fourths of the growers sell only one or two grades of apples. Growers reporting one grade do not sell their defective fruit, using it on the farm; when two grades are sold, one of them is usually culls.

CHART 11. Production of Principal Varieties, 1924.



Only 209 growers reported the sale of more than two grades, while 23 reported as many as four or more grades.

Massachusetts apples are sold in three graded and three ungraded classes. The graded classes are Fancy, A and B. The ungraded include one class from which legal grades have been removed; one from which culls and ciders only have been removed; and one which includes all apples as they come from the tree. The usual grades for the growers reporting three grades are A, B and culls or ungraded. Less than 1 per cent of the growers make a practice of putting up a Fancy grade. There is a widespread belief that too close grading is not profitable, and prices received offer some justification for this belief.

The percentage of each grade varies with the variety.* The following table shows the distribution into market classes of the crop of 1924. It will be noted that in every case the highest proportion of apples was sold as "ungraded, culls and ciders out", and that 65 per cent of all apples were sold ungraded. Sixty-three per cent of all graded fruit was found to be in A grade.

By varieties, it is of interest that Delicious apples show the highest percentage of Fancy, more than 10 per cent being reported in this class, in contrast with less than 3 per cent for all varieties. This is to be accounted for by the fact that the market demand for this variety is almost entirely for the better grades. Northern Spy shows a higher proportion of A grade than any other variety, 36 per cent, and the McIntosh stands second with 30 per cent in this grade. McIntosh likewise has the highest percentage of graded fruit. Only 35 per cent of the Baldwin crop was reported graded. This variety is grown largely in small orchards, where comparatively little grading is done.

* Summer varieties include Duchess, Transparent, Williams, Astrachan, etc.
Fall varieties include McIntosh, Wealthy, Gravenstein.
Winter varieties include Baldwin, Northern Spy, Delicious, Wagener, Greening, etc.

TABLE 2. Percentages in Grades of Summer, Fall and Winter Apples, 1924

Grade	Summer	Fall	Winter	Total
Graded:				
Fancy	2.9	5.4	1.69	2.76
A	24.5	28.9	19.95	22.6
B	9.95	10.1	9.6	9.8
Total graded	37.35	44.4	31.24	35.16
Ungraded:				
A and B out	1.75	1.17	1.23	1.24
Culls and ciders out	52.0	44.4	44.5	45.0
Tree run	7.5	9.2	20.5	16.9
Other salable*	1.4	.75	2.22	1.78
Total ungraded	62.65	55.52	68.45	64.92

* "Other salable" includes apples used for farm consumption and for farm manufacture, exclusive of culls and ciders. These probably belong largely with ungraded.

Furthermore, the Baldwin commonly produces few apples of the higher grades, making the cost of grading too high for profit.

Methods of Sale

The method of sale varies with the locality. Fifteen different methods were reported, but four are outstanding. The commission man is the most important figure in marketing the crop, and over one-third of all Massachusetts apples are sold through the various commission houses of the state. Country buyers, including peddlers, handle nearly one-fourth of the crop, and in some sections as much as three-fourths. More than 10 per cent is sold outright to wholesalers and an equal amount goes to retail grocers. Direct sales to consumers in one of several ways account for most of the remainder of the crop.

Door to door sales are most common in the Connecticut Valley and the southeastern part of the state, about 20 per cent of all apples in these districts being so distributed, while less than 8 per cent in Middlesex and Worcester counties are sold by this method.

Roadside stands sell about one-fourth of the apples reported in the southeastern part of the state, while but 4 per cent in Middlesex, Worcester and the western counties are sold in this way.

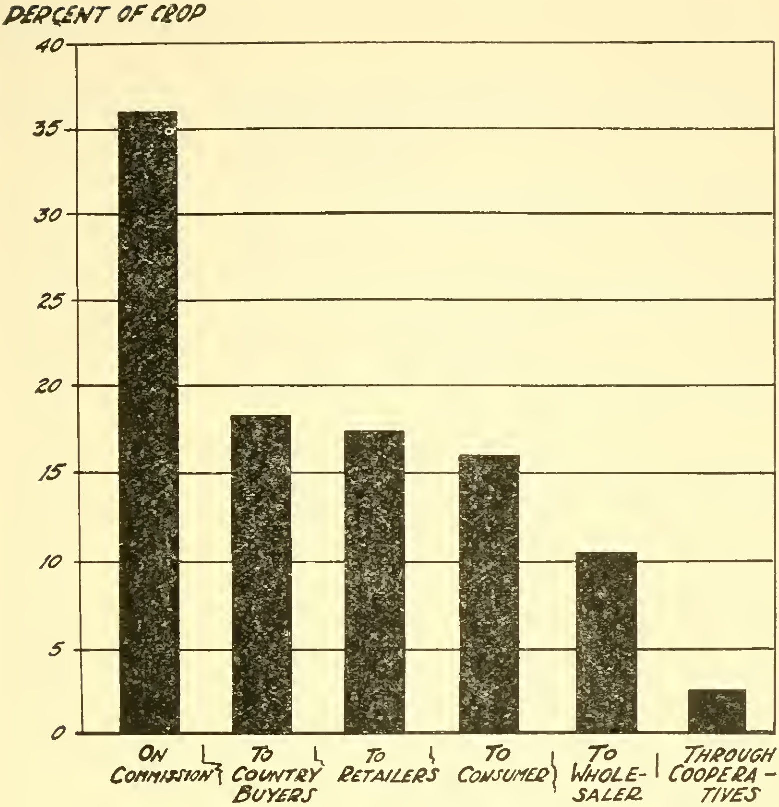
Sales to retailers comprise but 12 per cent of all sales in Middlesex and Worcester counties, although in some other sections retailers receive as high as 34 per cent of all apples.

While sale on commission is the most important method for the state as a whole, its use is by no means uniform. Only 1 per cent in Franklin County are so reported. In the central part of the state where it is used most, an average of 42 per cent of the apples are handled by commission men.

Sales to country buyers, who may be wholesalers, retailers or hucksters, are most common in Franklin County, where they receive 65 per cent of the apples. In the remainder of the state country buyers purchase only 12 per cent of the apples sold. Two per cent of the apples reported were exported, and these mostly on commission. Few exporters buy apples outright.

A comparison of methods of sale and varieties of apples shows that of all apples sold directly to consumers, either at the roadside or from door to door,

CHART 12. Methods of Sale Used by Growers, 1924.



6 per cent are summer varieties, 24 per cent, fall; and 70 per cent winter varieties. Of apples sold to retail distributors, 5 per cent are summer, 21 per cent are fall, and 73 per cent winter varieties. Winter apples comprise 80 per cent of wholesalers' purchases; less than 3 per cent are summer apples, and 16 per cent are fall varieties. Sales on commission are made up of 54 per cent winter apples, 38 per cent fall varieties and 8 per cent summer varieties.

Of 1,200,000 bushels on which the methods of sale were reported, 69,000 were summer apples, 326,000 were fall, and 797,000 winter varieties. Table XIV (appendix) shows that there is considerable difference in the methods of selling early and late varieties. Large growers produce most of the summer and fall apples, which are more perishable than the later varieties and must therefore be marketed as quickly as possible. Over 60 per cent of these apples are shipped to the wholesale markets, nearly half of them to commission men.

Country buyers purchase a smaller percentage of early apples than of the late varieties, because they prefer a storable apple of comparatively low grade. Most of the sales to country buyers are Baldwin. A larger proportion of early than of late apples is sold at roadside stands, automobile traffic being heaviest in the late summer and early fall.

Prices

A study of prices received for apples of different grades shows that graded fruit averages more than 25 cents a bushel above ungraded fruit. Local prices are more valuable to the fruit grower than a general average, and although price information was obtained for all fruit sold, it is not possible to present here all the figures obtained. Two sections, consisting of two towns in Franklin County and three towns in the Nashoba area, have been chosen as typical.

In the Nashoba district apples are commonly sold in boxes and the percentage of graded fruit is higher than in Franklin County, where most apples are sold ungraded and packed in barrels. Sales in the Nashoba area are mostly on commission in Boston, within easy hauling distance. In Franklin County the most common method of sale is to country buyers who come to the orchard, make whatever bargain they can with each grower, and buy the apples at the farm. These differences in method are undoubtedly factors which contribute largely to the differences in price reported from the two sections.

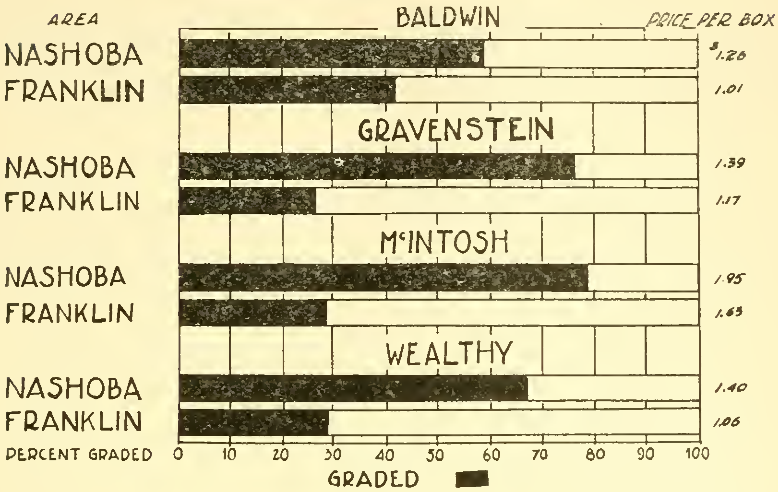
Table 3. Average per Bushel by Grades of Leading Varieties, in Two Selected Districts, 1924

Variety	A	B	Ungraded, Culls and Ciders Out	Tree Run	All Grades
Three Towns in the Nashoba District					
Baldwin	$1.44	$1.18	$1.02	$1.15	$1.26
McIntosh	2.14	1.81	1.58	1.64	1.95
Wealthy	1.49	1.41	1.37	1.15	1.40
Two Towns in Franklin County					
Baldwin	1.12	.91	1.03	.52	1.01
McIntosh	2.04	1.70	1.57	1.45	1.63
Wealthy	1.33	1.03	1.34	.88	1.06

The accompanying chart, Chart 13, presents the comparison of the prices and the proportion of graded and ungraded fruit sold of each of the four leading varieties, Baldwin, Gravenstein, McIntosh and Wealthy, for the two sections under consideration. It will be noted that the average prices in the towns of the Nashoba area run uniformly higher than in the towns of Franklin County for similar varieties and grades. (cf. Table 3). These differences are caused by accessibility of market, methods of sale, quality of fruit, and the amount of grading done, but it is obviously difficult to determine which has the greatest effect on price.

Baldwins, of which 59 per cent are graded in the towns of the Nashoba district, returned an average price of $1.26 per bushel. In the two Franklin County towns, with 41 per cent graded, this variety brought $1.01 a bushel. This margin of 25 cents represents the average difference in price for all grades between the two areas.

CHART 13. Amount of Grading and Average Prices Paid to Growers in Two Typical Sections, 1924.



The greatest difference in price between all graded and all ungraded in both districts is for McIntosh, amounting to a little more than 50 cents a bushel. McIntosh prices averaged from 50 per cent to 100 per cent higher than those received for any other commercial variety. The Baldwin prices are lower than those of any other variety, probably because of the quantities available and the relatively low quality. Prices received for Wealthy and Gravenstein apples average above those of most winter varieties.

Markets

Massachusetts apples are distributed widely, going by carlots to markets as far west as Chicago and as far south as Washington. From the reports of growers it is estimated that 15 per cent of the Massachusetts crop is sold outside the state, principally in New York.

A large amount of fruit in western Massachusetts is sold to storage companies and other dealers from New York State. The Connecticut Valley furnishes fruit to Hartford, Providence and New Haven. Providence is an important market also for the central and southeastern sections, and prices average higher on Rhode Island markets than on the local markets in those sections.

Boston is the most important Massachusetts market, receiving over one-third of the crop. Worcester and Springfield are important markets in the western part of the state, and are supplied almost entirely from nearby producing areas. Smaller cities, such as Pittsfield, Holyoke, Greenfield, Lowell and Haverhill consume large quantities of apples supplied locally. In some cities large quantities are sold by growers to retailers, while in others sales are almost entirely to wholesalers or on commission. Most of the smaller towns and cities are partly supplied with local fruit through door-to-door sales.

Exports

Only 2 per cent of the crop of 1924 was reported as exported. Most exports are handled on commission, the hazards of the business being so great that in general the dealers do not care to buy outright for export. A few growers have exported considerable portions of their apple crop for a good many years. These men have learned to pack for foreign markets so that comparatively few "slack" packages appear among their shipments.

Storage

Growers report available storage space for 919,000 bushels, but less than 20 per cent of the available space was used in 1924. The farm cellar is the usual place of storage, although more storage buildings are built each year. Many growers with young orchards intend to build or enlarge their storage space as their orchards come into full bearing.

Of the 227,000 bushels stored by farmers in 1924, over 50,000 bushels were placed in city storage warehouses. Boston handles half of the fruit going into city storage, but some storage was reported in Worcester, Springfield, Greenfield, Fall River and Providence.

The late winter varieties, such as Baldwin, make up the largest part of fruit stored on farms. These are usually kept until the holiday season or later. Many growers who supply their local markets from storage holdings, frequently have fruit on hand as late as March or April. However, the bulk of the fruit in farm storage is usually disposed of by January.

More McIntosh are stored each year, and they are held for a longer time than formerly. Most of the storage holdings are sold out by the end of the holiday season.

Transportation

Information on methods of transportation shows that at some point in their distribution 95 per cent of all Massachusetts apples marketed are hauled by motor truck. This may be all the distance to market, or the haul may be completed by rail. The same is true of hauls by wagon, which are confined almost entirely to Franklin County shipments. Over 70 per cent of all Massachusetts apples shipped in carlots during the four years 1920 to 1923 were from this county.

Future of the Industry

The future of the apple growing industry in Massachusetts and its profitableness to the farmer depend upon the amount and quality of future production. With favorable growing conditions, there is no doubt but that production of all of the important commercial varieties will increase each year. Large numbers of trees are just coming into bearing and yields will increase with maturity. Many of the large orchards of the state now bearing will not reach full production for at least ten years, and over 300,000 trees not bearing at present will come into bearing during the period. Barring the possibility of a disastrous winter which may kill the trees, the estimated future production, together with the number of bearing trees for the leading varieties, is indicated in the following table.

TABLE 4. Estimate of Future Production of Four Commercial Varieties of Apples on 1754 Farms in Massachusetts, 1924-1940 (bushels)

Year	Baldwin		McIntosh		Wealthy		Gravenstein	
	Bearing Trees	Production	Bearing Trees	Production	Bearing Trees	Production	Bearing Trees	Production
1924	280,000	790,000	118,000	205,000	36,000	66,000	28,000	115,000
1930	310,000	950,000	175,000	400,000	38,000	70,000	32,000	140,000
1935	350,000	1,200,000	235,000	700,000	40,000	75,000	35,000	175,000
1940	375,000	1,300,000	250,000	900,000	35,000	70,000	40,000	200,000

TABLE 5. Estimates of Future Commercial Apple Production in Massachusetts (bushels)

Year	1754 Farms		State Total	Per cent Increase Over 1924
	Four Varieties	Total		
1924	1,200,000	1,500,000	1,750,000	
1930	1,560,000	1,950,000	2,275,000	30
1935	2,150,000	2,730,000	3,185,000	82
1940	2,470,000	3,135,000	3,610,000	107

It is estimated that the total commercial crop of the state will increase at least 100 per cent within fifteen years. The largest part of this increase will be Baldwin and McIntosh, and the latter will undoubtedly show the greatest increase of any variety. In making the above estimates an estimated loss of from 10 to 40 per cent of the trees was deducted, depending upon the variety and age group. The largest deductions were made from the recent plantings, particularly of Baldwin. Allowances were also made for old trees dying out, and for removal of fillers. The estimates for 1935 and 1940 include probable plantings during the next ten years at a continual annual decrease of 10 per cent from the present rate. It is probable that by 1935 plantings will not be sufficient to replace losses of old trees. Annual plantings of at least 30,000 trees are necessary to maintain a million bearing trees.

It is estimated that within ten years 100 of the largest growers of the state will be producing approximately one-half of the crop. On farms of this type a high production per tree and high quality are the rule, and this fact has an important bearing on future estimates of the total crop. Each year will see a larger part of the commercial crop produced by professional fruit growers, in orchards planted during the past ten or fifteen years. Production in the small orchards may be expected to increase on account of recent plantings, but this increase will be partly offset by the dying of old trees which now largely make up this type of orchard. It is probable that the quality of fruit grown in the small orchard will be poorer than that of the large orchard because less care is given to growing, handling and marketing. Most of the small growers do not have the time or equipment to produce and pack the best grades of fruit.

Conclusions

Securing profitable markets for the probable increase in production is a matter of the utmost importance. One possible outlet is the building up of new markets outside of New England. Many dealers consider New York City as a promising market for McIntosh apples. This variety is coming into favor and there is a growing demand for Massachusetts McIntosh because of the excellent flavor and color. A few growers are now selling in Philadelphia, and further development of this market and others west and south is possible, especially for McIntosh.

A larger quantity of high grade home-grown apples, particularly McIntosh, is reducing the sale of Western apples on local markets. Doubtless this supplanting of Western apples can be carried still further.

According to the Federal Census reports the number of bearing trees in other New England states is declining, and while recent plantings have been heavy, they have not been sufficient to offset the dying of old trees. This decline will probably reduce outside competition on local markets to some extent.

Exporters report a growing demand for American apples of good grade in foreign markets. This market should be carefully guarded from apples of poor quality. Indeed, one method of improving the market generally is by keeping low grade apples off the market entirely. Some growers find it more profitable to make apples of B and lower grades into cider and other by-products than to send them to market. More care in growing, grading and packing fruit will mean profits instead of losses in the future.

A strong organization of fruit growers for the marketing of Massachusetts apples should be able to create or find more profitable markets for good grades of apples. An association of this sort could advertise more successfully than any individual. Advertising offers possibilities in building preferences for Massachusetts fruit in local markets; and it is also possible that through well-planned advertising people may be led to use more apples.

Under present conditions, the careful grower will not plant more trees until the market situation has been adjusted. Growing high grade fruit will remain profitable, although it is possible that the increase in crop will have some effect in lowering prices. Owners of small orchards are urged not to increase their plantings unless they are prepared to give their trees the same attention, and produce fruit of the same quality as that grown in the larger orchards.

The growing demand for McIntosh indicates that there will be little demand for other native varieties reaching the market at the same time. Prices of winter varieties will also be affected by the longer storage of McIntosh.

A study of the apple market, including both domestic and foreign demand, is now under way and will furnish definite information on the marketing situation.

TABLE I. Number of Apple Trees in Massachusetts, by Counties, 1925—Bearing, Non-bearing, Permanent and Filler.

County	Total Trees				Non-Bearing Trees				Bearing Trees			
	Permanent	Filler	Total	Per cent of Total	Permanent	Filler	Total	Per cent of Total	Permanent	Filler	Total	Per cent of Total
Middlesex	334,016	16,061	350,077	35.6	123,984	7,189	131,173	35.7	210,032	8,872	218,904	35.4
Worcester	225,019	23,363	248,382	25.2	98,243	14,368	112,611	30.8	126,776	8,995	135,771	21.9
Franklin	100,198	7,884	108,082	11.1	23,697	4,592	28,289	7.7	76,501	3,292	79,793	12.9
Hampshire	69,377	11,196	80,573	8.2	20,022	2,145	22,167	6.1	49,355	9,051	58,406	9.5
Essex	61,282	5,621	66,903	6.8	17,477	3,181	20,658	5.6	43,805	2,440	46,245	7.8
Hampden	29,944	833	30,777	3.1	7,840	625	8,465	2.3	22,104	208	22,312	3.6
Norfolk	25,663	397	26,060	2.5	9,362	7	9,369	2.5	16,301	390	16,691	2.7
Plymouth	20,703	2,818	23,521	2.4	7,827	1,934	9,761	2.7	12,876	884	13,760	2.2
Bristol	20,779	1,912	22,691	2.3	6,581	750	7,331	2.0	14,198	1,162	15,360	2.5
Berkshire	18,761	3,297	22,058	2.2	12,277	1,217	13,494	3.7	6,484	2,080	8,564	1.4
Barnstable	4,959	481	5,440	.6	2,835	350	3,185	.9	2,124	131	2,255	.4
Total	910,671	73,863	984,564	100.0	330,145	36,358	366,503	100.0	580,556	37,505	618,061	100.0

Table II. Age of Apple Trees in Massachusetts, by Counties, 1925

Age	Barnstable		Berkshire		Bristol		Essex	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	2,871	52.8	11,864	53.7	5,483	24.1	13,362	20.0
5–9 years	597	11.0	1,630	7.4	4,237	18.7	9,431	14.1
10–14 years	561	10.3	6,333	28.7	8,513	37.6	11,198	16.6
15–19 years	798	14.7	1,883	8.6	3,265	14.4	3,932	5.9
20–29 years	170	3.1	150	.7	517	2.3	2,275	3.4
Over 30 years	260	4.8	198	.9	666	2.9	13,421	20.1
Unclassified	183	3.3	. . . . .	. . . .	10	. . . .	13,284	19.9
Total	5,440	100.0	22,058	100.0	22,691	100.0	66,903	100.0

Age	Franklin		Hampden		Hampshire		Middlesex	
Under 5 years	17,505	16.2	5,210	16.9	11,150	13.8	71,103	20.3
5–9 years	17,988	16.6	5,113	16.6	19,855	24.6	97,560	27.9
10–14 years	17,500	16.2	8,227	26.8	19,146	23.8	58,210	16.6
15–19 years	9,934	9.2	3,875	12.6	6,516	8.1	20,664	5.9
20–29 years	14,141	13.1	3,653	11.8	6,808	8.5	20,149	5.8
Over 30 years	17,526	16.2	4,016	13.1	10,500	13.0	59,345	16.9
Unclassified	13,488	12.5	683	2.2	6,598	8.2	23,046	6.6
Total	108,082	100.0	30,777	100.0	80,573	100.0	350,077	100.0

Age	Norfolk		Plymouth		Worcester		Total	
Under 5 years	3,793	14.6	3,106	13.2	56,630	22.8	202,077	20.5
5–9 years	8,459	32.5	9,054	38.5	85,880	34.6	259,804	26.4
10–14 years	6,320	24.3	9,822	41.8	43,150	17.4	188,980	19.2
15–19 years	1,653	6.3	828	3.5	11,618	4.7	64,966	6.6
20–29 years	831	3.2	512	2.2	7,176	2.9	56,382	5.7
Over 30 years	1,189	4.5	195	.8	25,921	10.4	133,237	13.5
Unclassified	3,815	14.6	4	. . . .	18,007	7.2	79,118	8.0
Total	26,060	100.0	23,521	100.0	248,382	100.0	984,564	100.0

Table III. Number of Fillers by Varieties,

Bearing and Non-Bearing, 1925

Variety	Non-bearing	Bearing	Total	Per cent of Total
Transparent	1,648	2,836	4,484	6.1
Astrachan	631	453	1,084	1.5
Williams	108	590	698	.9
Duchess	3,898	4,136	8,034	10 9
Wealthy	18.059	16.455	34.514	46.8
McIntosh	5,188	4,432	9,620	13.0
Baldwin	200	1,228	1,428	1.9
Delicious	1,228	45	1,273	1.7
Wagener	4,330	3,095	7,425	10.1
Others	1,068	4,235	5,303	7.1
Total	36,358	37,505	73,863	100.0

Table IV. Age of Trees Planted as Fillers, 1925

Age	Non-bearing	Bearing	Total	Per cent of Total
Under 5 years	21,595		21,595	29.2
5–9 years	14,763	11,256	26,019	35.3
10–14 years		22,701	22,701	30.7
15–19 years		3,093	3,093	4.2
20–29 years		391	391	.5
Unclassified		64	64	.1
Total	36,358	37,505	73,863	100.0

Table V. Principal Varieties of Apples in Massachusetts—Bearing and Non-Bearing Trees, 1925, with Commercial Production, 1924.

Variety	Total Trees		Non-Bearing Trees		Bearing Trees		Commercial Production	
	Number	Percent of Total	Number	Per cent of Total	Number	Per cent of Total	Bushels	Per cent of Total
Baldwin	387,863	39.4	108,285	29.5	279,578	45.2	788,471	51.5
McIntosh	235,268	24.0	116,844	31.9	118,424	19.2	205,116	13.4
Wealthy	65,857	6.7	29,415	8.0	36,442	5.9	66,284	4.3
Gravenstein	49,424	5.1	20,839	5.7	28,585	4.7	114,786	7.5
Delicious	42,055	4.3	32,685	8.9	9,370	1.5	12,888	.8
Duchess	20,331	2.1	9,046	2.5	11,285	1.8	21,114	1.4
Transparent	16,252	1.6	6,743	1.8	9,509	1.5	20,461	1.3
Wagener	15,472	1.5	5,751	1.6	9,721	1.6	*	*
Greening	13,997	1.4	2,116	.6	11,881	1.9	26,079	1.7
Astrachan	13,545	1.3	6,089	1.6	7,456	1.2	22,247	1.5
Northern Spy	10,919	1.1	3,166	.9	7,753	1.3	13,565	.9
Williams	7,406	.7	2,249	.6	5,157	.8	17,370	1.1
Others	106,175	10.8	23,275	6.4	82,900	13.4	223,031	14.6
Total	984,564	100.0	366,503	100.0	618,061	100.0	1,531,412	100.0

* Production included in "Others".

Table VI. Age of Trees of Leading Varieties of Apples in Massachusetts, 1925

Age	Total Trees		Baldwin		McIntosh		Wealthy		Gravenstein		Others	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	202,077	20.5	55,062	14.1	60,950	25.2	18,289	27.8	11,056	22.4	56,720	23.0
5–9 years	259,804	26.4	69,785	17.9	95,156	40.9	20,135	30.6	14,714	29.4	60,014	24.4
10–14 years	188,980	19.2	58,064	15.0	58.759	24.8	18,452	28.0	8,113	16.5	45,592	18.5
15–19 years	64,966	6.6	30,521	7.8	11,415	5.0	6,007	9.1	3,396	7.0	13,627	5.5
20–29 years	56,382	5.7	34,641	8.9	4,323	1.9	1,839	2.8	4,306	8.8	11,273	4.6
Over 30 years	133,237	13.5	103,475	26.6	1,588	.7	419	.6	4,759	9.7	22,996	9.3
Unclassified	79,118	7.8	36,315	8.9	3,077	1.4	716	1.0	3,080	6.2	35,930	14.6
Total	984,564	99.7	387,863	99.2	235,268	99.9	65,857	99.9	49,424	100.0	246,152	99.9

Table VII. Age of Trees of Less Important Varieties* of Apples in Massachusetts, 1925

Age	Delicious		Duchess		Transparent		Wagener		Greening		Astrachan		Northern Spy		Williams		Others	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	25,065	59.6	5,473	26.9	3,986	24.5	1,233	8.0	880	6.3	3,344	24.7	1,211	11.1	1,489	20.1	14,039	13.2
5–9 years	10,925	26.0	6,759	33.2	6,084	37.4	7,606	49.3	1,439	10.3	4,669	34.5	2,846	26.1	1,640	22.1	18,046	17.0
10–14 years	4,797	11.4	5,643	27.8	4,012	24.7	4,906	31.7	2,493	17.8	1,990	14.7	3,427	31.4	1,370	18.5	16,954	16.0
15–19 years	778	1.9	1,336	6.6	840	5.2	643	4.1	688	4.9	828	6.1	975	8.9	672	9.1	6,867	6.5
20–29 years	229	.5	486	2.4	525	3.2	952	6.1	1,341	9.6	755	5.6	350	3.2	445	6.0	6,190	5.8
Over 30 years	144	.3	325	1.6	520	3.2	32	.2	5,804	41.5	1,150	8.5	1,524	14.0	1,367	18.5	12,130	11.4
Unclassified	117	.3	309	1.5	285	1.8	100	.6	1,352	9.6	809	5.9	586	5.3	423	5.7	31,949	30.1
Total	42,055	100.0	20,331	100.0	16,252	100.0	15,472	100.0	13,997	100.0	13,545	100.0	10,919	100.0	7,406	100.0	106,175	100.0

*Included in "Others" in Table VI

TABLE VIII. Average Number of Trees in Bearing Orchards of Different Sizes, 1925

Size of Orchard in Bearing Trees	Bearing Trees	Non-Bearing Trees	Total Trees per Orchard	Per cent Bearing
0	....	925	925	....
1-199	109	116	225	48.5
200-499	310	151	461	67.2
500-999	672	238	910	73.8
1000-1999	1,315	318	1,633	80.5
Over 2000	3,490	856	4,346	80.3
Average—all orchards	354	209	563	63.0

TABLE IX. Percentages of Trees and Production in Orchards of Different Sizes, 1925

Size of Orchard in Bearing Trees	Per cent of Growers	Per cent of Non-Bearing Trees	Per cent of Bearing Trees	Per cent of All Trees	Per cent of 1924 Production
0	5.4	23.9	....	8.9	....
1-199	49.4	27.3	15.3	19.8	19.2
200-499	27.4	19.7	23.9	22.4	28.2
500-999	11.5	13.1	21.9	18.6	23.4
1000-1999	3.8	5.8	14.2	11.0	13.0
Over 2000	2.5	10.2	24.7	19.3	16.2
Total	100.0	100.0	100.0	100.0	100.0

TABLE X. Commercial Production of Apples by Varieties, Graded and Ungraded, 1924 (bushels)

Variety	Graded	Ungraded	Per cent Graded	Total
Baldwin	285,038	503,433	36.4	788,471
McIntosh	107,439	97,677	52.2	205,116
Wealthy	28,001	38,283	42.4	66,284
Gravenstein	44,467	70,319	38.7	114,786
Delicious	5,125	7,763	39.7	12,888
Duchess	8,227	12,887	38.9	21,114
Transparent	7,808	12,653	38.2	20,461
Greening	7,970	18,109	30.5	26,079
Astrachan	7,579	14,668	34.1	22,247
Northern Spy	6,380	7,185	47.0	13,565
Williams	8,078	9,292	46.5	17,370
Others	41,778	181,253	18.7	223,031
Total Commercial Production	557,890	973,522	36.4	1,531,412
Total Culls, Ciders and Waste				181,328
Total Production				1,712,740

Table XI. Commercial Production of Leading Varieties of Apples, by Counties, 1924 (bushels)

Variety	Barnstable	Berkshire	Bristol	Essex	Franklin	Hampden	Hampshire	Middlesex	Norfolk	Plymouth	Worcester	Total
Baldwin	425	562	3,672	44,136	159,936	38,956	73,116	317,067	9,196	4,527	136,878	788,471
McIntosh	175	5,025	4,363	5,641	11,196	8,471	15,319	78,158	3,868	2,380	70,520	205,116
Wealthy	115	1,050	1,111	2,195	2,490	3,759	8,149	29,783	1,236	1,666	14,730	66,284
Gravenstein	135	. . .	770	3,623	1,623	1,637	1,877	84,521	2,060	461	18,079	114,786
Delicious	50	. . .	2,346	270	690	16	534	2,139	1,855	608	4,380	12,888
Duchess	8	600	729	1,304	1,224	2,010	2,469	9,718	256	360	2,436	21,114
Transparent	62	. . .	1,266	499	183	215	380	14,620	261	422	2,553	20,461
Greening	45	6	185	327	9,195	3,247	5,277	3,206	1,137	127	3,327	26,079
Astrachan	90	50	1,140	1,489	843	361	1,238	14,306	178	454	2,098	22,247
Northern Spy	70	9	79	682	1,410	3,027	2,341	3,381	339	255	1,972	13,565
Williams	20	. . .	635	634	72	1	109	13,388	113	66	2,332	17,370
Others	946	2,900	5,708	23,410	7,008	12,016	30,014	69,162	9,700	2,763	59,404	223,031
Total	2,141	10,202	22,004	84,210	195,870	73,716	140,823	639,449	30,199	14,089	318,709	1,531,412

TABLE XII. Total Production of Leading Varieties of Apples in Massachusetts, by Grades, 1924

Grades	Early Summer*		Wealthy		Gravenstein		McIntosh		Baldwin		Others		Total	
	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total
Commercial:														
Fancy	2,475	2.9	2,934	4.4	2,061	1.8	17,373	8.5	12,642	1.6	4,876	1.8	42,361	2.8
A	20,971	24.5	18,063	27.2	32,841	28.6	62,322	30.4	172,315	21.8	40,207	14.8	346,719	22.6
B	8,522	9.9	6,538	9.9	8,542	7.4	24,593	12.0	89,557	11.4	11,982	4.4	149,734	9.8
Ungraded, A and B out	1,502	1.8	466	.7	1,023	.9	3,151	1.5	10.524	1.3	2,410	.9	19,076	1.2
Ungraded, culls out	44,491	52.0	31,636	47.7	61,691	53.8	79,653	38.9	357,548	45.3	112,348	41.5	687,367	44.9
Tree Run	6,404	7.5	6,410	9.7	7,768	6.8	16,256	7.9	129,193	16.4	93,842	34.6	259,873	17.0
Farm Manufacture	71	. . .	4	. . .	38	. . .	36	. . .	1,215	.2	631	.2	1,995	.1
Farm Consumption	1,158	1.4	233	.4	822	.7	1,732	.8	15,477	2.0	4,865	1.8	24,287	1.6
Total Commercial Production	85,594	100.0	66,284	100.0	114,786	100.0	205,116	100.0	788,471	100.0	271,161	100.0	1,531,412	100.0
Culls, Ciders and Waste														
Culls and Ciders Sold	491		25		160		242		6,592		119,334		126,844	
Culls and Ciders Manufactured	25		. . .		60		65		2,411		22,650		25,211	
Culls and Ciders Consumed on Farm	1,056		27		150		12		7,861		14,778		23,884	
Shrinkage and waste	820		72		15		171		1,847		2,464		5,389	
Total Culls, Ciders and Waste**	2,392		124		385		490		18,711		159,226		181,328	
Total Production	87,986		66,408		115,171		205,606		807,182		278,560		1,712,740	

*Includes Transparent, Astrachan, Williams, Duchess, etc.

**Where only one figure for ciders was given, all varieties were included under "Others."

TABLE XIII. Percentages of Apples Sold by Different Methods, by Counties, 1924

Method of Sale	Barnstable	Berkshire	Bristol	Essex	Franklin	Hampden	Hampshire	Middlesex	Norfolk	Plymouth	Worcester	Total
Door to Door	28.5	6.1	12.3	9.6	8.2	17.0	30.3	6.3	25.8	18.3	9.3	10.3
Roadside	24.9	14.3	23.4	5.3	2.4	1.0	1.3	3.6	13.5	45.0	1.9	4.3
To Peddler	11.4		4.4	15.7	4.7	13.8	14.0	4.3	6.5		1.6	5.6
To Retailer	29.4	12.3	34.0	15.2	5.2	24 0	6.3	7.5	31.4	28.0	15.8	11.8
To Wholesaler		1.7	11.0	19.2	9.0	4.6	17.5	7.7	8.7		16.0	10.8
To Country Buyer			1.2	27.4	65.0	11.1	16.6	17.5	5.0	2.1	18.6	18.1
On Commission	5.7	65.5	13.8	6.7	.7	27.2	10.0	47.0	8.9		29.2	33.9
Farmers' Market					.2		1.0	.7		6.4	.5	.5
Co-operatively						.9	2.4	2.1			5.6	2.3
For Export				.7	1.6		.1	3.0			1.5	2.0

TABLE XIV. Percentage of Summer, Fall and Winter Apples Sold by Different Methods, 1924

Method	Summer	Fall	Winter	Total
Direct to Consumer	6.2	6.5	12.3	10.3
Roadside Market	8.8	6.4	3.0	4.3
Peddler	4.3	3.5	6.5	5.6
Retailer	11.5	10.0	12.5	11.8
City Wholesaler	6.1	7.4	12.6	10.8
Country Buyer	8.9	11.2	21.7	18.1
On Commission	51.0	46.5	27.2	34.0
Farmers' Market	1.0	.8	.4	.5
Co-operatively	.1	4.7	1.5	2.3
For Export	1.7	2.4	2.0	2.1

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

TECHNICAL BULLETIN No. 7 MARCH, 1926

BROODINESS IN RELATION TO FECUNDITY IN THE DOMESTIC FOWL

By F. A. HAYS and RUBY SANBORN

This bulletin is the seventh in the series of bulletins reporting the investigations of the Massachusetts Agricultural Experiment Station on heredity in the Rhode Island Red breed of poultry; and the second giving report of the study on broodiness in the same breed. In addition there have been published at various times scientific papers presenting the results of certain more or less minor phases of this study.

Expressed in terms of change in the character of the breeding flock, the data show that the percentage of broody birds has decreased from 90 in the foundation flock of 1912 to 27 in 1923, the last year reported in this publication. Associated with this decrease in broodiness, the average annual egg production has increased from 114 to 200 eggs. The data show, however, that decrease in broodiness is but one of many factors which have contributed to increased production.

Requests for bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

BROODINESS IN RELATION TO FECUNDITY IN THE DOMESTIC FOWL

By F. A. HAYS and RUBY SANBORN

Nature of Character Being Studied

Broodiness is the tendency of female birds to incubate or attempt to incubate eggs. The broody hen stays on the nest, clucks, ruffles feathers when disturbed, etc. It is a recurring cyclical trait in birds and should be considered as a normal phase of their reproductive process. It has no homologue in mammals since they reproduce viviparously (developed young). In reptiles, which are closely related to birds, we have oviparous reproduction, but the eggs are hatched without the attention of the mother.

All breeds of domestic chickens exhibit broodiness to some extent. The Asiatic or meat breeds are all intensely broody; the American breeds all exhibit the trait to a considerable extent; and the Mediterranean breeds, although said to be non-broody, always give some broody females.

There thus appear to be widely different degrees of broodiness. There have been birds in the Massachusetts Station flock that first showed broodiness in November of their pullet year and continued to exhibit its cyclical recurrence to the extent of ten or twelve times during the first laying year. Contrasted with this is hen C 960—non-broody during pullet year, twice broody the second year, and non-broody the third year. Also hen C 1347—non-broody as a pullet, broody once for 23 days her second year, and non-broody her third year. Hen C 4765 was broody once as a pullet for 17 days and non-broody her second year. On the other hand, we now have two hens (B [illegible]) and B 8797) that have completed four annual records without going broody. In general, three measures of broodiness may be used: namely, (1) the number of broody periods per year, (2) mean length of each broody period, and (3) total days of non-productiveness associated with broody periods. In all cases the length of a broody period has been taken as the period between last egg previous to going broody and first egg following "recovery."

Effect of Method of Handling

With the domestic fowl efforts are made to check the manifestation of broodiness so that the hen may begin laying again. Modern practice is to coop such hens in slat-bottom coops, making nesting almost impossible. After four to six days of such confinement, the bird may ordinarily be returned to the flock without resuming nesting. Such hens show wide diversity in length of time before resuming laying.

Trapnesting and regular removal of all eggs from the nests seem to "discourage" the onset of broodiness. Punnett reports two cases of hens from a broody-free race that were themselves non-broody for two years, later actually incubating and hatching eggs. This particular phase of the problem needs further elucidation.

Broodiness thus appears to be a normal phase of the reproduction of domestic chickens. Its occurrence seems to depend upon environmental and physiological stimuli as will be pointed out later.

Work Already Done.

By Other Investigators.

Bateson (1902) and Hurst (1905) both present data on crosses between broody and non-broody races, indicating that broodiness is a dominant character. No further information was obtained at that time.

Punnett and Bailey (1920) report some results using Black Langshans, Brown Leghorns and Gold-pencilled Hamburgs. Results:

Langshan ♀ x Leghorn ♂ gave all F_1* pullets broody. Of the F_2* generation 16 pullets were retained, 8 of which went broody as pullets. Punnett states that if the Langshans were of composition AABB and Leghorns aabb, F_2 should give 9 broody to 7 non-broody, a close approximation to actual ratio. The reciprocal cross, Leghorn ♀ x Langshan ♂ gave all broody in F_1, but in F_2 there were but 19 broody to 47 non-broody. Most of these birds were retained but one year. A few that were kept the second year added more broodiness so that the ratio is not 9 to 7, probably because of delayed appearance of broodiness.

In the Hamburg-Langshan cross, the F_1 hens were either non-broody or showed very little broodiness. Of 38 F_2 pullets, 4 were broody, 34 non-broody. These results suggest a third factor, N, which inhibits. F_1 birds would be NnAaCc, but factor N did not inhibit in all cases. The F_2 ratio gave 4 broody to 34 non-broody. Punnett states that his results are far from conclusive as to the true nature of the broody trait.

Pearl (1914) found much less broodiness in Barred Plymouth Rocks than exists in Reds. His method of measuring the intensity of broodiness was by the length of non-productive period. Other known factors, such as winter pause and molt make such a measure subject to error.

Work Done by the Massachusetts Station.

Goodale began the study of this trait in 1912. From that time up to 1921, when he severed his connections with the Station, very satisfactory progress was made in eliminating the tendency from the egg-laying strain of Rhode Island Reds †

Recent Work at the Massachusetts Agricultural Experiment Station.

In the fall of 1922 the writer took up this project using the same general plan with some modifications. The non-broody strain has been carried along with the intense broody strain and not as a part of the general flock in so far as the matings are concerned. The non-broody birds are now being carried along through the second and third laying years to definitely test their behavior with regard to broodiness. Similarly, the breeding males are being carried over and tested for genetic composition. In a paper entitled, "Inbreeding the Rhode Island Red Fowl with Special Reference to Winter Egg Production," the broody trait has been shown to confirm Goodale's AC theory which suggests that broodiness is due to the presence of two dominant, autosomal, complementary genes, A and C. Both must be present to produce broodiness, but either may be carried alone by non-broody birds.

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* F_1 and F_2 refer to generations one and two.

† See Mass. Agri. Expt. Sta. Bulls. 199 and 211.

Progress to Date.

General Progress from Year to Year.

Table 1.—Mean Degree of Broodiness by Years.

Year Hatched	Birds broody, per cent	Average number of broody periods per broody hen	Total number of birds available*	Annual Production
1912	89.60	4.4	125	114
1913	91.03	5.4	78	124
1914	85.95	4.3	121	103
1915	89.25	4.3	428	122
1916	86.31	3.5	431	134
1917	48.84	2.7	432	166
1918	61.40	2.9	215	169
1919	No annual records			
1920	46.03	2.9	126	200
1921	44.56	2.7	285	200
1922	28.91	1.9	399	200
1923	27.35	1.9	340	189

* This column includes all Rhode Island Reds except intense broodies and inbreds.

It will be observed that the percentage of broody birds has been reduced from 90 in 1912 to 27 in 1923. Great significance should also be attached to the fact that the mean annual egg yield has increased from 114 to 200 in the same period. In the 1912 flock each broody hen lost 75 days in broodiness her first year, while in the 1922 flock each broody hen lost but 29 days. The assumption seems justified, therefore, that progress in eliminating broodiness has been two-fold: namely, reduction in the percentage of broody birds, and reduction in the mean degree of broodiness.

The average number of days spent in broodiness for the 112 broody birds in the 1912 flock is 74.8. For the 71 broody birds in the 1913 flock the figure is 78.8 days. In the 1922 flock, made up of all birds except those bred for intense broodiness, there were 112 birds that were broody, with a mean of 28.71 days spent in broodiness. In the 1922 flock there were 33 birds bred for intense broodiness. These birds averaged 42.94 days broody for the pullet year.

Specific Results.

The non-broody strain has been strengthened during the past two years by the retention of non-broody hens up to five years old. Such hens have been used as breeders each season so that their genetic character for broodiness may be confirmed by the progeny test. Aged breeding males have also been retained for similar purposes.

An intense broody strain has been carried on from year to year. Females selected to perpetuate this strain have been selected with a view of combining the maximum number of broody periods with desirable traits from the standpoint of annual fecundity. This intense broody strain will eventually differ from the non-broody strain only in possessing the broody trait. It is possible in this manner to measure directly the effect of broodiness on fecundity. This intense broody strain differs from the foundation birds more in the distribution of broody periods throughout the laying year than in the number of broody periods.

Complete records of broodiness are also maintained on every female of the experimental flock to augment data collected in the broody experiment.

End to Be Attained

A flock of poultry breeding *true* for broodiness and non-broodiness.

Scope of This Report.

In this bulletin consideration is given to the actual relationship between pullet-year egg production and the broody trait as manifested during the first laying year. Coefficients of correlation have been calculated as follows:

Between broodiness and rate.
December rate—Sections 1, 2, 3, 4, 5, 16, 17.
Winter rate—Sections 6, 7, 8, 9, 10, 18, 19.
Annual rate—Sections 11, 12, 13, 14, 15, 20, 21.

Between times broody and length of broody periods.
Section 22.

Between winter rate and annual rate.
Section 23.

Between winter rate and annual egg yield.
Section 27.

Between annual rate and annual egg yield.
Section 28.

Between broodiness and egg yield.
Winter production—Sections 24, 25, 26.
Annual production—Sections 29, 30, 31, 32, 33, 34, 35.

Coefficient of Correlation.

The coefficient of correlation furnishes a concrete measure of the tendency of two characteristics to move together, to move in opposite directions, or to behave independently. In this particular study the characteristics studied both belong to the same individual fowl. Either a significant positive or negative correlation coefficient is useful to the breeder as a guide, and the magnitude of the coefficient shows him the relative amount of dependence between the traits or characters considered. The value of a coefficient of correlation from the biological standpoint depends upon its absolute magnitude and upon its relation to its probable error. A coefficient at least three times as great as its probable error is generally considered significant, even though its absolute magnitude is small. The deductions reported in this bulletin are based on the above conception. King (1923), however, states that the correlation coefficient should be more than six times its probable error. He further states that a correlation coefficient of less than .30 indicates a lack of marked correlation, that over .50 shows decided correlation. Furthermore, the correlation coefficient with its regression coefficients may be used for purposes of prediction. The value of a knowledge of the degree of correlation lies mainly in its use for selecting a group of breeders and not in the selection of individual breeders.

The true coefficient of correlation may only be calculated for a race pure with regard to the characteristics being studied, as Harris (1915) points out. False correlations result when two or more genetically different races are concerned in any calculation. Broody birds have been shown to be genetically different (Hays, 1924) from non-broody birds. In studying the relation of broodiness to fecundity, it has been deemed advisable to make three general groupings: namely, (1) total population of broody and non-broody combined, (2) only birds that went broody during the pullet year, and (3) broody or non-broody without regard to the degree of broodiness. The first series of calculations was made for two purposes: first, to confirm that broody and non-broody races are genetically different; second, to furnish evidence on the intensity characteristics in relation to the broody trait even in a mixed population of broodies and non-broodies. The third series of calculations was made by Yule's formula for presence and absence of a character, as given by Davenport (1907). All other calculations were made by the ordinary method for calculating the correlation coefficient for fluctuating variables.

The regression coefficient is readily calculated after the correlation coefficient is determined. It is useful to the breeder for selection purposes. If a group of hens, each five times broody, were selected, the regression coefficient might be used to estimate its probable average egg production. If the degree of correlation between days broody and annual production is known, it is a simple matter to calculate the probable annual egg record of hens broody for 25 days or for any other period of days. Thus the regression coefficient merely represents the amount of change in one character with respect to a unit change in another. For example, the regression coefficient of days broody on annual production is —.1171, and the regression of annual production on days broody is —.3295. What should be the average annual egg yield of hens broody for thirty days?

42.87 average days broody of all hens
30.00

—12.87 days broody below the average

—12.87 x—.3295 = 4.2407 + 164.885 (average production of all) =

169.1257, probable record of hens broody for 30 days

The correlation ratio is comparable to the correlation coefficient and has a similar use. The former is made use of where the correlation coefficient would be false. As a measure of association in mixed races the correlation ratio is reasonably accurate, but it is of less value than the correlation coefficient for prediction purposes. Since a constant is calculated for each of the two variables in correlation ratio, a difference in magnitude of these two constants sometimes occurs, probably due to genetic impurity. Correlation ratio has not been used extensively in these studies because the correlation coefficient has been calculated on the three classes of hens with respect to broodiness: namely, broody and non-broody, different degrees of broody, and broody or non-broody, so that regressions closely approach linearity.

Character of Birds Used.

Beginning in the spring of 1916 the plan of breeding Rhode Island Reds for high egg production was somewhat modified. On that year matings were planned to consider early sexual maturity, no winter pause, intensity, persistency, and especially non-broodiness. Particular attention was given to the elimination of the broody tendency by using females non-broody during the pullet year and males from non-broody mothers for breeding purposes. The original foundation stock was all standard-bred Rhode Island Red. No new blood has been introduced into the flock since the plan of mating for the five characteristics above referred to was inaugurated in 1916. Inbreeding has not been practiced to any considerable extent, but the line of ancestry has been markedly reduced so that the present flock traces to but a small number of the best foundation birds.

Records Kept

Records used in the study of broodiness include complete pedigree of all birds used; complete trapnest records of every female as long as retained; date hatched; date of first egg; age at first egg; weight at first egg; nesting records; date of appearance of broodiness; date of placing into broody coop; date of return to laying house; hatching record of females used as breeders; complete family record of the progeny from each mating; and daily, winter and annual records on all surviving females.

Intensity.

Intensity and rate are terms used interchangeably in this report. They refer to the number of eggs laid in a specific interval of time on a percentage basis of the maximum possible number of eggs in the time considered. *December Rate*, as used here, is a figure obtained by dividing the number of eggs laid by 31 if the hen began laying on or before December first. For birds that laid their first egg later than December first, the rate was calculated by dividing the number of December eggs by the number of days *from first egg* to the end of December. As a short-time measure of intensity this may be considered more accurate than the actual number of eggs laid during December, for obvious reasons. *Winter Rate* is calculated by dividing the total number of eggs from first egg to March first by the number of days from first egg to March first, less all pauses of four or more days in duration from November first to March first. *Annual Rate* is calculated by dividing the total eggs from first egg to 364 days thereafter, for all birds that showed no 30-day pause after March first, by the number of days from first to last egg. When a bird stopped laying for thirty or more days after March first, her laying year is assumed to terminate at the beginning of this pause, and her annual rate is calculated by dividing the number of eggs laid by the number of laying days before the pause.

Broodiness.

Broodiness has already been defined as the tendency of the female fowl to incubate or attempt to incubate eggs. The intensity of broodiness may be measured by the number of broody periods and by the mean length of broody periods. Both Pearl (1914) and Goodale (1920) have measured the length of each broody period by the cessation of egg production associated therewith. Goodale (loc. cit.), however, stresses the fact that winter pause and fall molt may prolong the non-productive period for a considerable time interval beyond the normal broody period.

In the present studies, the observation has been made that there is a remarkable degree of uniformity in length of broody periods in the same individual. In the occasional bird that goes broody during the fall or winter of her pullet year, the winter pause may greatly lengthen the period of non-production. In such cases we have allowed four days for the bird to begin laying after removal from the broody coop to the laying house. Such birds are removed from the broody coop only when they no longer show signs of broodiness. In such cases any pause up to March first, of greater duration than four days following removal of hen from broody coop to laying house, is not considered a broody pause.

Very frequently the laying year terminates with a broody period and no more eggs are laid for two or three months. In such cases the length of the last broody period is calculated in the same manner as outlined above for the winter season. This long period of non-production is without question due largely to the onset of complete molt and not to broodiness. The fact that non-broody birds exhibit this long period of non-production during molt is very convincing evidence on the point in question.

Relation of Broodiness to Fecundity.

In studying the relation of broodiness to fecundity, it has been necessary to study the degree of correlation between broodiness and rate of laying, times broody and mean length of broody periods, winter rate and annual rate, winter rate and annual egg yield, annual rate and annual egg yield, and broodiness and annual egg yield.

Unpublished data at this Station indicate that rate of laying or intensity is the most important single characteristic affecting egg yield. For this reason, the relation between broodiness and rate is of extreme importance. Either a positive or negative correlation between broodiness and rate would be far more significant genetically than would the absolute correlation between broodiness and egg production; for egg production has already been shown by Goodale and Sanborn (1922) to depend upon at least five characteristics and one of these characteristics is rate. In the present study of the relation of broodiness to fecundity these facts are fully considered.

1. *Correlation Between Times Broody and December Rate—Pullet Year.*

In this study pullets are included that were hatched on the following years: 1916, 1917, 1918, 1920, 1921, 1922 and 1923. The flock hatched in 1919 is not included because no annual records are available for that year on account of a disease epidemic. All Rhode Island Red pullets with normal records are included. In addition to the major portion of each flock that was bred for egg production, there are included a small number of inbred birds, a small number bred for intense broodiness, a small number bred for color, and a small number used in studying the inheritance of hatchability. Inasmuch as this report is a study of the relationship between broodiness and fecundity, there is no conceivable reason why a rather heterogeneous flock should not be as valuable for study as one of marked uniformity for all characteristics.

Some short-time record of production is often made use of by commercial poultrymen in predicting the laying ability of a pullet for the year. Winter pause is likely to appear in many birds during December and is very pronounced in earlier birds. Other birds beginning their laying year early and continuing to lay regularly through December, as well as those starting their laying year in December, will as a rule have high December rate. Possibly November records would be freer from the winter pause, but such records would be less valuable than December records for predicting either winter or annual egg records, as Harris and Goodale (1922) have shown. It therefore seems advisable to use December rate in studying the relation of broodiness to rate.

A total of 1945 birds consisting of both broody and non-broody are included in the study. The range in times broody is from 0 to 12, divided into 13 classes. The range in December rate is from 1 to 100, divided into five-unit classes. Constants calculated from this study follow:

Number of birds	1945
Mean times broody	1.41
Times broody standard deviation . . .	± 1.98
Mean December rate	59.60
December rate standard deviation . . .	± 20.40
Coefficient of correlation	$+.0639 \pm .0152$

The constants given above impress the reader with the marked variability in the birds studied, both with regard to times broody the first year and December rate of production. The apparently abnormal standard deviation in times broody is due to the large percentage of non-broody birds (51.23 per cent). In other words, an impure population is concerned.

The magnitude of the standard deviation in December rate signifies very marked variation in rate of laying for December. Even such a short-time measure of fecundity is subject to excessive variability.

The coefficient of correlation between times broody and December rate, although more than three times as great as its probable error, is of questionable magnitude and is a false correlation as Section 2 shows.

2. Correlation Between Times Broody and December Rate for Broody Birds Alone—Pullet Year.

In order to measure the relation of degree of broodiness, as indicated by the number of periods, to December intensity, only birds actually going broody have been used in the calculation of the correlation coefficient. Of the group of 1945 individuals studied in section 1, 949 birds actually went broody during the pullet year. This number has been used to study the relation of degree of broodiness to December rate. Constants arrived at follow:

Number of birds	949
Mean times broody	2.89
Times broody standard deviation . . .	± 1.95
Mean December rate	61.24
December rate standard deviation . . .	± 20.11
Coefficient of correlation	$+.0145 \pm .0219$
Regression broodiness on rate	$+.0014$
Regression rate on broodiness	$+.1498$

The very large standard deviation in times broody suggests a most pronounced variability in number of broody periods. The actual range is from 1 to 12. Since the modal class is broody but once, there can be but little further progress in reducing the mean number of broody periods within the broody race.

The mean December rate is slightly higher than that for both broodies and non-broodies combined, in section 1. The standard deviation in rate is of the same magnitude as that in section 1.

The coefficient of correlation between degree of broodiness and December rate is actually less than its probable error, and since it is of very small magnitude, the interpretation seems justified that December rate is independent of degree of broodiness, and that the correlation in section 1 is false.

3. Correlation between the Presence of Broodiness and December Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year.

The actual correlation between the presence of broodiness and high rate is of much importance to the breeder. Such a constant was calculated for the 1945 broody and non-broody birds by the method of Yule (loc. cit.).

December Rate	Broody	Non-Broody
Number above population mean	632	595
Number below population mean	317	401
Totals	949	996

Coefficient of correlation +.1466 ± .0150

Although the degree of correlation between the presence of broodiness and high December rate is not large, there can be no justification for any other deduction than that the presence of broodiness is partially linked with high December intensity. The elimination of the broody trait should result in something of a reduction in December rate for the flock as a whole.

A further consideration of this relationship in a flock high in broodiness and in a flock low in broodiness seems advisable. The 1916 flock showed 86.31 per cent broody and is unimproved, at least for broodiness. The 1923 flock showed 27.35 per cent broody and may be classified as an improved flock.

4. Correlation Between the Presence of Broodiness and December Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year (Unimproved Flock 1916).

In the total of 253 birds the following results were obtained:—

December Rate	Broody	Non-Broody
Number above population mean	138	14
Number below population mean	85	16
Totals	223	30

Coefficient of correlation $+.2996 \pm .0386$

The above constant suggests that in the 1916 flock there was a rather distinct tendency for broody birds to lay at a higher rate during December than non-broody birds. The constant given in section 3 for the entire period reported upon is $+.1466 \pm .0150$. A comparison of the two constants assigns them a similar value in comparison with their probable error, as each is about eight times its probable error. There is the possibility that December rate is higher in the early flock because they were slow to reach sexual maturity, so that winter pause was less pronounced in December than in later flocks.

5. *Correlation Between the Presence of Broodiness and December Rate above the Mean of Broodies and Non-Broodies Combined—Pullet Year (Improved Flock 1923).*

A total of 404 birds is studied in the 1923 flock, distributed as below:—

December Rate	Broody	Non-Broody
Number above population mean	78	157
Number below population mean	51	118
Totals	129	275

Coefficient of correlation $+.0695 \pm .0334$

The degree of correlation amounts to insignificance compared with its probable error. It indicates no dependence between the presence of broodiness and December rate above the mean. It is conceivable that early maturity may affect December rate, and winter pause is more pronounced in the flocks since the age at maturity has been reduced.

6. *Correlation Between Times Broody and Winter Rate—Pullet Year.*

This study included 2221 pullets hatched the same seven years as those studied for December rate. Winter rate is calculated on the period from first egg to March first, as already explained. Unpublished data at this Station indicate a rather intimate correlation between winter rate and annual production. Winter rate was calculated on a greater number of pullets than were studied for December rate, because the latter could only be calculated on individuals laying one or more eggs in December. The same classes were used in tabulating times broody and winter rate as were used in studying December rate. Constants calculated are as follows:—

Number of birds	2221
Mean times broody	1.43
Times broody standard deviation	±1.99
Mean winter rate	66.45
Winter rate standard deviation	±9.37
Coefficient of correlation	+.0706 ± .0142

The above constants show the mean winter rate to be greater than the mean December rate previously calculated. The above winter rate really signifies that, on the average, the birds laid 66.45 per cent of the maximum possible number of eggs when they were laying, since all pauses of four or more days have been deducted in calculating winter rate. The standard deviation in winter rate is only ± 9.37 compared with a figure of ± 20.40 for December rate. The winter pause and the fact that many of the birds actually lay their first egg during December account for the wider variability in December rate.

The coefficient of correlation between times broody and winter rate is almost identical with that between times broody and December rate. This is a constant of small magnitude, and is a false correlation because the population is made up of both broody and non-broody birds.

7. Correlation Between Times Broody and Winter Rate for Broody Birds Alone—Pullet Year.

In order to ascertain any possible relationship between winter rate and degree of broodiness, the correlation between times broody and winter rate has been calculated for broody birds alone. The constants obtained are as follows:—

Number of birds	1098
Mean times broody	2.89
Times broody standard deviation	±1.93
Mean winter rate	67.57
Winter rate standard deviation	±9.63
Coefficient of correlation	—.0314 ± .0203
Regression broodiness on rate	—.0063
Regression rate on broodiness	—.1564

The mean winter rate in those birds that actually went broody during their pullet year is 67.57 compared with 66.45 for broodies and non-broodies combined. Such a difference is of no significance.

The coefficient of correlation is negative. Its small magnitude, together with the size of its probable error, leads to the assumption that there is absolute independence between winter rate and degree of broodiness as measured by times broody.

8. Correlation Between the Presence of Broodiness and Winter Rate above the Mean of Broodies and Non-Broodies Combined—Pullet Year.

The absolute correlation between the presence of broodiness and high rate is of importance to the breeder. Such a constant will indicate whether or not the broody trait carries with it higher winter intensity than does the non-broody trait. The coefficient of correlation is calculated below according to Yule.

Winter Rate	Broody	Non-Broody
Number above population mean	674	558
Number below population mean	422	565
Totals	**1096**	**1123**

Coefficient of correlation $+.2358 \pm .0135$

The magnitude of the above constant points to a linkage between broodiness and high winter intensity. Herein lies a probable explanation why the heavier breeds, all of which carry the broody trait, are in general superior winter layers to the non-broody lighter breeds. In the history of the flock under consideration, the highest average winter records, 67.65 and 74.5 eggs, were made by the 1920 and 1921 flocks with a percentage of broodiness amounting to 46.03 and 44.56 respectively of birds included. The 1923 flock, for example, showed 27.35 per cent broody and a mean winter egg record of but 51.04. Probably broody birds carrying early sexual maturity and no winter pause are superior as winter layers to non-broody birds possessing the same two traits, because of some linkage between broodiness and high intensity. Further consideration is given to this important question in sections 9 and 10.

9. Correlation Between the Presence of Broodiness and Winter Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year (Unimproved Flock 1916).

Winter rate and broody records are complete for 332 birds in the 1916 flock. These have been correlated below:

Winter Rate	Broody	Non-Broody
Number above population mean	174	15
Number below population mean	115	28
Totals	289	43

Coefficient of correlation $+.4770 \pm .0286$

This is a rather pronounced correlation and shows winter intensity was associated with broodiness in an early flock.

10. Correlation Between the Presence of Broodiness and Winter Rate above the Mean of Broodies and Non-Broodies Combined—Pullet Year (Improved Flock 1923).

Winter rate and broody records for 430 birds hatched in 1923 are tabulated below:

Winter Rate	Broody	Non-Broody
Number above population mean	87	141
Number below population mean	51	151
Totals	138	292

Coefficient of correlation $+.2925 \pm .0297$

A significant coefficient of correlation between broodiness and high winter rate suggests that there is linkage between broodiness and high winter intensity. Further evidence has already been presented in sections 8 and 9. Herein lies the probable superiority of broody breeds over non-broody breeds in winter intensity.

11. Correlation Between Times Broody and Annual Rate—Pullet Year.

The method used in calculating annual rate does not allow for winter pause or for time lost while broody. It is simply a figure intended to measure the actual rate of laying between the time of laying the first pullet egg, and time of laying the last egg before the complete molt. Winter pause birds and broody birds are actually penalized in calculating annual rate. If there is absolute independence between broodiness and winter pause, the only normal handicap that the broody bird carries over the non-broody is the production loss during broody periods. Inasmuch as the magnitude of the annual rate depends most largely upon yearly egg production, this method of measuring rate should be most significant in breeding for fecundity. It is believed that this is a true measure of actual rate of laying during the year. Constants calculated from the 2245 individuals studied follow:—

Number of birds	2245
Mean times broody	1.44
Times broody standard deviation . . .	± 1.98
Mean annual rate	56.48
Annual rate standard deviation	± 9.85
Coefficient of correlation	$-.2620 \pm .0133$

The above constants show that the 2245 birds actually laid on 56.48 per cent of the possible days between their first egg and the time they ended their year with the complete molt. The standard deviation agrees closely with that for the winter rate. A mean rate of such a magnitude immediately suggests high annual production.

The coefficient of correlation between times broody and annual rate is negative; and its magnitude, together with its small probable error, suggests that broodiness and low rate tend to move together.

By the use of the regression coefficient we find that those birds with a mean rate of 60.48 will be less broody than the mean of all birds studied ($1.44 - .21 = 1.23$). The fact is very evident, therefore, that broodiness tends to lower annual rate of laying. The coefficient as determined, however, does not represent the true correlation, since the flock of 2245 birds is made up of both broody and non-broody races.

12. Correlation Between Times Broody and Annual Rate for Broody Birds Alone—Pullet Year.

A pure race in so far as the broody trait is concerned is to be found in the birds actually going broody during their first laying year. The total number of birds in this class for the seven years is 1122. By tabulating the annual rate of each individual against her number of broody periods a measure of the degree of correlation between degree of broodiness and annual rate is obtained. Constants calculated on this group follow:—

Number of birds	1122
Mean times broody	2.89
Times broody standard deviation	±1.91
Mean annual rate	54.93
Annual rate standard deviation	±9.24
Coefficient of correlation	—.3232 ± .0180
Regression broodiness on rate	—.0669
Regression rate on broodiness	-1.5610

The mean annual rate for the broody birds is slightly lower than was found for the total population in section 11 (56.48). No significant change is observable in standard deviation.

The coefficient of correlation is slightly larger than that obtained for the total number of birds, and represents a rather intimate negative correlation between times broody and annual rate. Degree of broodiness as measured by number of periods is therefore very inimical to high annual rate.

13. Correlation Between the Presence of Broodiness and Annual Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year (Flocks 1916-1923).

The true relation or correlation between the presence of broodiness and annual rate above the mean is of interest and value to poultrymen. Such a determination has been made for the 2245 birds being studied, by Yule's method.

Annual Rate	Broody	Non-Broody
Number above population mean	513	675
Number below population mean	609	448
Totals	1122	1123

Coefficient of correlation —.2828 ± .0131

The above constant does not differ significantly from that representing the whole population. In this particular case the mingling of a broody and a non-broody race in the same correlation table did not result in skew correlation. The constant —.2828 ± .0131 is known to represent a true value for the flock in question, and emphasizes the importance of breeding for non-broodiness to secure maximum annual records.

The next two sections are devoted to the correlation between the presence of broodiness and annual rate above the mean of broodies and non-broodies combined, using the high broody flock of 1916 and the low broody flock of 1923. Such a study shows the relative importance of broodiness in determining annual rate in a flock of low and high fecundity.

14. Correlation Between the Presence of Broodiness and Annual Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year (Unimproved Flock 1916).

Annual Rate	Broody	Non-Broody
Number above population mean	165	31
Number below population mean	159	18
Totals	324	49

Coefficient of correlation — .2480 ± .0328

This constant agrees well with that for the whole eight-year period. It is significant and illustrates the negative relation between broodiness and high annual rate in an unimproved flock.

15. Correlation Between the Presence of Broodiness and Annual Rate above the Mean of Broodies and Non-broodies Combined—Pullet Year (Improved Flock 1923).

Annual Rate	Broody	Non-Broody
Number above population mean	60	164
Number below population mean	76	129
Totals	136	293

Coefficient of correlation — .2338 ± .0308

This coefficient does not differ significantly from the coefficient obtained on the 1916 flock in section 14 or from the constant on all flocks in section 13. Evidently the relation of broodiness to annual rate has not changed with the improvement in fecundity.

In the previous sections, the relation between *times broody* and rate or intensity of production has been considered. A considerable body of evidence has been presented to indicate first, that hens with the broody trait do tend to lay more intensely during the winter season than non-broody hens; second, that broodiness is a considerable handicap to annual production in that it lowers the annual rate. The next consideration is the relation of *total days broody* during the pullet year to December rate, winter rate and annual rate.

16. Correlation Between Total Days Broody and December Rate—Pullet Year.

In this study the same group of 1945 birds both broody and non-broody that were studied in relation of times broody to December rate (section 1) is considered. It is important to know which is the more important from the standpoint of rate, the number of broody periods or the actual number of days spent in broodiness calculated so as to avoid winter pause and fall molt. Constants calculated on this group of birds follow:—

Number of birds	1945
Mean total days broody	23.20
Total days broody standard deviation . . .	±27.07
Mean December rate	59.60
December rate standard deviation . . .	±20.40
Coefficient of correlation	+.0529 ± .0153

The standard deviation in total days broody exceeds the mean total days broody because of the large percentage of non-broody birds in the group studied.

The coefficient of correlation agrees rather closely with the figure given in section 1 where times broody and December rate are considered. Evidently broodiness may be measured either by periods or by total days. The degree of correlation is slight, and it is really a false correlation because based upon a mixed population—broody and non-broody.

17. Correlation Between Total Days Broody and December Rate for Broody Birds Alone—Pullet Year.

The relation between degree of broodiness, as measured by total days of non-production associated with broodiness during the pullet year, and December rate may be determined by using only the birds that went broody the first year. Such a determination was made for the same group of 949 birds that was considered in section 2. The following are the constants:—

Number of birds	949
Mean total days broody	42.84
Total days broody standard deviation . . .	±27.38
Mean December rate	61.24
December rate standard deviation . . .	±20.11
Coefficient of correlation	—.0002 ± .0219
Regression broodiness on rate	—.0003
Regression rate on broodiness	—.0001

That degree of broodiness and December rate are entirely independent is shown by the above coefficient of correlation which is practically zero. This is rather conclusive evidence that December intensity bears no relation to the presence or absence of the broody trait.

18. Correlation Between Total Days Broody and Winter Rate—Pullet Year.

A total of 2221 birds studied in section 6 are included in this study to discover the degree of dependence or independence between total days broody and winter rate. The constants calculated follow:—

Number of birds	2221
Mean total days broody	23.50
Total days broody standard deviation	±27.04
Mean winter rate	66.45
Winter rate standard deviation	±9.37
Coefficient of correlation	+.0178 ± .0142

The coefficient of correlation is practically the same figure as was obtained between times broody and winter rate. This is also a false correlation because broodies and non-broodies each represent a genetic type. Since winter production and annual production are so intimately correlated (Hervey 1923; Hays, Sanborn and James 1924), high winter record is of very great importance in breeding for fecundity.

Blakeman's test for linearity of regression has been applied in this study with the following results:

Correlation ratio for days broody	+.1134
Correlation ratio for winter rate	+.1695
(Cor. Ratio)^2 — (Cor. Coeff.)^2 =	.0075 ± .0024
(Cor. Ratio)^2 — (Cor. Coeff.)^2 =	.0233 ± .0043

The difference between the correlation ratio for winter rate squared and the correlation coefficient squared is .0233 ± .0043, a difference more than five times as great as its probable error. This fact indicates that the coefficient of correlation is false, as might be anticipated from the fact that two genetic races are concerned.

19. Correlation Between Total Days Broody and Winter Rate for Broody Birds Alone—Pullet Year.

Winter rate records are available on 1098 birds that were broody the first year. In this study days broody is tabulated against winter rate to further discover the correlation between degree of broodiness and winter rate. Constants are as follows:—

Number of birds	1098
Mean total days broody	42.85
Total days broody standard deviation	±27.14
Mean winter rate	67.57
Winter rate standard deviation	±9.63
Coefficient of correlation	—.0241 ± .0203
Regression broodiness on rate	—.0679
Regression rate on broodiness	—.0085

The coefficient of correlation as shown above signifies independence between degree of broodiness and winter rate. The intensity of the broody trait is therefore of no concern in affecting winter intensity.

20. Correlation Between Total Days Broody and Annual Rate—Pullet Year.

The total days broody for each bird are tabulated against her annual rate. The lowest rate class is 16-20; the highest rate class is 86-90 The lowest broody class is 0-9; the highest broody class is 150-159 days. This study on the 2245 birds used in section 11 will show if broodiness is an advantage or disadvantage from the standpoint of annual rate. Are broodiness and high intensity linked together? Constants calculated are:—

Number of birds	2245
Mean total days broody	23.68
Total days broody standard deviation	±26.98
Mean annual rate	56.48
Annual rate standard deviation	±9.85
Coefficient of correlation	—.2720 ± .0132

The coefficient of correlation between days broody and annual rate is negative and of such magnitude as to be of considerable significance, were it not for the fact that the two races of birds give a false correlation.

21. Correlation Between Total Days Broody and Annual Rate for Broody Birds Alone—Pullet Year.

The same group of birds considered in section 12 is used in this study. The coefficient of correlation is here used to measure the degree of association between degree of broodiness and annual intensity. Constants obtained are the following:—

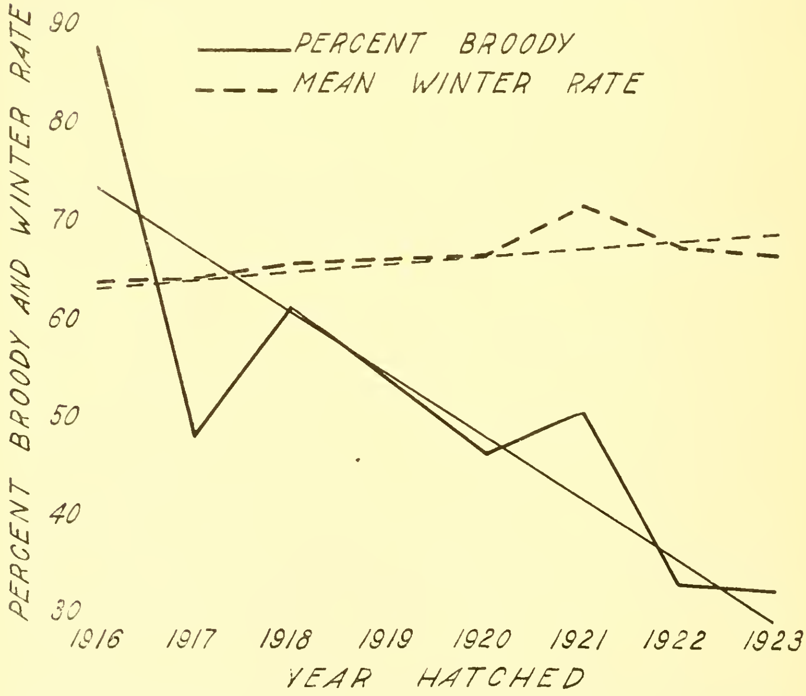

Chart I. Relation of percentage of birds broody to mean winter rate by years.

Number of birds	1122
Mean total days broody	42.87
Total days broody standard deviation . . .	±26.84
Mean annual rate	54.93
Annual rate standard deviation	±9.24
Coefficient of correlation	—.3622 ± .0175
Regression broodiness on rate	—1.0526
Regression rate on broodiness	—.1246

A rather marked degree of negative correlation exists between days broody and annual rate. The degree of broodiness influences annual rate because of the loss of time while broody. This constant agrees substantially with the constant for times broody and annual rate (—.3232 ± .0180).

Relation of Broodiness to Winter Rate and Annual Rate.

In charts 1 and 2 the mean percentage of birds broody on the different years is illustrated graphically by a solid line. The mean winter rate and

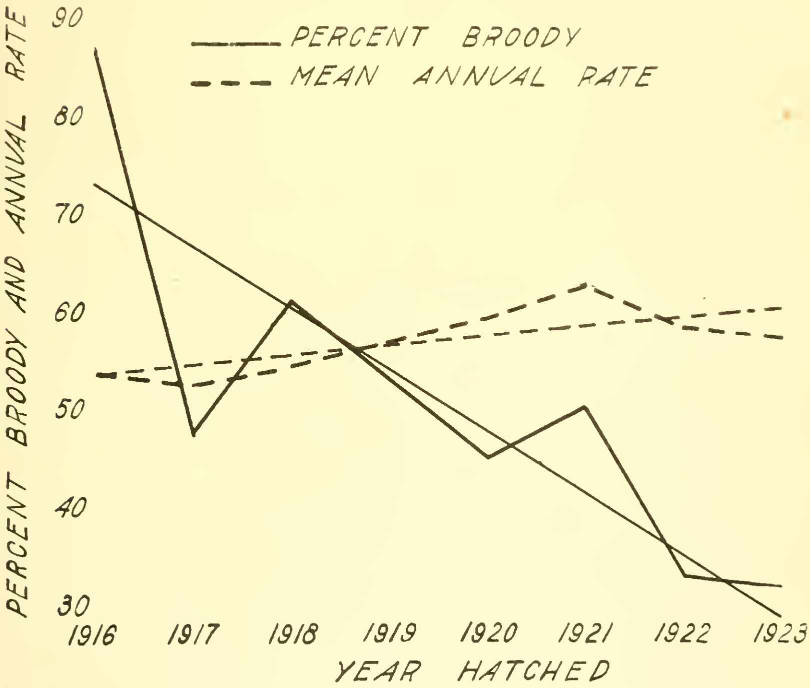

Chart 2 Relation of percentage of birds broody to mean annual rate by years.

mean annual rate are represented by broken lines. The groups of birds used in making the two charts are not identical because winter rate records are available on a considerable number of individuals that did not survive to complete annual records. However, the two groups are so nearly identical that the mean percentage of broody birds closely agrees in the two charts.

The increase in mean winter rate from 1916 to 1923 is 4.06, while the increase for annual rate in the same period is 6.00. This fact indicates that annual rate has increased more rapidly than winter rate as the percentage of broody birds has been reduced from year to year. The greater degree of parallelism in the two graphs on chart 1 suggests that a change in percentage of broody birds is usually accompanied by a change in winter rate. Chart 2 shows a lesser relationship between percentage broody and annual rate.

In general the two charts furnish evidence that both mean winter rate and mean annual rate may be increased while the percentage of broody birds is being reduced. The lowering of the percentage of broody birds to at least 30 per cent, as has been accomplished in the flock studied, appears to be advantageous from the standpoint of annual production.

The next section is devoted to a study of the relation between the number of broody periods and the mean length of broody periods. It seems desirable to ascertain if the average length of broody period is affected by the number of periods. Does the frequency of onset of broodiness tend to shorten or lengthen the period? The coefficient of correlation is again made use of and the number of broody periods is tabulated against the mean length of period, using 1135 birds that were broody in the pullet year.

22. Correlation Between Times Broody and Mean Length of Broody Periods—Pullet Year.

Any attempt to decrease the intensity of broodiness must be accomplished either by reducing the number of periods or by reducing the length of these periods. The coefficient of correlation is here calculated to discover a possible relationship between number and length of broody periods. Constants calculated are as follows:

Number of birds	1135
Mean times broody	2.89
Times broody standard deviation	±3.67
Mean length of periods	15.10
Length of periods standard deviation . . .	±3.78
Coefficient of correlation	—.2338 ± .0189
Regression times broody on length . . .	—.4620
Regression length on times broody . . .	—.1183

The total number* of birds showing one or more broody periods is slightly greater than the number in sections 12, 21, 30 and 32, broody records being available on a few birds on which annual rate records are lacking. The stand-

*The total number of birds going broody was 1135. Of this group, 1017 individuals were first broody after March first so that the actual length of the period of non-production attributable to broodiness could be definitely recorded. There were 118 birds broody before March first. The mean length of broody period for the 1017 birds is 15.95 days, while that for the group of 1135 birds is 15.10 days. This slight difference in mean length of period is not significant and may be attributed to our inability to separate broody pause from winter pause in those 118 birds going broody before March first. The method of allowing a bird but four days to begin laying after her return to the laying house following broodiness during the winter season is faulty in that it actually assigns a shorter broody period during winter than the mean of summer broody periods.

ard deviation in times broody is greater than the mean because 951 birds (83 per cent) fell into classes 1-4, leaving only 17 per cent in classes 5-13. The modal class is 2.

The mean length of broody periods is 15.10 days with a standard deviation of $\pm$ 3.78. There is, therefore, much greater uniformity in length of period than is observed for number of periods. Evidently the number of periods offers a more fertile field for improvement than is offered by the length of period.

The negative coefficient of correlation indicates that an increase in number of broody periods is accompanied by a decrease in their average length. A reduction in number of periods would therefore be accompanied by an increase in their length. That this relationship is far from absolute is shown by the magnitude of the correlation coefficient. Certainly the time lost in non-production has been very significantly reduced by decreasing the number of broody periods, as table 1 shows.

23. Correlation Between Winter Rate and Annual Rate—Pullet Year.

The records for 2242 individuals both broody and non-broody are available for study. This relationship is important because both rates bear a rather intimate relation to egg production. The fact has previously been pointed out that broody birds tend to be more intense winter layers than are non-broody birds, but that the former are likely to carry a lower annual rate. An intimate correlation between winter rate and annual rate would suggest that rate of laying for the year may be predicted from the winter rate. Constants calculated are as follows:—

Number of birds	2242
Mean winter rate	66.41
Winter rate standard deviation	$\pm$9.38
Mean annual rate	56.46
Annual rate standard deviation	$\pm$9.85
Coefficient of correlation	$+.1900 \pm .0108$

The above constants indicate a slightly greater relative standard deviation in annual rate than exists for winter rate. Such a condition might be surmised from the fact that broodiness and complete molt may both affect annual rate but for the most part are not concerned in winter rate.

A rather intimate correlation exists between winter and annual rate. Evidently those birds above the average in winter rate would be expected to be above the average in annual rate. The practice of selecting for high winter rate is without doubt sound from the standpoint of securing high annual rate.

24. Correlation Between the Presence of Broodiness and Winter Production above the Mean of Broodies and Non-broodies Combined—Pullet Year (Flocks 1916-1923).

The absolute correlation between the presence of broodiness and winter production above the mean of all birds is of much concern to poultrymen striving for high winter records. Such information will show whether or not broody birds tend to lay more eggs before March first than do broody-free birds. In section 8 some evidence is presented to indicate that broody birds do actually lay at a slightly higher rate than non-broodies when they are laying; but late sexual maturity, winter pause and the occasional winter broody period may possibly be more pronounced in the broody population. The actual correlation between the presence of broodiness and winter production above the mean is shown by the following table:—

Winter Production	Broody	Non-Broody
Number above population mean	561	561
Number below population mean	534	563
Totals	1095	1124

Coefficient of correlation $+ .0264 \pm .0113$

The above coefficient is so small as to be of no significance and it is less than three times the magnitude of its probable error. The deduction must be made from this study that broodiness and winter egg production are entirely independent even though broody birds do lay at a slightly higher rate in winter when they are laying.

25. Correlation Between the Presence of Broodiness and Winter Production above the Mean of Broodies and Non-broodies combined—Pullet Year (Unimproved Flock 1916).

Winter Production	Broody	Non-Broody
Number above population mean	149	14
Number below population mean	140	29
Totals	289	43

Coefficient of correlation $+ .3759 \pm .0318$

The above constant shows that broodiness bears a rather intimate correlation to high winter production in the 1916 flock. Such an assumption is based on the conclusion that the individuals laying more eggs in winter than the average of the flock (46.87 eggs) are high producers. Even though a small percentage of the 1916 flock reduced this winter record by being broody before March first, broody birds appeared to carry intensity to a sufficient extent to enable them to lay more eggs for the period than did the non-broody birds. It is rather striking that the total population (section 24) should not exhibit a constant similar to that for the 1916 flock. No doubt changes in early maturity and winter pause have operated to modify winter production to a greater extent than any possible lowering of intensity by the elimination of broodiness has been responsible for.

26. Correlation Between the Presence of Broodiness and Winter Production above the Mean of Broodies and Non-broodies Combined—Pullet Year (Improved Flock 1923).

Winter Production	Broody	Non-Broody
Number above population mean	77	140
Number below population mean	61	152
Totals	138	292

Coefficient of correlation + .1563 ± .0317

This constant is of questionable magnitude and signifies that winter production of the 1923 flock above the mean of 53.62 eggs is but little dependent upon the presence of the broody trait. The fact should be recalled, however, that the maximum winter production (74.5 eggs) was made by the 1921 flock with 44.56 per cent of the birds broody during the pullet year.

The later sections of this report are devoted to a consideration of the correlation between rate and egg yield and broodiness and egg yield.

27. Correlation Between Winter Rate and Annual Egg Production—Pullet Year.

In commercial poultry breeding for fecundity, a short-time measure of probable annual production is of vast importance. If the winter rate could be used as a basis for selecting breeding females as efficiently as the yearly record, it would be of vast economic importance. By making use of the coefficient of correlation, a measure of the probable worth of the winter rate in selecting for large yearly records is obtained. The constants arrived at in this study are given below:—

Number of birds	2242
Mean winter rate	66.41
Winter rate standard deviation	±9.38
Mean annual production	174.37
Annual production standard deviation . .	± 44.59
Coefficient of correlation	+.4561 ± .0113

The mean annual egg production of the 2242 birds used in section 27 was 174.37, with a standard deviation of 44.59, or a coefficient of variation of about 25 per cent. The class range in egg production is from 21 to 300 with class intervals of 10. This wide range in production is due to the heterogeneity of the flock and to the number of characteristics that affect production.

The magnitude of the correlation coefficient, together with the small probable error, suggests that winter rate is rather intimately correlated with annual egg production.

28. Correlation Between Annual Rate and Annual Egg Yield.

Annual rate as calculated for this flock is a rather concise measure of intensity for the entire pullet laying year. It should furnish a reasonably true measure of the bird's ability to lay throughout the year. Since the relation of broodiness to annual rate has already been considered, it seems advisable to correlate annual rate with annual yield. The calculations gave the following constants:

Number of birds	2289
Mean annual rate	56.38
Annual rate standard deviation	±9.86
Mean annual egg yield	172.21
Annual egg yield standard deviation . . .	±46.61
Coefficient of correlation	+.6717 ± .0077

A very sensible positive correlation was found between annual rate and annual egg yield. Annual rate is thus a very dependable measure of a bird's ability to lay during her pullet year.

29. Correlation Between Times Broody and Annual Production—Pullet Year.

The records of 2245 birds broody and non-broody are tabulated and the coefficient of correlation calculated between times broody and annual production. Constants arrived at follow:—

Number of birds	2245
Mean times broody	1.44
Times broody standard deviation	±1.98
Mean annual production	173.06
Annual production standard deviation . .	±46.40
Coefficient of correlation	—.2126 ± .0136

This constant is false because the table is made up of two genetically distinct races, namely, broody and non-broody.

Table 2.—Relation of Broodiness to Egg Record.

Times Broody	Number of Birds	Egg Record
0	1121	181.31
1	312	178.32
2	259	156.62
3	220	156.50
4	149	158.65
5	72	162.58
6	47	153.59
7	28	140.14
8	17	155.50
9	9	147.72
10	5	145.50
11	2	160.50
12	1	155.50
13	1	145.50

Reference to table 2 above shows that the 1121 non-broody birds averaged 181.31 eggs per year. Close to this group in production is the class of 312 birds with but one broody period, averaging 178.32 eggs. A somewhat gradual but not regular decline begins with the group broody twice. No further decline is observed until the group with six broody periods is reached, after which the mean egg yield falls significantly. The probable error increases so rapidly due to small numbers when the class with eight broody periods is reached that very little significance can be attached to the mean in this and later classes. On the whole, this table suggests in a general way that increased broodiness does lower the annual record.

30. Correlation Between Times Broody and Annual Egg Yield for Broody Birds Alone—Pullet Year.

A true measure of the correlation between times broody and annual production can only be found within the broody population as previously stated. In the eight-year period 1122 broody birds are concerned. This group has been tabulated and constants calculated.

Number of birds	1122
Mean times broody	2.89
Times broody standard deviation	±1.91
Mean annual production	164.89
Annual production standard deviation . . .	±45.03
Coefficient of correlation	—.1791 ± .0195
Regression broodiness on production . . .	—.0076
Regression production on broodiness . . .	—4.2167

A negative coefficient of correlation of .1791 ± .0195 indicates that the correlation between times broody and annual production may not be considered intimate. Such a constant leads to the assumption that broodiness as measured by periods has played some part in limiting annual production for the eight-year period studied.

31. Correlation Between Total Days Broody and Annual Production—Pullet Year.

Broodiness may next be measured in total days for the year. This method of measuring has been made use of between total days broody, and annual egg production. The birds used in this tabulation are 2245 in number, both broody and non-broody. Constants calculated follow:—

Number of birds	2245
Mean total days broody	23.68
Total days broody standard deviation . . .	±26.98
Mean annual production	173.06
Annual production standard deviation . .	±46.40
Coefficient of correlation	—.2200 ± .0135

An interesting and important fact is brought out by the above constants in that the correlation between total days broody and annual egg record is negative and of almost the same magnitude as that obtained between times broody and annual egg record (section 29). The deduction that broodiness lowers annual record again seems warranted, but the coefficient obtained in this table is false because of the presence of the genetically different broodies and non-broodies.

32. Correlation Between Total Days Broody and Annual Egg Yield for Broody Birds Alone—Pullet Year.

A tabulation made of the 1122 broody birds gives the true correlation between degree of broodiness and pullet-year production. Constants obtained are the following:—

Number of birds	1122
Mean days broody	42.87
Days broody standard deviation	±26.84
Mean annual production	164.89
Annual production standard deviation . .	±45.03
Coefficient of correlation	—.1964 ± .0194
Regression days broody on production . . .	—.1171
Regression production on days broody . . .	—.3295

The degree of correlation between total days broody and annual egg record is not at all intimate. It is in very close agreement with the constant for times broody and annual egg yield, in section 30. On the whole, broodiness has been shown to be negatively correlated with annual production to a rather moderate degree over the eight-year period covered in this report.

33. Correlation Between the Presence of Broodiness and Annual Production above the Mean of Broodies and Non-broodies Combined—Pullet Year (Flocks 1916-1923).

The true correlation between the presence of broodiness and high annual egg production is determined below.

Annual Production	Broody	Non-Broody
Number above population mean	514	665
Number below population mean	608	458
Totals	1122	1123

Coefficient of correlation .2640 ± .0132

The above constant is statistically significant and is of sufficient magnitude to warrant the assumption that broodiness is negatively correlated with high annual production. The fact that annual egg record depends upon a vast array of genetic and non-genetic factors should not be overlooked. During the eight-year period being considered there has been constant progress in eliminating broodiness, yet the mean annual egg records of the flocks have been stable since 1920. Very likely broodiness has played a greater part in affecting production in some years than on others. The two following sections show that the correlation between broodiness and annual record has not been intimate either in 1916 or 1923.

34. Correlation Between the Presence of Broodiness and Annual Production above the Mean of Broodies and Non-broodies Combined—Pullet Year (Unimproved Flock 1916).

Annual Production	Broody	Non-Broody
Number above population mean	165	27
Number below population mean	159	22
Totals	324	49

Coefficient of correlation — .0837 ± .0347

The correlation coefficient is negative and less than three times its probable error. The conclusion seems to be warranted that in the 1916 flock there is no significant correlation between broodiness and annual production.

35. Correlation Between the Presence of Broodiness and Annual Production above the Mean of Broodies and Non-broodies Combined—Pullet Year (Improved Flock 1923).

Annual Production	Broody	Non-Broody
Number above population mean	67	164
Number below population mean	69	129
Totals	136	293

Coefficient of correlation — .1339 ± .0320

This coefficient is about four times its probable error and is probably of some significance. The degree of correlation between broodiness and annual production is slight on the two years studied; a fact that probably indicates more correlation on the intervening years.

General Summary and Deductions

The means for the broodies and non-broodies for the three rates and for winter and annual production for the eight-year period are as follows:—

	Broody		Non-broody	
	Number of Birds	Mean	Number of Birds	Mean
December Rate	949	61.24	996	58.05
Winter Rate	1098	67.57	1123	65.36
Annual Rate	1122	54.93	1122	58.04
Winter Production	1094	60.46	1123	58.79
Annual Production	1122	161.89	1121	181.31

1. Birds carrying the broody trait lay at a slightly higher rate when they are laying than do non-broody birds. This characteristic is observable in both December records and in winter records.

2. A much more intimate correlation between the presence of broodiness and high December intensity was observed in the 1916 flock than in the 1923 flock. This difference may probably be attributed to changes in sexual maturity and to the time of onset and termination of winter pause.

3. Intensity for the winter period is rather intimately correlated with the presence of broodiness. Such a relationship is observed in the total population for the eight years, in the 1916 flock and in the 1923 flock.

4. Degree of broodiness is not correlated with either December rate or winter rate.

5. The degree of correlation between broodiness and high annual rate is constant but negative and significant.

6. Degree of broodiness may be measured with equal accuracy by number of broody periods or by total days broody during the pullet year.

7. Winter rate and annual rate are distinctly positively correlated.

8. The duration of the broody period is somewhat lessened as the number of periods increases.

9. Correlation between the presence of broodiness and winter production above the average is negligible when all the birds are considered over the eight-year period. There is a significant positive correlation for the 1916 flock and probably a slight correlation within the 1923 flock.

10. The mean winter egg record of broodies is not significantly greater than that of non-broodies.

11. Annual egg production is significantly negatively correlated with broodiness in the total population studied; to a very minor degree in the 1916 flock; and to a rather moderate degree in the 1923 flock.

12. The elimination of broodiness has had but little significance in breeding for high winter production but a pronounced significance in breeding for high annual records.

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SOIL REACTION AND BLACK ROOT-ROT OF TOBACCO

By P. J. ANDERSON, A. VINCENT OSMUN and W. L. DORAN

Black root-rot is a serious menace to successful tobacco production in the Connecticut Valley. The causal fungus is found in most tobacco soils of the Valley. Low temperature during the growing season, and high lime conditions in the soil, both stimulate its activity. Injury may vary all the way from complete destruction of the crop, on heavily limed soils in cold growing seasons, to a damage scarcely noticeable. Not only does the root-rot depress yield, but it may injure quality of leaf as well.

There are but two known methods of combating the disease: first, through control of lime conditions in the soil; and secondly, through the use of root-rot resistant strains of tobacco. This bulletin reports results of research on the former.

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By P. J. ANDERSON, A. VINCENT OSMUN and W. L. DORAN[1]

Black root-rot probably causes greater loss to the tobacco growers of the United States than does any other disease. In the Connecticut Valley, according to published records, it has caused varying amounts of damage since 1906. It was probably prevalent long before that time, but had escaped attention. Within the last decade its ravages have been reduced considerably through improved cultural practices, based on a better knowledge of the effect of certain environmental factors on the virulence of the disease. Nevertheless it still takes its annual toll from the crop and, as one of the causes of "tobacco sick" soils, is an important factor in tobacco production in Massachusetts.

Symptoms of Black Root-Rot

The first symptom of the disease which the grower notices in the field is that the tobacco doesn't grow. The plants remain stunted, with narrow, thick, tough leaves and either a starved yellow color or, where the nitrogen supply is high, a very dark green color commonly called "black" by the tobacco man. On hot days the leaves wilt and "flag" more quickly than healthy tobacco plants. The dwarfed plants "top out" prematurely. Only rarely is a field equally affected in all parts. Usually there are "patches" from a square rod to several acres in extent, where the tobacco is short while in other parts of the field the growth is normal. In the diseased "patches" the plants are frequently very uneven in growth.

From the above ground symptoms, however, it is not possible for even an expert to be sure that this is black root-rot. Other troubles such as brown root-rot, lack of fertilizer, or water-logged soil may produce the same appearance. One must dig the plants and wash the soil from the roots to see the lesions which are the unmistakable signs of black root-rot. Normal young roots are white, but on a diseased plant many are black (brown at first), either throughout their length or frequently only in segments, with other segments appearing normal. Most of the ends of the small roots are black, indicating that in digging the plant, the root broke at this point and the decayed end was left in the soil. The tissue of the smaller roots is rotted through, but on the large roots there occur enlarged, rough, scurfy lesions which may or may not kill the interior tissues. Frequently the tap root is entirely rotted off at the bottom and there is an increased number of laterals. This results in a brush-work of intermingled brown, black and white small roots just above the blackened end of the main root. The brown lesions are caused by the same organism (*Thielavia basicola* Zopf)[2] which later produces the black ones, the color depending on the age of the lesion. The character which distinguishes this disease from all other tobacco diseases is the coal black color of parts of the roots. The reduced root system is unable to se-

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1 During the first year of this investigation the work was conducted by G. H. Chapman, formerly research professor of Botany at this Station.

2 McCormick (Conn. Agr. Exp. Sta. Bul. 269, 1925) considers this *Thielaviopsis basicola* (Berk.) Ferraris.

cure sufficient water and soil nutrients for normal growth of the above ground parts of the plant, hence the dwarfed slow growth and "flagging" on hot days.

Black root-rot may also occur in the seed-beds, where it exhibits the same symptoms, viz., slow growth, yellow or "black" color of leaves, "flagging," and black rotted roots. Many of the plants also die. The beds look very uneven.

Previous Investigations

In the first experiment station publication which recorded and described the disease in the Connecticut Valley, Jenkins and Clinton (5:7)[3] stated:

"It is not definitely known whether an acid, alkaline or a neutral soil is best adapted to the growth of the fungus, which we know can grow in the soil itself apart from the tobacco root, but it is reasonable to suppose that this factor may have its influence."

Later (5:8):

"One of the growers whose fields suffered severely was inclined to lay it to the excessive use year after year of potash fertilizers, which gradually accumulated in the soil, and especially to the use of the carbonate of potash."

The first, and up to the present date the most important, contribution on the relation of soil reaction to root-rot was a brief circular by Briggs (1) describing results of experiments in Connecticut in 1907. His conclusions are best summarized in the following statements which we quote:

"The results of the writer's investigations thus far indicate that the tobacco is much more severely injured by the fungus on fields where the soil has been made alkaline by the long-continued use of large amounts of lime, ashes and fertilizers containing carbonate of potash."

"In all cases it was found that the plots on which carbonate of potash was used gave the smallest plants and the lowest yields. The use of lime with the carbonate of potash still further diminished the yield. The use of carbonate of potash and lime with cottonseed meal and ground fish gave a yield of but 900 pounds per acre. This yield was 200 pounds less to the acre than when no fertilizer was used and was only a little more than half the yield obtained from some of the other plots."

In pot experiments he found that:

"In soils free from root-rot, the use of 1 per cent of lime gave a better growth of tobacco than where no lime was used. This shows that the lime does not injure the tobacco directly . . . . The use of hydro-chloric acid, on the other hand, increased the yield by about 10 per cent although this acid carries no plant food . . . . The root systems of the plants in all the pots to which lime or carbonate of potash was added were badly diseased . . . . The roots of the plants grown in acid-treated soil were perfectly clean and white, and entirely free from the fungus."

All of Briggs' experiments were with naturally infested soils from fields where the soil acidity had been greatly reduced by use of alkaline fertilizers and lime. The reaction of the soil was not determined either before or after the treatments which he applied.

Johnson and Hartman (7:53-60) determined the influence of soil reaction on root-rot by growing plants in pots after adding graduated quantities of

3 Numbers in parenthesis refer to bibliography at the end of this bulletin. Numbers after the colon give the page on which statement referred to may be found.

calcium hydroxide to a naturally very acid soil inoculated with macerated diseased roots. Acidity was determined in terms of lime requirement according to the Truog method. From these experiments they concluded that:

" . . . the highest acidity practically eliminated damage from root-rot, but that heavy infection still occurred in fairly acid soil."

When they inoculated all the soils heavily with spores of the fungus *just before planting*, they found that:

"A heavy infestation apparently reduced the efficacy of the acid soils to nothing, at least in the presence of a susceptible variety. The disease appeared, in fact, more virulent in the most acid soil."

This last experiment indicates that the effect of the acid soil is not to increase the resistance of the plant but to retard the development of the fungus.

They also tested in the field the effect of application of acid fertilizers and concluded that:

"For Wisconsin conditions . . . . application of acid fertilizers to soil, alkaline or neutral in reaction, will not reduce infection by *T. basicola*."

Chapman (2) in connection with an investigation of "tobacco sick" soils of Massachusetts made 300 determinations of the lime requirement of tobacco soils and correlated them roughly with the condition of the crop and prevalence of root-rot. He concludes (2:38) that:

"Soils with a lime requirement up to 3000 pounds CaO per acre are not producing good crops as a rule and are comparatively free from root-rots. Those with a lime requirement of from 3000 to 8000 pounds CaO per acre are in good tobacco condition; but in this group, pathogenic fungi are abundant in the soil, and the plants during certain seasons, are very liable to suffer from root-rots caused by some of these fungi. Soils with a lime requirement of 8000 pounds CaO up are usually comparatively free from such fungi, and even in unfavorable seasons, little disease is found."

He explains the relative freedom from root-rot of the soils which show the lowest lime requirement by assuming that these soils are too alkaline for the development of the fungus. His results on this point are at variance with those of Johnson and Hartman. The poor yield is attributed to the unfavorable effect of a too alkaline soil on the tobacco plant.

Chapman questioned the lime requirement method as a means of measuring the acidity of the soils.

Need of Further Investigation

We may summarize the results of all the investigations recorded up to the present: A soil made less acid by the use of lime, carbonate of potash, or ashes favors the development of black root-rot. When, however, the acidity is increased, there is a corresponding reduction in amount of root-rot injury until a point is reached where it is negligible. In regard to the particular degree of acidity which must be attained to escape root-rot and, in general, the correlation of reaction and infection throughout the soil range, Briggs gives no information while Johnson and Hartman and Chapman had contradictory results. In view of this situation and the fact that it is now commonly accepted that the development of fungi is proportionate to *intensity* of acidity as measured by the hydrogen ion concentration method, rather than the *amount* of acidity, as measured by the lime requirement method, there seemed to be need for further experimentation.

Two related problems concerned (1) the effect of lime on tobacco in the absence of root-rot and (2) the effect of the timothy cover crop.

In regard to the first, it is safe to assume that the growers considered lime beneficial, else it would not have come into such general use. Briggs found that 1 per cent of lime in disease-free soil increased growth. Hartwell and Damon (3:437) include tobacco among the lime loving plants. McCall (9) reports that, on heavy loam soil in Maryland, lime increased the yield of tobacco, but that direct applications of lime tended to lower the quality of the leaf. Hutcheson and Berger (4:7) found that, in Virginia, lime at first gave a larger yield but the tobacco was coarse and "bony." In the later years of the experiments, however, they found the tobacco reduced both in quantity and quality by lime. It is quite possible that in this case the later effects were due to root-rot rather than to the direct effect of lime. This is true in other similar experiments where the first effects were good but in later years there was a reduction. Since in most cases root-rot is not mentioned, one cannot be sure whether the experimenter was measuring the effect of the lime or of root-rot. This difficulty renders worthless most of the literature on the effect of lime on tobacco.

During the last decade, the use of timothy as a cover crop has come into considerable favor with tobacco growers of the Connecticut Valley. It reduces washing and blowing of the light soils during the long period between tobacco crops and also adds considerable humus to the soil. Some growers also have the impression that it reduces black root-rot by neutralizing in some way the ill effect of lime. When this experiment was begun there were no published records of experiments to determine the effect of its use on the succeeding crops of tobacco. It became desirable, therefore, to test by accurate experiments its immediate and cumulative effects.

The Five-Year Experiment

In 1921 a series of experiments was, therefore, started for the purpose of answering these three questions:

1. What effect does application of lime have on growth of tobacco in the absence of root-rot?
2. What is the relation between severity of infection and acidity as measured by hydrogen ion concentration?[4]
3. What is the effect of a timothy cover crop on the yield and quality of tobacco and on the severity of root-rot?

During the last five seasons Havana tobacco has been grown continuously on a field of 1.2 acres on the experiment station farm where no tobacco has been previously raised for at least 8 years. The soil is apparently of the Gloucester series. The field was divided into 24 plots of 1-20 acre each according to the diagram presented in figure I. It will be noted from this diagram that limed strips of plots alternated with unlimed strips in one direction; while at right angles, there were duplicate strips of plots (1) without

4 In measuring reaction in terms of hydrogen ion concentration method, a neutral soil or other substance is designated by the number pH 7, acid substances by the numbers below 7, alkaline substances by those above 7 up to 14. Thus a soil designated by 6 is slightly acid; 5, much more so; 4, more than 5; etc. We are not concerned here with the alkaline end of the scale since all our tobacco soils are naturally acid, and fall within the range from 4 to 7. Even when a large amount of lime is applied, they do not remain above 7 for any considerable time. The degrees of acidity are usually written pH 5, pH 4.5, etc.

cover crop (2) with timothy cover crop and (3) with clover cover crop.5. One-half of the field was inoculated while the duplicate half was not inoculated. All cultivation was in the direction of the cover crop strips, thus avoiding as far as possible carrying the fungus to the uninoculated half.

The limed plots were treated year by year as follows:

1921, ground limestone,		4000 lbs. per acre
1922, precipitated lime	(51 per cent CaO),	2000 " " "
1923, agricultural lime	(60 " " CaO),	4000 " " "
1924, no lime		
1925, no lime		

The fertilizers applied each year just before setting the plants are described in the following table.

Fertilizers Used—Pounds per Acre

Material	1921	1922	1923	1924	1925
Cottonseed Meal	1200	1200	1481	1270	828
Ammonium Sulfate	120	120	62	90	100
Dry Ground Fish	180	180	247	195	200
Acid Phosphate	160	160	......	....	....
Precipitated Bone	120	120	432	276	....
H. G. Sulfate of Potash	240	240	278	252	280
Ammo-Phos	....	....	....	....	234
Total rate per acre	2020	2020*	2500†	2083‡	1642‡

* Plus a quickly available side dressing at the second hoeing.
† Plus 250 lbs. nitrate of soda per acre applied in July.
‡ Equivalent to 3000 lbs. per acre of a 5-4-5 fertilizer.

That half of the field which was inoculated (see Figure 1) was first inoculated in 1921 by setting in it diseased plants taken from a badly infested seed bed. In order to secure heavier infection on the inoculated half, a handful of soil from a heavily infested greenhouse bed was placed in the furrow where each plant was set in 1922. The inoculated half of the field was again inoculated just before setting the plants in 1923, when two cartloads of heavily infested soil from a greenhouse bed were scattered broadcast over it and harrowed in.

Timothy and clover cover crops were sown after harvesting the tobacco in 1921, 1922, and 1923. None were sown in 1924.

Soil samples for pH determination were taken from all plots each year, and the hydrogen ion concentrations which were determined are recorded in Table I.6 These soil samples were taken before the ground was broken in

5 Since the clover winter-killed every year, its effect if any must be attributed to the very small growth between sowing and freezing of the soil.

6 These and subsequent determinations were made by F. W. Morse, Henri D. Haskins, and L. S. Walker, chemists on the staff of the Massachusetts Agricultural Experiment Station. The determinations were made on air dried soils by the Clark and Lubs colorimetric method. The water extract was made by adding 200 cc. of distilled water to 20 grams of air-dry soil in a flask and allowing it to stand about 1 hour with frequent shaking. The extract was then filtered by turning the soil mixture on a small filter in a large funnel. The first portions of the filtrate were returned to the soil flask until the extract was running clear. By this time, the paper was filled with soil, and the filtration was through soil supported by a small paper. By this means, any absorption by the paper was reduced to its lowest terms.

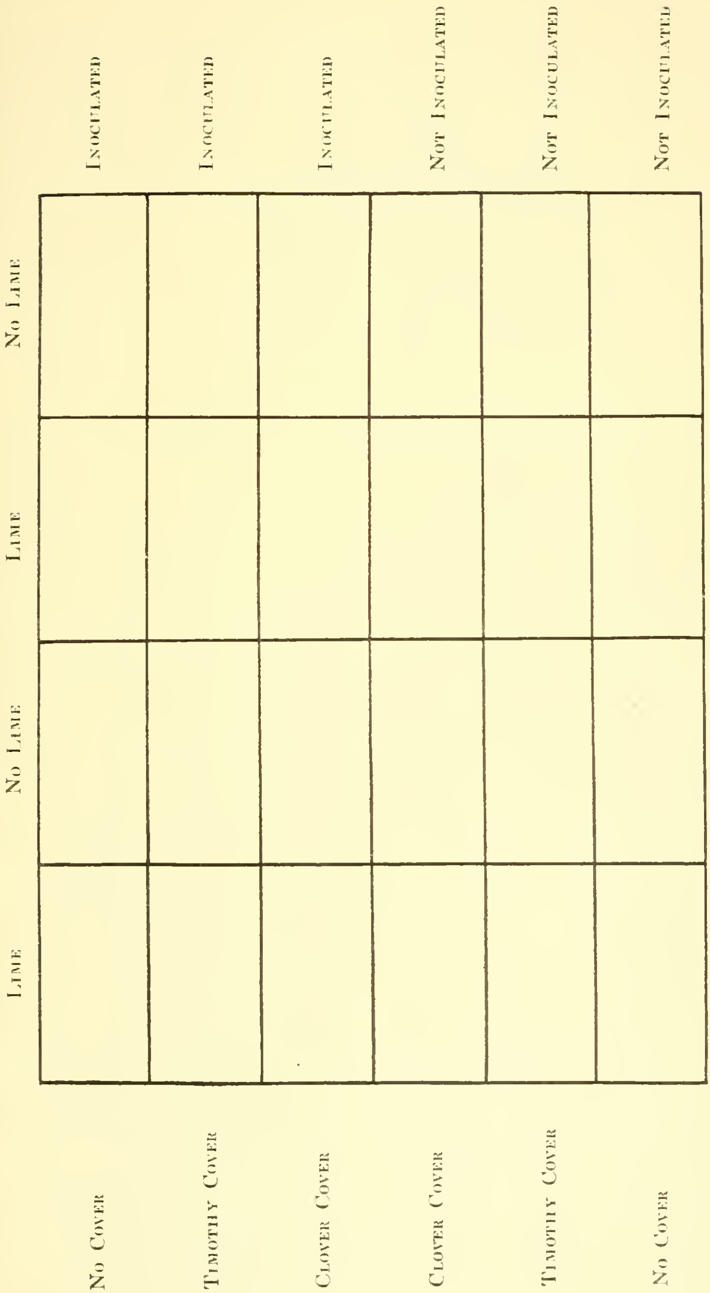

Figure 1. Diagram of Field Experiments Showing Inoculation, Cover Crop, and Lime Treatment of Plots.

May in 1922, 1923, and 1924, and in April, 1925.

During each growing season observations on growth were recorded. Immediately after the crop was harvested roots from each plot were examined for black root-rot.

No yield records were taken in 1921 because of the uneven stand, due principally to setting at different periods. When the crop of 1922 was harvested, 160 plants from the four center rows of each plot were weighed. These green weights are recorded in Table I. At the time of harvesting in 1923, 1924, and 1925, the tobacco from each entire plot, except for the borders, was hung, stripped, and cured separately. The weights of cured leaves are tabulated by plots in Table I, and the results summarized in Table II. Sorting records for the crop of 1925 were made, and the percentage for each grade and length of leaf in each plot is given in Table III.

The work and results of each of the last four years are presented separately before discussing conclusions from the whole experiment.

Season of 1922

Throughout the summer it was apparent that (1) the timothy strips were making a poorer growth than those which had no cover crop or had clover; (2) the limed plots were making a better growth than the corresponding unlimed plots both on the inoculated and uninoculated parts of the field; (3) the inoculated half was not making as much growth as the uninoculated. These field observations were all substantiated by the yield records as given in Table I and summarized in Table II. This shows that by liming there was a gain of 12 per cent both on inoculated and uninoculated plots; by the use of a timothy cover crop there was a loss of 13 per cent on the inoculated and 18 per cent on the uninoculated half; and finally that the inoculated half was 15 per cent lighter all through than the uninoculated half. After cutting the tobacco, some of the roots from each plot were dug and washed. Lesions were found on practically all of the roots from the inoculated plots, but were not much worse on the limed than on the unlimed plots. They were located especially on the large roots at the bottom of the stalk where the roots had to grow through the handful of infested earth that was deposited at planting time. A few lesions were found on the roots from the uninoculated half.

In 1922 the use of lime was associated with an increase in the yield of tobacco, and was not associated with any great increase in the amount of root-rot.

This year there was a decided loss in weight of tobacco following the timothy cover crop. The percentage of loss from timothy was not as heavy on the inoculated half as on the uninoculated half.

Inoculated plots uniformly yielded a lighter crop than uninoculated, although examination of the roots did not indicate very severe infection. Most of the injury was in the region where the handful of infested soil was in contact with the roots and not general over the whole root system.

Season of 1923

About the middle of the summer it became apparent that in the infected half of the field the tobacco on the limed strips was lagging behind the unlimed strips in growth. This difference increased throughout the summer. The fact that a similar difference was not apparent on the uninoculated half indicated that the dwarfing effect was due to the influence of lime on the root-rot. When the roots were examined it was found that (1) the disease was very bad on all the inoculated limed plots, (2) the lesions were fairly prevalent on the roots of the unlimed inoculated plots (but much less so than on the limed plots), (3) there were frequent lesions on the uninoculated limed plots, and (4) only rarely could a lesion be found on the uninoculated, unlimed plots.

The results noted in 1923 may be summarized as follows: In the inoculated half of the field, the yield on limed plots was 16 per cent less than the yield on unlimed plots. In the uninoculated half of the field, the yield on limed plots was still 7 per cent more than the yield on unlimed plots, but this was a drop of 12 per cent from the previous year. On the inoculated half of the field even the unlimed plots suffered some loss from black root-rot, the yield being about 8 per cent less than on unlimed plots in the uninoculated part of the field.

In 1923 there was a small loss from the use of timothy, and, as in the preceding year, this loss was less on the inoculated than on the uninoculated plots.

Season of 1924

It became apparent early in the season that the limed plots were making a much poorer growth than the corresponding unlimed ones. This was particularly striking on the inoculated half, but it was also quite apparent from the poor growth that there were many places in the uninoculated half where root-rot was doing serious danage. It was plainly evident that root-rot was no longer confined to the inoculated end of the lime strips but that it was now present even to the extreme opposite end. A second very apparent fact was that there were some very good plots of tobacco (unlimed) in the inoculated part of the field, showing that the effect of very thorough inoculation was not lasting when the soil condition was not right. These observations during the growing season were substantiated by examination of the roots after the crop was harvested. It was then found that, irrespective of inoculation, the number of lesions was very small on all plots which had not been limed. On the limed strips, lesions were particularly numerous on the roots from the inoculated plots; but many of the roots from the other end were in just as serious condition, while others were relatively free. This indicated that on the uninoculated limed plots, the infestation was still uneven. Nevertheless it seemed to be spreading rapidly in these. The cured weights per acre as given in Tables I and II showed a loss from liming of 17 per cent on the inoculated plots and 12 per cent on the uninoculated plots.

In 1924, the fourth year of the experiment, the loss from black root-rot on limed plots was more severe than in the previous years, although no lime was applied this year.

In the unlimed plots, the amount of root-rot was small, whether or not the plots were inoculated. The yield on the inoculated plots was only 4 per cent less than on the corresponding uninoculated plots.

For the third successive year a reduction in yield was associated with the use of the timothy cover crop.

Season of 1925

The effect of lime on black root-rot and yield and the effect of timothy cover crop on yield were never more conspicuous than in 1925, although no cover crops had been planted and no lime applied since 1923.

Throughout the season growth was much superior in unlimed plots to growth in limed plots. It was apparent that on plots which had had a cover crop of timothy in previous years the tobacco was making a better growth than on plots which had never had a cover crop of timothy. In other words, the depressing effect of timothy which had been observed in previous years was not in evidence after this cover crop was omitted for one year. There was no visible difference in growth between the inoculated and uninoculated halves of the field. It was evident that, regardless of inoculation, black root-rot was causing loss in all limed plots.

When the roots from all plots were examined at harvest time, an average of 98 per cent of the plants in all limed plots was found to be severely infected with black root-rot. In unlimed plots an average of only 14 per cent of the plants showed symptoms of this disease, and infection on them was slight. The previous cover crop was found not to affect the amount or severity of black root-rot. Infection, as revealed by the examination of the roots, was the same on the inoculated and uninoculated parts of the field. Brown root-rot was slightly more pronounced on limed than on unlimed plots, but the difference was small.

The soil in limed plots had, in April 1925, pH values from 6.4 to 7.0. In all these, plants were severely infected and there were no visible differences between them as regards infection. The soil in unlimed plots ranged in pH values from 4.5 to 5.0. Infection in these plots was absent or slight, and there were no appreciable differences between them.

In 1925 the yield on inoculated plots was no less than the yield on plots not inoculated. The black root-rot fungus was evidently present in all plots, but had not become established in unlimed plots because of unfavorable soil conditions. It had, however, become established in limed but uninoculated plots. The black root-rot fungus is probably present in all tobacco soils, but it is evident that it causes no loss in soils having a reaction unfavorable to the fungus.

The average reduction in yield due to liming (35 per cent) was greater in 1925 than in any previous year of the experiment, although no lime was applied in either 1924 or 1925. During this two-year period without more lime added, the soil in the limed strips had, however, become slightly less acid. The omission of lime for two years on land on which tobacco was grown continuously did not result in any immediate relief from black root-rot. The greater loss in 1925 was probably not directly due to any change in the soil reaction, but to the fact that the soil is becoming more completely infested with the fungus.

The injurious action of lime as expressed in black root-rot was not more pronounced in its effect on yield than on quality and value. This is recorded in Table III under per cent darks, seconds, mediums, fillers, and brokes. The average per cent mediums and seconds on limed plots was 6, and on unlimed plots 22. The average per cent fillers on limed plots was 39 and on unlimed plots 17.

In 1924, for the third consecutive year, the use of timothy cover crop was associated with a reduction in yield. No cover crop was sown in 1924. In

1925 the plots which had previously had a timothy cover crop yielded more than plots on which a cover crop had never been grown. The average increase of plots which had had timothy cover crop over plots which had had no cover crop was 17 per cent. The increase following timothy was greater on limed than on unlimed areas. An examination of roots showed that after the omission of timothy cover crop for one year there was no significant difference between the amount or severity of brown root-rot on plots with and without timothy cover crop. The depressing effect of timothy cover crop on tobacco seems to disappear if the cover crop is omitted for but a single year.

Discussion of the Five-Year Experiment as a Whole

Occurrence of Thielavia in Tobacco Soils and Rate of Infestation

This fungus probably occurs to a limited extent in all of our soils. It has been shown that it occurs on the roots of nearly a hundred other species of plants besides tobacco (6). Many of these are common cultivated and weed plants. Further investigation would undoubtedly show that there are many other hosts. But even though its host plants were not present—they do not seem to be necessary—it apparently lives indefinitely in the soil on dead organic matter. In the examination of tobacco roots from fields which appeared quite normal and healthy above ground there are usually found occasional lesions of black root-rot. The reason that most Connecticut Valley tobacco fields do not suffer severely from black root-rot is not the absence of the fungus, but the maintenance of a soil condition which is unfavorable for its rapid propagation. Soil reaction is probably the most influential factor. An extensive survey of Massachusetts tobacco soils has not been made, but those which have been tested have been fairly acid with a reaction ranging between pH 4.5 and 5.8 except where they have been limed within a few years. Within this range there seems to be very little spread and the degree of infestation is light. But when raised above this range by application of lime or other alkaline substances, conditions are made more favorable to growth of Thielavia and the soil becomes more heavily infested. Increase in degree of infestation however is a slower process than has been commonly supposed. Most investigators of the disease have assumed that when acidity was reduced the disease would immediately become serious. In our own experiments it was not until the second year after liming was started that a high infestation was secured. We have seen a number of cases where growers have applied lime or wood ashes and the effect the first year was an increase in the yield of tobacco. It was only in the second or third year after liming that the trouble became serious. Hutcheson and Berger (4:7) noticed in their experiments that the first effect of lime was beneficial but its ultimate effect was to reduce the yield. It has been the common experience of those who have tried to produce the disease by soil inoculation that their first attempts were unsatisfactory. Since infection of the roots is local, i.e., the fungus does not travel far from the point where it enters the root, the amount of damage is in direct proportion to the number of places at which the root has been infected by the fungus. The degree of soil infestation must therefore be high before the disease becomes serious.

Similarly it is probable that a return of infested soil to a more acid condition will not be immediately followed by a great reduction in the amount of black root-rot. The results in 1925 indicate that the omission of lime and the continuous culture of tobacco do not quickly result in the disappearance of black root-rot injury. Further field work on this point is in progress.

Effect of Lime on Yield of Tobacco in the Absence of Root-Rot

It has been previously mentioned (p. 121) that certain investigators have found that the yield of tobacco was increased by liming the soil, and one of the objects of the work at the Massachusetts Agricultural Experiment Station was to determine whether such was the case under our conditions and if so, to measure the extent of increase. This was also a necessary preliminary to drawing any conclusion as to the effect of liming on root-rot. No records of yields for the first year of the experiment (1921) were made. The records of the second year show an increase of 12 per cent on both the inoculated and uninoculated parts of the field. Theoretically, this should have been larger the first year, since root-rot must have taken a slight toll the second year. During the third year the loss from root-rot more than counterbalanced the gain from lime on the inoculated part, and there was a total loss of 16 per cent. Even on the uninoculated part, root-rot was beginning to reduce the gain which would otherwise have been anticipated from liming, but there was still a final gain of 7 per cent on this half. During the fourth year of the experiment, root-rot had increased to such an extent that it more than overcame the benefit of the lime on the uninoculated part, and we had a final loss even on that side of 12 per cent as opposed to a 17 per cent loss on the inoculated part. In 1925 root-rot had increased so much that the benefit of lime was overcome even more and the loss was about 35 per cent on both the inoculated and uninoculated areas. This is a much greater loss than could have been predicted, since at the previous rate of progress the loss would have been about 17 per cent.

In answer to the first question which was proposed as the object of this experiment we may state that the immediate effect of lime in this soil was to increase the yield. In this case it was 12 per cent the second year. Undoubtedly, the degree of increase from liming depends on the reaction of the soil before application is made. On a soil less acid than this, one would hardly expect the same degree of increase.

How Acid Should the Soil Be?

It has again been demonstrated that the ultimate effect of heavy applications of lime is to increase root-rot and thus reduce yield. The facts that (1) neutral calcium salts such as land plaster do not produce this effect and (2) other alkaline substances such as carbonate of potash do produce it, show that the influencing factor is not the calcium but the alkaline character of the lime. The less acid or neutral soil thus produced does not render the tobacco plant more susceptible to attack but it favors the growth of the fungus and results in a larger number of lesions on the root system. Although there are probably no tobacco soils free from Thielavia, it is apparent that many of them, by virtue of their acid reaction, are so nearly free that their infestation is negligible; while others, by virtue of their less acid reaction, are so heavily infested as to render profitable tobacco growing impossible. The all important question now is: Just where is the dividing line between safety and certain loss? Just what degree of acidity must a soil possess in order to be safe from root-rot?

The data on the soil and crop of 1924 are valuable in determining the location of the dividing line, because at that time the soil must have more nearly reached an equilibrium after the treatment of the three preceding years, and because this equilibrium was not disturbed by artificial inoculation or application of lime in 1924. Correlating for that year the root inspection records, the yield and sorting records and the soil reaction records, we find that root-rot was not serious on any of the twelve plots which had an average reaction of slightly over 5; but that it caused serious damage on all the inoculated and most of the uninoculated plots with an average of 5.9. By using individual plot records it may be confined more closely. Especially instructive is the record of plot 13 which kept a reaction of 5.5-5.6 throughout the three years and which was inoculated as thoroughly as any other plot in the field for three years; but on the 4th year only an occasional lesion on the roots could be found and it was the best plot in the field. Similarly, an inspection of the individual limed plots indicates pretty severe loss at 5.8.

In 1925, soil reactions were determined in April and in October. The pH values were found to have changed considerably during the growth of the tobacco in 1925. This was especially conspicuous in the limed plots, in which the soil became more acid, probably because of the removal of some of the lime by the crop. The pH values determined in April are indicative of the environment in which the crop grew. The reaction of plots without lime was between pH 4.5 and 5.0, and in these plots black root-rot caused no apparent loss. Limed plots had pH values between 6.4 and 6.9, and in all of them black root-rot caused serious damage. There were this year no plots having pH values between 5.0 and 6.4, and so the critical point cannot be located any more closely than has been done above on the basis of the results in 1924.

Experiments in pots in the greenhouse, which are to be described in a later paper, have led us to the conclusion that loss from black root-rot occurs whenever the pH value of the soil is 5.9 or higher, and that loss from black root-rot does not occur at pH 5.6 or below, except in exceptionally cold soils.

We may *therefore conclude that the critical point is somewhere between 5.6 and 5.9.* It is apparent however that there cannot be in reality a critical *point* but rather a critical *region*, below which damage from root-rot may be expected to be little if any, and above which root-rot is almost certain to cause trouble. There are at least three reasons why this region cannot be defined more accurately than the limits given above:

1. The transition from a soil reaction unfavorable for growth of Thielavia to a reaction which favors is a matter of degree—not of plus and minus.

2. During a very warm summer the critical region would probably be higher since a higher soil temperature reduces the effect of root-rot, as has been shown experimentally by Johnson and Hartman (7:60). A cold summer on the other hand would probably depress the critical region toward the acid range.

3. On compact, poorly drained soil black root-rot is commonly worse than in looser soil in the same field, due probably to the difference in the rate of leaching and to lower soil temperature. This also is in accord with the experimental results of Johnson and Hartman (7:80). It is not improbable that

on such a soil the location of the critical region would be lower. On the basis of the yields of the last three years it may be stated that, as the acidity of the soil becomes less above 5.9, the loss caused by black root-rot becomes greater. (The upper limit of alkalinity has not been determined.) Plots on the limed areas in this experiment may be placed in four groups on the basis of the pH values of their soils. These are correlated with average yields as follows:

pH	5.9	to	6.1	—	yield	1233	pounds
"	6.1	"	6.2	—	"	1183	"
"	6.2	"	6.3	—	"	1120	"
"	6.3	"	6.4	—	"	1039	"

We have, then, quantitative evidence of the increasing injury from black root-rot which results when by the addition of the lime the soil is made less and less acid to a point beyond pH 5.9.

How Much Lime May Be Used with Safety?

If the soil has reached such a point, and if it is seriously infested with the black root-rot fungus, what then may be done? If no further lime is applied and if tobacco is continuously grown on such soil, the loss of lime by leaching and by removal in the plant will gradually result in a more acid condition. Of course the loss from black root-rot may be so great as to make tobacco growing on such land unprofitable. Continuous tobacco, no further liming, and the use of acid fertilizers, such as sulfate of ammonia and sulfate of potash, are all the remedial measures to be suggested at this time. A quicker method of increasing soil acidity is desirable, and this matter is now under investigation.

The Effect of Timothy

Since timothy is extensively used and widely recommended as a cover crop for tobacco soils, it was assumed at the outset that it was known to increase the yield of tobacco by virtue of the organic matter which was added to the soil or the plant food which was saved from leaching through its use. It was included in the present experiment to see whether it influenced the damage from black root-rot and as a check against the clover cover crop which was supposed to increase root-rot because it is a host plant of Thielavia. At the end of the first season, therefore, it was a surprise to find that both the inoculated and uninoculated timothy plots showed a reduction in yield—13 per cent and 18 per cent on the inoculated and uninoculated plots respectively. It could not have been a result of the timothy depleting the soil water because 1922 was an extremely wet year. Losses from the use of timothy both on the inoculated and uninoculated plots, but in a smaller degree, were also recorded in 1923 and 1924. Certain plots at times showed small increases over adjacent plots without cover, but considering the experiment as a whole, the conclusion is inescapable that the effect of timothy has been to decrease both the yield and value of the tobacco. This is in agreement with data recently published by Jones (8) who reports an average decrease in yield of 13 per cent associated with the use of the timothy cover crop. The percentages of loss during two of the years were not so high on the inoculated as on the uninoculated plots, but the reverse was true the third year. Certainly there was not, on the whole, sufficient evidence from either the yield data or the examination of the roots to prove that timothy had any influence on the prevalence or severity of black root-rot.

In 1925, after one year's omission of cover crops, the plots which had had timothy cover crops yielded 17 per cent more than the plots which had never had cover crop. It would appear from this that the depressing effect of timothy cover crop quickly disappears and is replaced by a beneficial effect when the cover crop is not sown for one year. This increase following timothy after an interval of one year was greater on limed than on unlimed plots. In this connection it is interesting to consider the previous depressing effect of timothy on limed versus unlimed plots. For the three years previous to 1925, the average reduction in yield associated with the use of timothy cover crop was 5 per cent on limed plots and 10 per cent on unlimed plots.

When the roots of the plants on the timothy plots were compared with those on the adjacent plots without cover in years previous to 1925, it was found that many of the laterals—especially the lower ones—were brown and dead. The symptoms were quite typical of the disease which is now commonly called brown root-rot. The disease was not entirely lacking in any of the plots but was certainly more pronounced on the timothy plots. On the timothy plots which had been limed, black root-rot was also present, and it was not always possible to separate the influence of the two; but on the unlimed plots the brown root-rot was unmistakable. Brown root-rot, then, is apparently one of the causes of depressed yields on the timothy plots. It is known that timothy in rotation encourages this disease, and it is not surprising that we should now find the same effect from timothy used as a cover crop. This, however, is not a satisfying explanation, because we do not yet know what brown root-rot is. Whether or not it is caused by soil organisms or by toxins or malnutrition has never been determined. We are not even sure that all the tobacco-sick soil troubles which we include under the title of brown root-rot are the same. The only characters they have in common are the presence of some dead brown roots and consequent reduced growth.

Pure Culture Experiments on the Relation of H-ion Concentration to Growth of Thielavia

From the preceding, it is apparent that the adverse effect of lime on tobacco is due to the favorable influence of an alkaline reaction on the growth of Thielavia. In order to see whether this conclusion is supported by growth of the fungus in pure culture, synthetic culture media (Czapek's) were prepared and adjusted to the following reactions: 1.5, 2.0, 3.05, 3.45, 3.8, 3.9, 4.25, 4.55, 5.35, 6.05, 6.2, 7.2, 7.9, 8.55, 8.9, 9.6, 9.9, 11.05, 12.1, and 12.9. The reactions were determined both colorimetrically and electrometrically. Three series of cultures were made, one in tubes and the others in Petri dishes. Records of measurements and notes on growth were made at intervals of 3 or 4 days. Briefly summarized, the results were: On all cultures between 6.05 and 12.9 the growth consisted of a dense black mat of mycelium on the surface and dark hyphae under the agar. Both chlamydospores and conidia were produced in great abundance. Within this range no difference in character or quantity of growth could be observed. Apparently the reaction was optimum throughout this entire range. But below this it was otherwise. At 5.35 the rapidity of growth began to decrease. Below 5.35, all growth on the surface ceased and even under the surface it was progressively more scanty down to 3.05. Below this, growth ceased altogether. The production of chlamydospores also decreased progressively with the scantiness of growth until there were none at all at 3.05. A few conidia were produced even to the most acid point where mycelium grew.

Since in pure culture the fungus will grow even at reactions which are more acid than any tobacco soils, it is pertinent to ask why we do not have loss from root-rot below 5.5. The answer is probably to be found in the difference between conditions which the fungus encounters in a sterile artificial medium and what it encounters in its natural medium, the soil. In the latter case it meets keen competition from other soil organisms and it is only the strong vigorous growers that get the available food and thrive. But, as was noted above, Thielavia at 5.35 is beginning to lose its vigor and at more acid ranges it dwindles to nothing. When in its weakened condition due to unfavorable reaction it is being crowded out by other organisms better adapted to acid conditions, it is not strange that Thielavia should be able to make but little headway at 5.35 or lower. Incidentally it should be kept in mind that Thielavia does occur sparingly on roots in more acid soils, and the lesions are just as pronounced but are not numerous enough to cause much loss. The critical point at which vigor of growth begins to diminish is thus lower than 6.05 and higher than 5.35. Thus it must fall somewhere in the region which we have called the critical region, and the results from the pure culture tests support those of the field tests.

Summary

1. The immediate effect of liming an acid soil was to increase the yield of tobacco.

2. If sufficient lime is added, black root-rot is ultimately promoted, and there is consequently a reduction in yield.

3. Black root-rot is present in most soils but is more injurious in nearly neutral soils because the causal fungus, *Thielavia basicola*, grows more rapidly and vigorously in a nearly neutral medium.

4. In the field under experimentation, black root-rot caused little or no loss in soils more acid than pH 5.6. It caused severe loss on all soils less acid than pH 5.9. It should be understood that this critical region between pH 5.6 and 5.9 is an intermediate zone which may be shifted to a somewhat higher or lower position by variations in temperature and compactness of soil, and by differences in the degree of infestation of the fungus in the soil. Growth of the fungus in pure culture on media confirmed the results in the field.

5. As the soil becomes less acid above pH 5.9, the loss from black root-rot increases. The upper limit of alkalinity has not been determined.

6. After repeated applications of lime brought the soil reaction to a point favorable to the fungus, the omission of lime for two years, with tobacco grown continuously meanwhile, did not result in any immediate reduction in the severity of black root-rot.

7. If, because of extreme acidity, lime is considered necessary, it should be applied with great caution and in small applications, always preceded by determinations of soil reaction in order to avoid approaching too closely the danger point of pH 5.9.

8. The use of timothy cover-crop was found to have no significant effect on the prevalence of black root-rot.

9. The use of timothy cover-crop reduced the yield of tobacco for three consecutive years. This effect was associated with brown root-rot.

10. When timothy cover crop was omitted for one year, the depressing effect of timothy quickly disappeared and was replaced by a beneficial effect. In these experiments the yield on plots so treated exceeded by 17 per cent those without cover crop.

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Table I. Treatment, Yields, and Reaction Analyses by Plots throughout the Five Years of the Root-Rot Experiment

Plot	Inoculation	Cover Crop 1921–24	Lime in May 1921	pH May 1922		Lime in May 1922	Green Weight 160 Plants Sept. 1922 Lbs.	pH May 1923		Lime in May 1923	Cured Leaves Lbs. per Acre 1923	pH May 1924		Cured Leaves Lbs. per Acre 1924	pH April 1925		Cured Leaves Lbs. per Acre 1925
1	+	None	None	5.0	Average 5.11	None	396	5.2	Average 5.56	None	1231	4.9	Average 5.01	1453	4.6	Average 4.76	1131
2		Timothy		5.2			201	6.0			1372	5.2		1320	4.6		1362
3		Clover		5.1			345	5.2			1358	4.9		1449	5.0		1389
4	—	Clover		5.1			349	5.5			1590	4.8		1468	5.0		1184
5		Timothy		5.2			348	5.7			1457	5.0		1528	4.8		1237
6		None		5.0			387	5.8			1670	5.3		1608	4.6		1187
7	+	None	Ground Limestone 2 tons per acre	5.4	Average 5.73	Precipitated Lime 1 ton per acre	323	6.2	Average 6.06	Agricultural Lime 2 tons per acre	976	6.0	Average 5.9	1150	6.9	Average 6.7	696
8		Timothy		6.2			353	6.3			891	5.8		1315	6.7		1050
9		Clover		6.2			349	6.2			1216	6.0		1182	7.0		748
10	—	Clover		5.6			388	5.7			1599	6.0		1324	6.4		766
11		Timothy		5.5			374	6.2			1373	5.7		1500	6.5		1005
12		None		5.4			477	5.8			1500	5.8		1354	6.7		632
13	+	None	None	5.6	Average 5.70	None	378	5.5	Average 5.68	None	1472	5.5	Average 5.03	1621	4.7	Average 4.72	1492
14		Timothy		5.8			348	5.6			1245	5.0		1354	4.8		1344
15		Clover		5.7			301	5.6			1486	4.9		1566	4.8		1196
16	—	Clover		5.8			430	5.6			1641	5.0		1563	4.7		1303
17		Timothy		5.7			356	6.3			1269	5.2		1522	4.8		1433
18		None		5.4			441	5.5			1231	4.6		1488	4.5		1273
19	+	None	Ground Limestone 2 tons per acre	5.3	Average 5.77	Precipitated Lime 1 ton per acre	393	6.1	Average 6.05	Agricultural Lime 2 tons per acre	1132	5.8	Average 5.9	1278	6.5	Average 6.65	820
20		Timothy		6.0			391	6.0			1245	6.6		1117	6.7		888
21		Clover		6.5			394	6.2			1415	5.8		1257	6.7		796
22	—	Clover		5.5			471	6.0			1886	5.8		1313	6.4		732
23		Timothy		6.0			388	6.0			1316	5.8		1207	6.9		994
24		None		5.3			486	6.0			1401	5.6		1437	6.7		714

Table II. Summary of Yields for 1922, 1923, 1924, and 1925

Pounds per Acre

Treatments	1922 Green	1923 Cured	1924 Cured	1925 Cured
Average of all limed plots:				
Inoculated . . .	7340	1146	1217	868
Not inoculated . .	8620	1579	1356	807
Average of all unlimed plots:				
Inoculated . . .	6560	1361	1461	1319
Not inoculated . .	7700	1476	1535	1269
Average of timothy cover plots:				
Inoculated	6460	1193	1277	1161*
Not inoculated . .	7320	1354	1439	1167*
Average of plots without cover crop:				
Inoculated	7450	1203	1375	1034
Not inoculated . . .	8960	1450	1472	951
Average of all plots:				
Inoculated . . .	6960	1253	1338	1076
Not inoculated . .	8160	1494	1443	1038
Percentage Gain (+) or Loss (—)				
From liming:				
Inoculated	+12	—16	—17	—34
Not inoculated . . .	+12	+ 7	—12	—36
From timothy cover:				
Inoculated	—13	— 1	— 7	+12*
Not inoculated . . .	—18	— 7	— 2	+23*
From inoculation:				
Limed	—15	—27	—10	+ 8
Unlimed	—15	— 8	— 5	+ 4

*Timothy not sown in 1924, no cover crop plowed under in 1925.

Table III. Sorting Record of Crop of 1925

Plot	Treatment	pH*	Yields per Acre Lbs.	Darks		Seconds		Mediums		Fillers	Brokes
				Per cent	Length Inches	Per cent	Length Inches	Per cent	Length Inches	Per cent	Per cent
	No Lime:										
1	No cover crop	4.6	1131	50.9	15–25	24.9	15–25	0.6	Not sized	15.8	7.8
2	Timothy	4.6	1362	56.0	15–25	18.7	15–23	None		16.0	9.3
3	Clover	5.0	1389	49.3	15–27	22.9	15–23	None		21.5	6.3
4	Clover	5.0	1184	53.6	15–25	17.9	15–23	0.9	21–23	20.4	7.0
5	Timothy	4.8	1237	51.6	15–25	21.7	15–23	2.5	21–25	17.8	6.4
6	No cover crop	4.6	1187	51.2	15–27	21.1	15–25	2.8	21–25	17.8	7.1
	Lime:										
7	No cover crop	6.9	696	59.8	15–21	0.5	15	None		39.7	None
8	Timothy	6.7	1050	44.4	15–21	27.9	15–21	None		27.0	0.7
9	Clover	7.0	748	46.5	15–21	3.0	15. 19	None		48.6	1.9
10	Clover	6.4	766	54.9	15–21	1.9	15–19	None		43.2	None
11	Timothy	6.5	1005	65 6	15–23	5.3	15–19	None		27.5	1.6
12	No cover crop	6.7	632	41.7	15 23	1.5	15–19	None		56.1	0.7
	No Lime:										
13	No cover crop	4.7	1492	56.8	15–27	23.5	15–25	0.6	Not sized	13.6	5.5
14	Timothy	4.8	1344	55.6	15–27	16.6	15–23	None		17.2	10.6
15	Clover	4.8	1196	50.8	15–27	22.3	15–23	0.6	Not sized	16.4	9.9
16**	Clover	4.7	1303	54.9	15–27	14.7	15–25	2.2	21–25	15.4	12.5
17	Timothy	4.8	1433	51.5	15–27	21.5	15–23	1.6	21–25	17.5	7.9
18	No cover crop	4.5	1273	51.2	15–27	19.2	15–25	2.6	21–25	17.5	9.5
	Lime:										
19	No cover crop	6.5	820	51.9	15–21	5.6	15–19	None		41.6	0.8
20	Timothy	6.7	888	63.1	15–21	9.3	15–19	None		27.1	0.5
21	Clover	6.7	796	46.5	15–21	6.0	15–19	None		45.0	2.5
22	Clover	6.4	732	44.6	15–23	3.9	15–19	None		50.5	0.9
23	Timothy	6.9	994	52.9	15–23	13.7	15–21	None		26.6	6.6
24	No cover crop	6.7	714	38.7	15–23	2.9	15–19	None		56.6	1.5

*April, 1925. **0.3 per cent (3.9 lbs.) overdamp.

Massachusetts

Agricultural Experiment Station

BULLETIN No. 230 APRIL, 1926

RESEARCH SERVICE TO MASSACHUSETTS ANIMAL INDUSTRY

PROGRESS REPORTS

This bulletin contains five papers summarizing the experimental work of the Station which has to do with the feeding of farm animals. More complete reports of some of this work have been published in scientific journals. The subjects reported upon are as follows:

Requests for bulletins should be addressed to the
Agricultural Experiment Station
Amherst, Mass.

MINERAL MATTER FOR DAIRY COWS

By J. B. LINDSEY and J. G. ARCHIBALD

Introduction

It is a well-known fact that all animals require a certain amount of mineral matter in their diet. The fondness of all classes of stock for common salt is so well known that mention of it seems almost superfluous. The sight of a cow chewing a bone or an old shoe, licking the earth, or gnawing at a fence rail is familiar to anyone who has ever lived on a farm.

Until recent years, however, comparatively little attention has been paid to these outward evidences of mineral hunger, because of the belief that the feeds commonly fed to cows contained sufficient mineral matter (common salt excepted) for their needs. Gradually it has come to be realized that such is not always the case and that shortage of available mineral matter, under certain circumstances, may be a limiting factor in growth and production. The situation has been well summed up by the late Professor Armsby, who said: "Most feeding stuffs, and particularly the mixed rations of farm animals, contain what appear at first sight to be much larger amounts of ash ingredients than the body requires . . . . . This is doubtless true of animals living in a state of nature, but it is a questionable assumption under the artificial conditions to which many farm animals are subjected."

This point of view has become prevalent only within the past decade. Its establishment on a firm basis of fact has been due, in large measure, to the work done in recent years at certain of the experiment stations in this country. For example, it has been shown that in spite of liberal feeding, heavy milking cows excrete daily more mineral matter, particularly calcium and phosphorus, than they consume, or are in what is termed negative mineral balance, and it is only when they reach the advanced stages of lactation (10 pounds of milk daily) that the reverse is true; that is, that they consume more minerals than they give out. There is, however, no record of prolonged experiments on the effect of feeding mineral supplements to milking cows to help out a mineral deficiency. Realizing the dearth of such information and its importance, this department instituted such an experiment in the autumn of 1921, which, modified from time to time to meet changing conditions in the station herd, is still in progress. This paper is a brief report of the work up to October 1, 1925.

Plan of the Experiment

The main features of the experiment have been:

1. Feeding the whole herd a ration deficient according to prevailing standards in calcium and phosphorus but adequate in all other respects.

2. Division of the herd into halves as nearly alike as possible, and the addition to the grain ration of one group, of supplemental calcium and phosphorus in the form of special steamed bone meal containing but little animal matter.

3. Including in the experiment the heifer calves from the cows in the two groups and keeping them as far as possible on the same diet as their dams, in order to see if any effects of the treatment are more marked in the second or even in the third generation than in the original animals used.

4. Observation of the effects of the feeding upon:
   - (a) the general condition and weight of the animals,
   - (b) growth of heifers,
   - (c) milk production,
   - (d) composition of the milk, especially its content of calcium and phosphorus,
   - (e) reproduction, under which general heading have been observed:
     - (1) recurrence of heat,
     - (2) difficulties in getting cows bred,
     - (3) number of abortions and retained afterbirths,
     - (4) condition of the calves at birth and subsequently.

The Herd

The station herd is made up of high-grade Holsteins with a few Jerseys, and usually numbers, including young stock, eighteen to twenty head. At present there are nineteen animals included in the experiment,—fourteen milch cows, one two-year-old heifer, and three eight-months-old heifers.[1] There have of necessity been some changes in the herd since the experiment was started, but of the nineteen individuals originally included, ten are still in the herd. Since the commencement of the experiment in December, 1921, the milking herd has had an average annual production per cow of 8000 pounds of milk, testing 4.21 per cent of fat.

All cows are given a two months dry period during which time they are liberally fed, but they are not sent to pasture. They are maintained on dry feed the year around, except for a period commencing about June 25 and ending about October 10, during which time each cow is fed about 25 pounds daily of such green soiling crops as oats, millet, sorghum and fodder corn, as a substitute for a portion of their hay. Ensilage, roots or legume hay have not been fed during the experiment.

Rations Fed

The rations have purposely been made as poor in mineral matter as a wise choice of feeds, other factors being considered, would permit. The hay has consisted principally of timothy, with some red top, blue grass and orchard grass.

The grain ration has consisted of the following mixture:

	Per cent
Ground oats	39¼
Gluten meal	20
Red dog flour	20
Wheat bran	20
Salt	¾
	100

[1] All heifer calves are included in the experiment as soon as old enough to subsist on hay and dry grain. The age varies with the calf from five to seven months.

The mineral content of the entire ration was still further lessened by substituting for a portion of the hay, during certain periods of the experiment, such mineral-poor materials as chopped oat straw, starch, or apple pomace.

The whole herd has been fed as described above for four years, and in addition, one-half of the herd, known as the "bone meal" group, has received supplemental calcium and phosphorus in the form of steamed bone meal specially prepared for animal feeding. The bone meal was thoroughly mixed with the grain before feeding and the amount for each cow has varied with her weight and the amount of milk she gives, from three to eight ounces daily, the aim being to supply approximately a 60 per cent excess over the theoretical requirements of each cow. This excess is provided as a safeguard; for, although little is known about how completely mineral matter in the form of ground bone is utilized by the dairy cow, it is safe to assume that it is only partially digested and made available.

Results of the Experiment

General Condition and Weight of the Cows.

The condition of the animals has been carefully noted by means of observations made and recorded from month to month. At no time has it been possible to note any marked difference in the mature cows. Irrespective of the group in which they belong they have maintained themselves well. This has been especially true of the Holstein cows.

Among the young cows and heifers the effects of the low mineral ration have been much more apparent. Several of them are considerably undersized for their age, and present a general unthrifty appearance. Recently some of them have had very poor appetites, refusing at times both hay and grain. The young Jerseys seem to have been particularly susceptible, and while some of the Holsteins have also been affected they have stood up under the low mineral feeding better than the Jerseys. As with the aged cows the effects noted have been irrespective of whether they received bone meal or not, although recently there has been some evidence to favor the bone meal.

All of the cows that were mature at the commencement of the experiment have maintained their weights well, there being no significant variation from year to year in either group.

Growth of Heifers

Study of the growth records of the young stock in comparison with those of their dams shows that of twelve individuals, six are as large as their dams were at the same age and six are smaller than the dams were. These two groups are composed according to breed as follows:

Large as dam	*Smaller than dam*
Holstein—4	Holstein—3
Jersey—2	Jersey—3

According to grouping in the experiment they are divided thus:

Large as dam	*Smaller than dam*
Bone meal—3 (2H & 1J)	Bone meal—3 (1H & 2J)
No bone meal—3 (2H & 1J)	No bone meal—3 (2H & 1J)

So far, then, as growth records go the evidence is about evenly divided, there being nothing in favor of the bone meal.

Milk production

The milk yield has remained at a fairly constant average level all through the experiment. The average daily yield per cow from year to year is given below, *commencing two years before the experiment was started.*

Year	Average daily yield of milk per cow, lbs.
1920	21.87
1921	21.65
1922	22.67
1923	21.56
1924	21.06
1925	22.30

The above record is for the whole herd. Dividing the herd into the two groups, those that received bone meal and those that did not, we find the following records:

Year	Average daily yield of milk per cow, lbs.	
	"Bone Meal" Group	"No Bone Meal" Group
1922	22.20	23.13
1923	19.85	23.00
1924	21.36	20.76
1925	20.65	23.94

On this basis it would seem that the cows not receiving bone meal were the better producers. When we subjected our data to careful analysis, studying the records of the individual cows from year to year, and took into account the influence of breed, age, and length of lactation on the milk yield of the two groups, it was found that the evidence is not so favorable to the "no bone meal" group. In fact, it favors slightly the "bone meal" group of cows.

Composition of the Milk

The milk from each cow in the herd is sampled for five consecutive days each month. Total solids and fat have been determined in the composite samples each month during the course of the experiment. In addition the total ash, and calcium and phosphorus content of the milk have been determined from time to time,—on an average, about four times a year.

Average Composition of the Milk
since Commencement of the Mineral Experiment.*

(Expressed as percentages of the liquid milk)

	Whole Herd, (Dec. 1921-Oct. 1925)	"Bone Meal" Group.	"No Bone Meal" Group.
Total solids	12.74	12.83	12.67
Fat	4.21	4.27	4.16
Solids not fat	8.53	8.56	8.51
Total ash	0.724	0.722	0.725
Calcium (Ca)	0.117	0.118	0.117
Phosphorus (P)	0.096	0.093	0.098

* These figures have been corrected for differences in the relative number of Holsteins and Jerseys in each group, otherwise the much richer Jersey milk might give the figures a wrong significance. In the case of total ash, calcium and phosphorus, they have also been corrected for any influence that difference in stage of lactation of the cows in the two groups might have. It is well known that as a cow advances in lactation her milk becomes richer. This correction has not been necessary for the total solids and fat, as they have been determined regularly every month for all cows.

Effect on Reproduction

Recurrence of Heat.

Regarding regularity, the records show the following:

Regularity	Whole Herd	"Bone Meal" Group.	"No Bone Meal" Group
Good	15	7	8
Fair	4	3	1
Poor	0	0	0

The average length of time after calving before the first heat has been:

"Bone Meal" group,	37 days
"No Bone Meal" group,	39 days

The condensed data show that both groups were quite similar in their behavior in these respects. In fairness, however, it must be stated that as the experiment has progressed, the cows that received the bone meal have tended to come in heat sooner after calving, while the reverse has been true of those that did not receive bone meal.

Difficulties in Getting Cows Bred.

Considerable trouble has been experienced in getting the cows with calf, some of them needing the attention of a veterinarian, and having to be served four or five times before they would hold. Up until the past year or so the trouble became somewhat more prevalent as the experiment progressed. Since then, for some unaccountable reason, the cows have improved considerably in this respect. The groups have been quite evenly divided with respect to it, as the accompanying figures show.

Average Number of Times Bred.

Year	"Bone Meal" Group.	"No Bone Meal" Group.
1922	1.60	1.67
1923	2.25	2.67
1924	2.67	2.57
1925	1.60	1.50

Abortions and Retained Afterbirths.

There have been three cases of abortion and one premature birth in the herd since the commencement of the experiment. Two of the abortions were in the "bone meal" group, the other one and the premature birth were in the "no bone meal" group. Two of the abortions were caused by accidents and it is doubtful if the other two were due to the effect of the experiment. There have been six cases of retained afterbirth, of which four have been in the "no bone meal" group. This fact may be of some significance, or it may be mere chance.

Condition of the Calves at Birth and Subsequently.

All calves dropped during the course of the experiment have either been raised to maturity or kept a sufficiently long time to enable us to form an accurate opinion as to their constitutional vigor. The following table summarizes the records.

Condition of Calves.

Group and Year.	Vigorous.	Good.	Fair.	Delicate
Bone meal				
1922	1	1	...	1
1923	2	.	2	1
1924	1	2	2	...
1925 (to Oct. 1)	2	...	1	...
Total	**6**	**3**	**5**	**2**
No bone meal				
1922	1	1	2	2
1923	2	2	2	1
1924	2	1	1	2
1925 (to Oct. 1)	2	4	1	...
Total	**7**	**8**	**6**	**5**

The only result of any significance here is the somewhat higher number of delicate calves from the "no bone meal" cows. Proportionately the difference between the groups in this respect is not so great as a first glance at the figures seems to show, the ratio being roughly 3 to 2 instead of 5 to 2. Also the delicate calves have with one or two exceptions been from Jersey cows, so that it is probable that breed characteristics have had more influence than has the experimental treatment.

Summary

The object of the work reported here has been to ascertain what benefit may be derived from adding steamed bone meal, with the animal matter largely extracted, as a source of lime and phosphorus to the ration of dairy cows.

The entire herd has been fed for four years on a ration low in mineral matter, particularly in lime. One-half of the herd has had the deficiency made good in theory by adding bone meal to the grain.

The results in brief are as follows:

1. The experiment has had no appreciable effect on the general condition of the cows that were mature when it commenced. This has been especially true of the Holstein cows. The low mineral rations have adversely affected some of the young cows, as evidenced by their unthrifty appearance and poor appetite. The young Jerseys show this more than do the young Holsteins, although there are exceptions in both breeds. For a long time there seemed to be no difference in general condition between the "bone meal" and the "no bone meal" group; but recently there has been some slight evidence to favor the bone meal.
2. The mature cows have not shown any significant changes in weight, but about half of the young cows are smaller than their dams were at the same age. In this respect the evidence is about evenly divided, not favoring either group.
3. Milk production has been maintained well all through the experiment. The evidence on this point favors slightly the "bone meal" cows.
4. The composition of the milk has not been significantly affected.
5. The reproductive function has been more seriously disturbed than any other, considerable difficulty being experienced in getting the cows with calf. The two groups have been quite similar in this respect.
6. Each group has produced about the same proportion of strong, healthy calves. The "no bone meal" group has had a somewhat higher proportion of delicate calves, but this may have been due in part to breed characteristics.

Conclusions and Recommendations

Our work has led us to the conclusion that while dairy stock, especially growing heifers, must have an adequate supply of lime in their food in order to attain maximum development and productive capacity, the advantage to be gained from the practice of supplying lime in the form of steamed bone meal seemed to be very slight.

While we have still much to learn on the subject of mineral feeding of cows, the following recommendations are tentatively made:

1. Supply lime and other minerals in feeds that are naturally rich in ash, rather than by supplementing feeds low in ash with bone meal or other lime salts. All the leguminous hays are high in lime, in addition to their very desirable protein content. Alfalfa hay contains five times as much lime as does timothy hay. There is as much lime in a ton of red clover hay as in 100 pounds of ordinary bone meal, and it is in what is probably a more desirable form. It is in the choice of roughage that care must be used. The ordinary grains and concentrates are characterized by relatively low lime and

high phosphorus content, so that in so far as ash requirements are concerned it makes little difference what grain ration is fed.

2. All dairy cows should have a dry period of two months, during which time they should be liberally fed on a legume roughage, or on early cut hay containing clover, or on rowen, as well as on some grain to make up for the losses in mineral matter during the period of heavy milking. Good pasturage will also prove very satisfactory.

3. Growing heifers should receive special care with respect to the ash content of their rations. Here again some kind of properly cured legume or clover-mixed hay is the best safeguard.

4. Put the bone meal and other mineral substances on the land, rather than in the manger. Used in this way the yield and ash content of the crop are likely to be increased and thus indirectly the ash requirements of human beings and animals will be taken care of.

5. Common salt is the one exception to all the above statements. Animals should have free access to it at all times.

The above recommendations are what many successful dairymen now practice, and are within the reach of all who wish to improve their feeding practices in this respect.

NOTE: It is possible that most cows when fresh are in negative calcium balance; that is, they excrete in the milk and manure more calcium than they consume. This condition in all probability is more pronounced and continues for a longer period in case of cows bred for heavy milk production. It has been shown recently by the Wisconsin Station that direct sunlight checks this tendency to a limited extent. Whether the antirachitic vitamin is of pronounced influence in aiding calcium assimilation in case of dairy cows is still an open question.

SKIM MILK POWDERS IN THE REARING OF YOUNG CALVES

By J. B. LINDSEY and J. G. ARCHIBALD

In our studies of substitutes for whole or liquid skim milk in the rearing of young calves, we have tried both the drum dried and the spray dried skim milk powders.

Method of Manufacture of Milk Powders

In the spray process, the liquid milk is forced under high pressure through nozzles into the upper part of a heated chamber. The fine spray is dried to a fine powder by the time it reaches the bottom of the chamber. The chief advantage of this process is that the powder is very readily and completely soluble in water.

In the drum or roller process, the skim milk is fed from a gravity tank onto steam-heated rolls. It spreads out into a thin film, drying as the rolls slowly revolve. The dried film is removed from the rolls by scrapers, ground, sifted and packed. It is somewhat coarser in texture than the spray dried product and does not dissolve in water as readily. The manufacturers claim that the process is not destructive to the vitamins in the milk, especially Vitamin C.

Preparation of Skim Milk Powder for Feeding

One pound of the milk powder and a scant even teaspoonful of salt are added to each gallon of lukewarm water.[1] The milk powder and salt should first be stirred with a small quantity of cold water to avoid lumping, and after a creamy consistency has been secured, the necessary amount of lukewarm water added, the mixture well stirred and thus fed. Enough can be made up, if desired, to last twenty-four hours, but it should not be fed cold.

Method of Feeding

Whole milk was fed for the first week after weaning and then the skim milk solution gradually substituted. Not over nine quarts daily were fed to each calf and it is better, although not necessary, to continue feeding a minimum of two quarts of whole milk daily during the first six or eight weeks of the calf's life. After the first month, the calf was taught to eat rowen and a calf meal made up of 30 pounds red dog flour, 30 pounds ground oats, 15 pounds linseed meal, 24½ pounds of corn meal and ½ pound salt. By the time the calf reached four months of age it was eating one and one-half to two pounds of grain daily and a considerable amount of hay.

The experiment was ended when each calf reached the age of four months at which time the milk was gradually removed and dry feeds substituted. It is preferable, however, in case of promising dairy heifers, to continue giving some of the skim milk until the animals are five or six months of age, in order to promote rapid growth.

[1] If desired, one pound of the milk powder may be used to 5 quarts of water.

THE RESULTS

Relative Growth, Gains and Costs of Rearing Calves on Skim Milk Powders

Material	Number of Calves*	Average daily gain Lbs.	Dry matter required for 100 pounds gain Lbs.	Food cost per pound of gain Cents
Skim milk powder (drum process)	6	1.50	287.79	16.5
Skim milk powder (spray process)	6	1.39	277.72	22 2
Liquid skim milk for comparison	6	1.68	250.78	14.3

* All grade Holstein calves.

Liquid skim milk was charged at 1½ cents a quart, drum dried powder 7½ cents and spray dried powder 11 cents a pound (drum dried solution, 1.9 and spray dried solution, 2.75 cents a quart). The table shows:

1. That neither skim milk powder promoted as rapid growth as did the liquid skim milk.

2. That the drum process powder produced slightly better growth than did the spray process powder. The difference is not great and too much stress should not be placed upon it. Inasmuch, however, as the drum dried powder may often be purchased for several cents a pound less, it is to be preferred for calf feeding.

3. Dried skim milk offers the best substitute for liquid skim milk in the rearing of young calves. At the present, the price has advanced to 11 cents for the drum dried and 13½ per pound for the spray dried, which renders their use of doubtful economic value. The price will vary according to supply and demand.

BETTER FEED FROM PERMANENT PASTURES

By SIDNEY B. HASKELL

In the spring of 1921 the Massachusetts Experiment Station instituted certain fertilizer experiments on a typical, rock-bound, weed-grown permanent pasture. The pasture must have been last plowed more than 100 years ago, in the days of cheap labor and ox team power. A part of the pasture had once been tilled, had degenerated into pasture, had then grown a crop of wood and timber; and then after many years had been brought back to pasture in a century-long rotation. Of clover and blue grass there were but the scantiest traces. Running cinquefoil and great clumps of green moss had crowded out the better types of vegetation.

It was under these discouraging conditions that the first fertilizer was applied, as a top-dressing, in the early spring of 1921. A second, more elaborate experiment was started in 1922. The fertilizers applied, and the rates at which they were used, were as follows:

Acid phosphate, 480 and 960 pounds per acre.
Muriate of potash, 80 and 160 pounds per acre.
Ground limestone, 2400 pounds per acre.
Acid phosphate and muriate of potash as above, at the two different rates.

Space does not permit of extended description of the remarkable effect of these fertilizers. By 1923 many of the plots had developed a dense growth of white clover. Potash was the most effective of any of the treatments; lime and acid phosphate, used alone or together, were relatively ineffective. Potash and acid phosphate combined, especially when used in the limed areas, showed a distinct advantage over the potash alone. As time has elapsed, the apparent effectiveness of lime has been increasing; also, but to a less marked degree, has that of the acid phosphate.

Photographic records best portray the remarkable results of this experiment. A camera was suspended over a typical area, and in each of three successive years an exposure was made of the same portion of the sod. The upper picture shows the character of the sod as it was before fertilizer was applied; that in the center, taken a year later, shows the changing vegetation as produced by fertilizer; and the lower picture shows the results of 1923, which was definitely a "clover year." The fertilizer here used was the potash and acid phosphate mixture with lime. Similar results were obtained in the experimental plots started in 1922; but here, probably on account of more favorable weather conditions, the fertilizer had more rapid effect.

Effect of Fertilizer on Quality of Pasturage

About the middle of June, 1923, animals were barred for a three weeks period from the pasture plots fertilized in 1922. Samples of the three weeks' growth were cut, the product dried, weighed and subjected to chemical analysis. Results are shown in the following table:

Fertilizer Treatment	Dry Matter per Acre, Pounds	Protein	
		Per cent	Pounds per Acre
Acid phosphate 960 lbs.; no lime	863	14.17	122
Acid phosphate 960 lbs.; limestone 2400 lbs.	1050	18.70	196
Muriate of potash 160 lbs.; no lime	676	20.78	140
Muriate of potash 160 lbs.; limestone 2400 lbs.	1023	23.29	238
No fertilizer; no lime	703	14.60	103
Limestone 2400 lbs.	766	17.97	138
Acid phosphate 960 lbs.; muriate of potash 160 lbs.; no lime	1272	20.56	262
Acid phosphate 960 lbs.; muriate of potash 160 lbs.; limestone 2400 lbs.	1576	24.53	387

The greatly increased yield of protein on the best treated plot is most significant, with a total production equal to that contained in 2400 pounds of wheat bran. The cause of this change is of course the stimulation of clover and the suppression of the weeds brought about by the use of lime and fertilizer.

The Grass Cycle

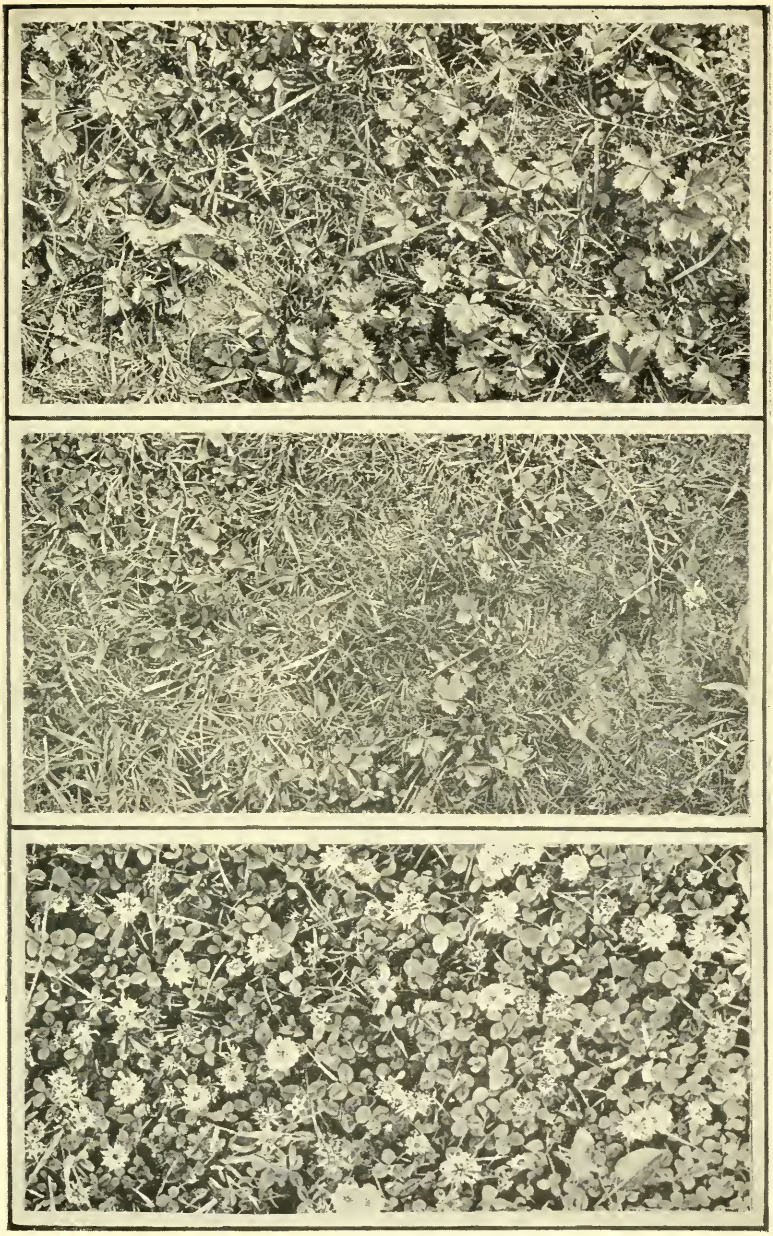
White clover, however, comes and goes. By the fall of 1924 it had disappeared from these plots almost absolutely and been replaced by blue grass. In the spring of 1925 no clover was in evidence, even on those plots which had been densely carpeted in the summer of 1923. In the early summer of 1925, however, drouth conditions prevailed, to be broken during the end of June by generous rains. These conditions favored clover, and by the end of that year it was once more dominant on all of the better fertilized areas.

It is impracticable to translate the above figures into terms of profit and loss. We have no means of knowing how long a time fertilizer will continue to show benefit. Yet the fact that large areas have already reverted to forest shows what must happen to existing pastures in case fertilizer be not applied; or in case the price of milk be too low to make profitable such fertilizer application.

What Fertilizers Are Needed.

On the relatively coarse grained, depleted granitic soils of the Station farm, potash was the plant food most needed. Best growth was obtained with lime. Acid phosphate applied in addition to lime and potash still further bettered the yield. The total expense of application of these three materials was, of course, very heavy. On heavier pasture soils, acid phosphate may be all that is required. In certain demonstrations west of the Connecticut River, instituted by the Department of Agronomy, M. A. C., this is indicated most clearly. It is probable that, where the soil is fairly close grained and has a favorable moisture supply, acid phosphate, with lime if the soil be extremely acid, will be all that is required. These of course must be applied as top dressing, which means that action is certain to be relatively slow.

The fertilizing of pastures is a most interesting field for farm experiments. There are, however, certain discouraging conditions attending it. Returns from fertilizer application are always delayed, for only by stimulating white clover and grass so that it can crowd out the weeds is the better pasture secured. If the weather be dry, there may be a period of weeks or even of months in which there will be no growth on either fertilized or unfertilized portions of the pasture. Even when good growth is produced, as should usually be the case, the fact may not be noticed, for increased forage may be pastured off as rapidly as it is grown. Yet with all of these uncertainties, the goal is worth the effort. A pasture which is in a weedy or run-down condition because of a lack of plant food can be brought back to productive condition only by the use of plant food.



Progressive Change in Pasture Vegetation.
Top—Before Fertilizer was Applied.
Center—One Year after Application.
Bottom—Two Years after Application.

THE UTILIZATION OF FEEDS BY HORSES

By J. B. LINDSEY AND J. G. ARCHIBALD

Although it is recognized that for many industrial purposes the automobile, auto truck and farm tractor have replaced the horse as a source of power, we believe that the horse, for a long time to come, will continue to have his place upon the farm and in certain other lines of industry.

For a number of years studies have been made at this Station of the digestibility, metabolizable energy and net energy of the ordinary roughages, grains and by-products likely to be fed to farm and other work horses in order to ascertain their relative nutritive values.

Units of Measurement.

In order to get at relative nutritive values, we must have one or more units of measurement. Obviously the foot rule or the yardstick would not serve for such a purpose. The best units we have are (a) chemical analysis of the feed, (b) its digestibility, (c) its total, metabolizable and net energy values.

(a) *Chemical analysis* tells how much of each of the several groups, protein, fat, carbohydrate and ash, a feed contains but it does not tell how much of each group the animal can finally utilize.

(b) *Digestibility.* By digestibility is meant the amount of each ingredient the animal can digest or so transform that it can be carried into the blood stream and made use of as food. The solid excreta or feces is the undigested portion of the feed which, subtracted from the total feed, leaves that which is digested. The *digestion coefficient* means simply the *percentage* of the feed or ingredient digested. Thus, if a feed contains 30 per cent or pounds of fiber in 100 pounds and 15 pounds is digested, the coefficient is 50.

(c) *Energy.* Every food may be regarded as a mass of latent energy. Digestion liberates this energy and the animal lives and produces, as a result of the liberation.

Total energy represents all of the energy contained in a feeding-stuff, and is determined by the use of a complicated piece of apparatus known as a bomb calorimeter

Metabolizable energy is the total energy less that contained in the feces and urine.

Net energy is the total energy minus that lost in the feces and urine and that used in the process of digestion and assimilation.

While the determination of digestibility tells us the amount of a food digested, it does not tell the cost to the animal of the energy expended in the digestive processes. Comparative digestibility of feedstuffs, however, is a very helpful unit of measurement, but net energy is the more exact. Unfortunately the present method for determining net energy is very difficult, expensive and time consuming. The only equipment available in the United States for large animals is that at the Institute of Animal Nutrition in Pennsylvania, financed by the National Government. The late Professor Armsby, the director of the institute, as a result of his own experiments and those conducted in Europe, deduced a formula for determining net energy, based upon chemical analysis, total energy and metabolizable energy. In the experiments here reported, we have made use of this formula after having determined the composition and the total and metabolizable energy in each feedstuff, as well as its digestibility; and it is these two units of measurement—*net energy,* expressed in therms[1], with *digestibility* as an aid— that we have used in getting at the relative values of the feeds studied.

Method of Procedure

Two horses were used in each trial. Each feed was analyzed and its total energy determined. Definite amounts daily were fed, the feces and urine collected, and the energy contained in them determined and subtracted from the total energy of the feed, which gives the metabolizable energy. By the application of the formula mentioned above, the net energy was estimated. In the above procedure we were able also to determine digestibility. Each actual experiment required about three weeks for its completion, in addition to a large amount of work in the chemical laboratory and in the calculation of the results.

Some Results of the Experiment

The Story of Alfalfa.

Two different lots of alfalfa were tested, one grown in New York state and the other on the Experiment Station grounds. The New York sample contained 11.7 per cent protein and 35.2 per cent fiber, while the Station sample contained 17.7 per cent protein and 27.5 per cent fiber. It is evident that the former sample was more mature than the latter.

Average Digestion Coefficients and Net Energy Values

Material	Digestion Coefficients (Per cent)				Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	
Alfalfa, New York sample	49	66	34	60	14
Alfalfa, Massachusetts sample	53	73	38	62	36
Alfalfa fed to cattle (for comparison)	58	72	46	66	34

These results indicate that the New York sample was more mature and less utilized by the horses than the Massachusetts sample; while the net energy values show that the horses had to expend considerably more energy to digest the New York, or late-cut sample.

The comparison of the digestibility of alfalfa by horses and cattle, given in the table, shows that cattle are able to digest alfalfa to a greater degree than are horses, although the protein is well and about equally digested by both classes of animals.

[1] The therm represents the amount of heat required to raise 1000 kilograms of water 1 degree Centigrade, and is used as a unit of measurement for energy.

What the Horses Did with Timothy and Kentucky Blue Grass Hay.

Five of the samples tested were largely Timothy, and contained from 3.86 to 7.68 per cent protein and from 28.9 to 31.7 per cent of fiber. It is evident that some samples were cut earlier than others. One sample was fine in quality, was composed mainly of Kentucky blue grass, and contained 7.70 per cent of protein and 28.35 per cent fiber.

The average digestion coefficients and net energy value are given in the following table:

Average Digestion Coefficients and Net Energy Values

Material	Number of Samples	Digestion Coefficients (Per cent)				Net Energy per 100 pounds (Therms)
		Dry Matter	Protein	Fiber	Nitrogen-free Extract	
Timothy Hay (coarse)	5	47	44	43	53	27
Kentucky Blue Grass (fine)	1	50	58	47	56	33
Timothy Hay fed to cattle (for comparison)	72	55	47	51	62	43

It was found that the total digestibility of the Timothy varied from 40 to 54 per cent, with an average of 47 per cent, and that the digestibility was inversely proportional to the fiber percentage; that is, the higher the percentage of fiber, the lower the digestibility. The net energy varied from 18 to 38 therms per 100 pounds, with an average of 27 therms. The sample containing the highest percentage of fiber, 31.68 per cent, contained but 18 therms of net energy per 100 pounds; while the lot which contained only 28.8 per cent fiber had 38 therms of net energy. The teaching is the same as in the case of alfalfa: namely, that late cutting, high fiber content and low net energy go hand in hand. The conclusion is clear, that the later the hay is cut, the less its nutritive value per pound or ton. Horse feeders prefer late-cut, coarse hay, not for its high nutritive value but because of its distention of the intestinal tract and its less laxative effect. They depend largely upon the grain ration for nutrition, and upon coarse hay as a distributor.

The fine hay was more digestible and had more therms of net energy than the coarse. The average results with cattle show that they are able to make better use of Timothy hay than do horses.

A Kansas Ration v. a Substitute Ration.

The Kansas ration, so-called, was a combination of alfalfa, corn and oats, recommended by the Kansas Experiment Station and the United States Department of Agriculture, who experimented jointly for a period of 140 days with 17 artillery horses, doing what was termed rapid light draft.

The combination which proved satisfactory in the trials cited was recommended on the ground that a relatively small amount of roughage (alfalfa) fed with a relatively large amount of corn and oats would require a minimum of energy for its digestion; and that the alfalfa furnished the necessary amount of protein and was not fed in sufficient amounts to prove injurious.

Inasmuch as alfalfa was but little grown in Massachusetts, we compared the Kansas ration with a substitute ration composed of Timothy hay, corn, oats, bran and dried brewers' grains, the latter furnishing the protein lacking in the Timothy.

The two combinations fed to determine digestibility and net energy requirements were as follows:

	Kansas Ration Lbs.	Substitute Ration Lbs.
Alfalfa	8.25	--
Timothy	.....	9.00
Corn	6.60	4.20
Oats	1.65	2.40
Bran	......	1.21
Brewers' grains	......	1.80
Totals	16.50	18.61

Chemical Composition

Ration	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Kansas	13.72	4.68	13 66	19.30	58.82	3.55	201.42
Substitute	11.42	4.55	11.91	21.56	58.17	3.80	203.84

In chemical composition one notices little difference except that the Kansas ration is lower in fiber and higher in protein.

Average Digestion Coefficients and Net Energy Values

Ration	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Kansas	63	78	?	78	54	76
Substitute	53	65	?	64	35	59

The horses in each case digested little fiber and the results are not reported. A study of the digestion coefficients and net energy values shows that the horses made better use of the Kansas ration.

On the basis of 1000 pounds live weight, the horses in the experiments conducted at the Kansas station were fed, daily, 8.5 pounds of alfalfa, 6.8 pounds of corn and 1.7 pounds of oats while doing their work. These amounts seemed to us quite small, and practical experiments with our own horses, as well as comparisons with generally accepted standards, confirmed this conclusion.

As a result of our digestion and energy study, as well as of practical feeding trials, we have concluded that a combination of alfalfa, corn and oats in the proportions indicated above, known as the Kansas ration, proved superior to a combination of Timothy, corn, oats, bran and dried brewers' grains but that the amount of the Kansas ration fed per 1000 pounds live weight should be at least 20 per cent more than recommended by the original experimenters. The Kansas station emphasized the fact that alfalfa, when cut in full bloom and free from mold, smut and excessive dust, is suitable for horses; and that one and one-fifth pounds daily per 100 pounds live weight is the maximum amount to be fed to work horses.

Trials with the Cereals.

Experiments were made with whole corn, cornmeal, corn cobs, oats and oat hulls. Their chemical composition and total energy value are stated in the following table. For the sake of comparison the analyses are all stated on a dry matter (water free) basis.

Chemical Composition

Material	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Corn meal	16.81	1.54	10.09	2 59	82 13	3.65	203.67
Corn, whole	13.40	1.38	9.88	3.05	81.58	4.13	199.58
Corn cobs	18.67	1 70	3.14	30.23	64.22	0 72	205.48
Oats, whole	10.97	3.35	13.38	10.39	67 56	5.32	207 75
Oat hulls	8 57	6.59	2.52	33 04	56 83	1.02	197.32

The cereals have about the same type of chemical composition; that is, they are relatively low in protein and high in carbohydrate or starchy matter. Oats contain more protein and fat and decidedly more fiber than corn. Corn cobs and oat hulls are quite deficient in protein and fat and are made up largely of fiber and of complex carbohydrates.

The results given below represent the averages secured with two horses.

Average Digestion Coefficients and Net Energy Values

Material	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Corn meal	72	71	None	85	62	117
Corn, whole	74	62	None	85	51	113
Corn cobs	25	None	None	45	None	None
Oats, whole	61	75	None	72	57	118
Oat hulls	22	?	?	10	82	None

A little study of the figures in the table shows that the two horses digested the whole corn and corn meal in equal amounts and derived about the same net energy from them. One would suppose that corn meal would yield rather more net energy than whole corn because of the energy required for chewing the latter; but our method of measurement was not sufficiently sharp to detect the difference. Although the horses were able to digest 25 per cent of the corn cobs, they did not derive any net energy from them, all the energy being required for the efforts of digestion; hence we may conclude that the cob is without food value for horses.

Oats were not as well digested as corn, due to the presence of about 30 per cent of hulls, which were not digested by the horses in the present trial. Strange to say, the oats furnished fully as much net energy as the corn, namely 118 therms. This result is not confirmed by the few trials on record, which show 93 therms. A further study of the comparative net energy values of corn and oats for horses is desirable. Oat hulls were digested to about the same extent by horses as were corn cobs, and did not furnish any net energy. They are, therefore, without value as a source of nutrition for horses. The nutritive value of the oat for horses is contained in the groat.

Wheat Bran and Brewers' Dried Grains.

These materials are well known to all feeders. The question is often raised as to the value of wheat bran as a horse feed. Brewers' grains, both wet and dried, have been used with apparent success by many feeders of horses. The average chemical composition of the samples tested is stated below.

Chemical Composition

Material	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Wheat bran	11 74	7.25	16 79	10.95	59 86	5 16	202 65
Brewers' grains	7 68	3.35	28.79	15.59	45.33	6 26	229.30

Both feeds contain a considerable amount of fiber. The brewers' grains are rich in protein and fat, the latter ingredient giving this feed its extra energy value.

Average Digestion Coefficients and Net Energy Values

Material	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Wheat bran	52	83	None	61	None	52
Brewers' grains	51	77	27	50	46	?

The *average* digestion cofficients for the two feeds do not differ very much. The horses were able to digest about one-half of the entire dry matter, as against 62 and 66 per cent by bovines. The protein was well digested but the animals were unable to make much use of the fiber. The utilization of the fat in the present experiments seemed uncertain.

The ten single trials with wheat bran gave rather wide variations in coefficients as well as in net energy values which indicated that the horses experienced difficulty in making use of it. We are, therefore, led to conclude that as a source of nutrition, it is not to be recommended. It may be fed in limited amounts (1-2 pounds daily) as a component of a ration because of its gentle laxative effect.

The four digestion trials with brewers' grains gave reasonably uniform results. It was quite evident that the horses could digest the protein easily but had difficulty with the fiber. The variations in net energy value are so great that the average result is not stated. The reason for this is not apparent. While in many cases, depending upon local conditions and cost, brewers' dried grains may prove satisfactory as a component of the horse ration, it is believed they can be used to better advantage as a food for dairy stock.

The Utilization of Cottonseed Meal.

Two different lots were fed, testing as follows:

Chemical Composition

Material	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Cottonseed meal, Lot I	7.62	7.10	37.51	19.69	28.04	7.66	224.53
Cottonseed meal, Lot II	8.76	6.68	41.27	12.79	31.22	8.01	225.44

The first lot of cottonseed meal was inferior to the second lot. It is evident that extra cottonseed hulls had been added to it, increasing the fiber to 19.69 per cent, much above the normal.

Digestion Coefficients and Net Energy Values

Material and Horse	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Cottonseed meal Lot I						
Joe	61	84	23	71	90	61
Chub	71	89	65	58	100	87
Cottonseed meal Lot II						
Joe	62	87	38	36	87	73
Chub	69	84	19	62	93	104

It is hardly fair to average the two lots of meal, as one contains so much more fiber or hulls than the other. The horse Joe did not utilize the meal as well as did Chub. Both horses made excellent use of the protein and fat but failed to digest the fiber fully. Joe did not secure as much net energy as did Chub. It would be expected that Lot II, containing less fiber, would yield more net energy than Lot I, and such proved to be the case. On the basis of our results, exact figures for net energy cannot be deduced. It is believed that the data secured with Chub are more reliable than those secured with Joe. On this supposition it may be assumed that the therms of net energy in 100 pounds of cottonseed meal will be from 87 to 104. Much, however, depends upon the percentages of fiber and fat contained in the meal.

Our trials show that horses are able to digest cottonseed meal fairly well, especially the protein and fat; and that a liberal amount of energy was derived from its use,—nearly as much as from corn. Its chief use for the horse would be as a source of protein, especially for hard-worked horses, to the extent of from 5 to 10 per cent of the grain ration.

A Word About Linseed Meal.

Two experiments were carried out with this meal, but some of the results were so uncertain that they are not presented. The protein was quite as well digested as that contained in the cottonseed meal. The results for net energy varied widely. The writer would assume, however, that it would not vary greatly from those secured for cottonseed meal. Earlier feeding trials with linseed meal mixed with whole corn and oats, to the extent of 20 per cent, indicated that it did not mix evenly with uncrushed feeds. Horses do not care for it if fed unmixed, but will eat a reasonable amount readily if it constitutes part of a mixture. The addition of 5 to 10 per cent of linseed meal to a grain ration of one or more cereals will furnish the extra protein needed by hard-worked horses and will be eaten without trouble.

Percentage Energy Efficiency of Feeds for Horses.

The total energy contained in all feeds tested, expressed in therms, was 205.46 with extremes of 191 and 229, the latter figure being obtained from brewers' grains which contained considerable fat. The therms of total energy per 100 pounds of dry matter, for most cattle feeds, will not vary much from 200, except for those having more than the ordinary amount of fat.

The percentage of energy utilized—net energy—varied widely, from zero in case of corn cobs and oat hulls to 57 in case of corn. Two samples of alfalfa showed extremes of from 7 to 18 per cent of energy utilized, with an average of 13; six samples of Timothy hay from 9 to 19, with an average of 14. The amount of net energy and the percentage of energy utilized in coarse feeds depends evidently upon stage of growth. Corn was 57 per cent utilized, oats 57 per cent, cottonseed meal 36 per cent, and wheat bran 26 per cent.

We fail to find on record data of the utilization of energy of individual feeds by horses. It can be said, however, in general, that the less the percentage of crude fiber, and in roughages the less mature the material, the greater will be the energy available. Armsby has computed the availability of the energy for ruminants as varying between 5 and 24 per cent for roughages, 46 per cent for corn and hominy meals, and 29 per cent for wheat bran.

Summary

The results of the feeding trials with horses, reported in the preceding pages, may be summarized as follows:

Timothy hay and alfalfa had about the same net energy value, but different samples varied widely, depending upon the stage of growth.

Corn cobs and oat hulls were without net energy value.

The cereal grains had substantially the same net energy values—somewhat more than did the high-grade nitrogenous concentrates such as cottonseed and linseed meals.

Wheat bran had a low energy value and as a source of nutrition proved inferior to other concentrates fed.

The protein in dried brewers' grains was well utilized, but the results for net energy were uncertain. This material is recommended more as a feed for dairy stock than for horses.

Cottonseed and linseed meals have quite high net energy values and their protein is well utilized. They may serve in limited amounts (1 to 2 pounds daily) as a supplement to the grain ration for hard-worked horses.

The percentage energy utilization varied from 57 per cent in case of corn to zero in case of corn cobs and oat hulls; the energy in timothy hay and alfalfa hay was utilized to the extent of from 7 to 19 per cent with an average of 14 per cent.

The net energy value of feeds depends to a considerable extent upon the percentage of crude fiber present—the higher the percentage of fiber, the less the net energy and *vice versa.* In case of coarse feeds, the later the stage of growth and hence the more mature the material, the less its net energy value.

The *character* of fiber influences its digestibility and net energy value. Fiber in straw and oat hulls is less digestible than in corn bran and in early cut hay. The more mature a plant, the more woody the tissue becomes, with an increasingly lessened digestibility.

IMPROVING THE FEEDING VALUE OF GRAIN HULLS AND SAWDUST

By J. G. ARCHIBALD

Foreword

A great deal of study has been devoted by numerous investigators in different countries to improving the digestibility and consequently the feeding value of straws and other fibrous or woody materials. Straw of various kinds is only from 46 to 52 per cent digestible, oat hulls scarcely 40 per cent and cottonseed hulls 53 per cent digestible, while rice hulls, flax shives and sawdust show little if any digestibility. Furthermore, so much energy is required in the digestive processes that these materials, in their natural state, have but little net energy or actual nutritive value. Attempts to improve the feeding value by fine grinding, soaking in water and steaming under pressure have proved to be useless; so also has mixing the fine material with such a palatable substance as molasses.

The straws have also been treated with various chemicals such as dilute sulfuric and hydrochloric acids, lime in the form of the sulfide and oxide, sodium carbonate and sodium hydrate, both by boiling in open kettles and under pressure. Many of these methods have greatly improved the feeding value of the straws.

Why Wood, Straws, Grain Hulls and Similar Fibrous Materials Have Low Feeding Values.

Plant fibers (crude cellulose) are an aggregation of cell walls of certain specialized cells occurring in the plant. These cell walls become elaborated, enlarged and strengthened with age until maturity is reached, at which time, in high fiber plants at least, they constitute the major portion of the individual cells, the cell contents or protoplasm having been almost, if not altogether, absorbed or transported to the seeds.

In the early stages of growth, the cell wall consists of pure cellulose and hemi-cellulose and is soft and reasonably well digested, but as growth proceeds and maturity is reached, it becomes changed to a compound known as ligno-cellulose and the process is known as lignification. This ligno-cellulose complex cannot be digested to any extent because the digestive fluids cannot penetrate it. Some silicic acid also incrusts the complex and still further hinders the action of the digestive fluids and micro-organisms. The action of chemicals, particularly the alkalies, dissolves out the silicic acid and also breaks the bonds holding the cellulose and lignin together, and the cellulose thus set free can be acted upon and converted into nutritive material. As a result of the process, the lignin is more or less decomposed but is of little, if any, nutritive value.

Work at the Massachusetts Station.

Experiments with Oat, Barley, Cottonseed and Rice Hulls and Flax Shives. The normal output of oat hulls by three of the leading oat-milling concerns in the United States has been estimated at over 100,000 tons. Data are not available for the other materials. Ground cottonseed hulls are added in limited amounts to cottonseed meal, and are also fed extensively in the South, unground and mixed with one-quarter their weight of cottonseed meal. Formerly, if not now, they were used as fuel in the cottonseed mills. Rice hulls and flax shives, ground fine, have been used in low-grade feeding stuffs or discarded by millers and farmers.

Any method which would bring about an increased digestibility of these, and similar by-products, was considered worthy of investigation. Aside also from the possible practical results, it was felt that the facts likely to be brought out would be of considerable scientific significance and open the way for further study.

Method Employed.

Originality is not claimed for the method used. It was devised by Dr. Ernst Beckman and employed by him and others during the World War for improving the value of different straws. Briefly stated, the method consisted in treating the hulls for three hours, with frequent stirring, with eight times their weight of dilute sodium hydrate (1.0, 1.5 or 3 per cent) after which the darkened soda liquor was allowed to drain off and the hulls thoroughly washed with cold water and dried.

Chemical Composition of the Untreated Hulls.

Material	Water as fed	Dry Matter (Per cent)				
		Ash	Crude protein	Crude fiber	Nitrogen-free extract	Crude fat
Oat hulls	7.70	6.33	2.26	33.24	57.24	0.93
Cottonseed hulls	6 93	2.13	4.08	43.99	48.60	1.19
Rice hulls	6.25	19.06	3.02	41.80	35.38	0.75
Flax shives	6.78	4.09	5.24	53.81	35.05	1.81

The analyses show the several substances to be quite low in protein and fat and high in fiber. The cottonseed and rice hulls, and particularly the flax shives, are very fibrous in character. The character of the fiber governs to an extent digestibility, depending upon the exact nature of the linkage between the cellulose and lignin and possibly upon the chemical nature of the lignin.

The Action of the Soda (Sodium Hydrate) on the Hulls.

The above materials were treated with dilute sodium hydrate (1.5 per cent), as already described. The chemical dissolved out a little of the protein and fat and more of the nitrogen-free extract, the total losses varying from 10 pounds, in case of the cottonseed hulls, to 25 pounds, in case of the flax shives, for each 100 pounds of dry material treated. The nitrogen-free extract lost consisted principally of pentosans, substances similar to starch and cellulose.

Digestibility of the Treated Materials

After the treatment had been completed and the materials dried, experiments were carried out with sheep to determine digestibility.[1]

Summary of Digestion Coefficients.

	Total Dry Matter	Crude Fiber	Nitrogen-free Extract
Oat Hulls, untreated	36	52	34
Oat Hulls, treated	81	91	79
Percentage increase	**122**	**73**	**132**
Cottonseed Hulls, untreated	53	58	59
Cottonseed Hulls, treated	55	53	68
Percentage increase	**3**	**—10**	**15**
Rice Hulls, untreated	very little	very little	very little
Rice Hulls, treated	29	28	38
Flax Shives, untreated	0-30	0-19	4-33
Flax Shives, treated	29	23	38

The results in the above table represent the average for two sheep. The action of the soda solution is reported on the total material, designated as total dry matter, and on the crude fiber and nitrogen-free extract matter. The other ingredients (protein and fat) were present in such small amounts as to be without practical significance.

It is clear that the digestibility of the oat hulls as a whole (total dry matter) was very much improved, and the same can be said for the fiber and extract matter. The cottonseed hulls were not improved by the treatment. The sheep were not able to digest the untreated rice hulls to any appreciable extent, but did digest the treated hulls somewhat. The increase in digestibility was not sufficient to render the treated product of any practical value. The same can be said of the flax shives.[2]

On the basis of water free material (dry matter), after making an allowance for losses due to treatment, a ton of oat hulls was increased in digestibility from 725 pounds to 1345 pounds, the digestibility of the crude fiber from 349 to 732 pounds, and the nitrogen-free extract from 390 to 622 pounds.

It is evident, therefore, that as a result of chemical treatment,[3] a marked increase in nutritive value of the oat hulls has been secured and that such treatment would be of service in case of a pronounced shortage of cattle feed. Further study is warranted, in order to devise a method that will

[1] For description of method, see Mass. State Agr. Expt. Sta. Rept. 11, pp. 146-149, 1893; also Mass. Agri. Expt. Sta. Bul. 181.

[2] Barley hulls were also tested but they contained so much of the barley meal as to render the results valueless.

[3] A fuller report of these studies has been given in the Journal of Agricultural Research, Vol. XXVII, No. 5.

decrease the cost of treatment so that such materials could be handled economically in large amounts.

Work with Sawdust.

Sawdust from various woods has been proved to be without value as a food for domestic animals. Numerous investigations have been made and patents issued for the conversion of this inert material into a cattle food. The method of procedure in most cases has been the treatment of the sawdust with dilute mineral acids under pressure, or treatment with alternate portions of acid and alkali. These processes have resulted in converting more or less of the cellulose and hemi-celluloses into sugars. The cattle foods thus manufactured have not met with any extensive use, and so far as we are aware, are not at present on the market. Some time ago, the Forest Products Laboratory of the United States Department of Agriculture, located at Madison, Wisconsin, carried on extensive investigations in the conversion of the sawdust from several species of wood into more soluble forms, for the production of industrial alcohol and as a possible source of cattle food. The Forest Products Laboratory asked that the Massachusetts Experiment Station cooperate in making a study of the feeding value of the product. The material was prepared by them and shipped to this Station for study.

Method of Preparation.

The treatment consists in cooking the sawdust under 120 pounds pressure with dilute sulfuric acid (1.8 per cent) which converts a portion of the cellulose and allied substances into sugar. The liquor resulting from this treatment, together with water used in washing the residue, is neutralized with lime, and evaporated under reduced pressure to a thick syrup and then mixed with the previously dried residue. The product when ready for feeding is a dark brown, somewhat powdery meal, with a slight woody odor and a sweetish woody flavor. The materials sent were prepared from the sawdust of Douglas fir and white pine.

The work at this station consisted in the making of numerous analyses of the products, noting their palatability with dairy animals, determining their digestibility and noting their feeding value for milk production. We present below the results secured.

1. The treated or prepared sawdust is composed of crude cellulose and lignin together with some 28 per cent of sugars.

2. Animals will not eat the treated sawdust when fed by itself. In order to promote consumption it is necessary to mix it with other grains. Occasionally an animal will refuse to eat the mixture of which the sawdust is a component.

3. About 4 pounds daily is all that the mature dairy cow will consume, especially if it is fed for any length of time.

4. Digestion studies show that the dry matter of the Eastern white pine sawdust was about 46 per cent digestible, while that of the Douglas fir sawdust was about 33 per cent digestible. In the case of the Douglas fir sawdust, digestion was confined principally to the sugar formed by the treatment, while in the case of the white pine sawdust apparently some of the cellulose was digested also.

5. If the process of treatment could be modified so as to convert a larger proportion of the cellulose of the wood into sugar, or more completely separate the cellulose from the lignin, the food value of the material would be enhanced.

6. On the basis of equal amounts of digestible nutrients the sawdust when fed to dairy cows produced only slightly smaller amounts of milk than did corn starch, but it took, on an average, 2.75 pounds of sawdust to equal one pound of starch. The cows fed on the treated sawdust ration produced rather less milk, shown more in their milk yield at the beginning of the experiment, and gained less in body weight, on the treated sawdust than on the starch ration, all of which is indicative of the fact that, on the basis of equal amounts of digested matter, the treated sawdust was inferior to the starch.

7. On the basis of the present supply and cost of carbohydrate concentrates it is believed that the product as now prepared has no economic value. Under unusual conditions, as in the case of an extreme shortage of ordinary feedstuffs, it might be used as a partial substitute for the cereal grains or starchy by-products.

4,000. 5-'26. Order 5317.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

TECHNICAL BULLETIN No. 8 JULY, 1926

WINTER CYCLE AND WINTER PAUSE IN RELATION TO WINTER AND ANNUAL EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

In this bulletin are reported the results of a statistical study of winter cycle and winter pause records taken over a period of nine years, with as many separate flocks. The records show that winter cycle furnishes a significant short-time measure of probable annual egg production in the flock. Winter pause is shown to be a potent cause of lowered annual egg production; and any increase in length of pause is but partially compensated for by later increased activity in egg production.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

WINTER CYCLE AND WINTER PAUSE IN RELATION TO WINTER AND ANNUAL EGG PRODUCTION.

By F. A. HAYS and RUBY SANBORN

Introduction

Winter cycle is represented by a period of continuous egg laying during the winter season. February 28 or 29th is arbitrarily chosen as the closing date of the winter period. A distinct cessation of laying before the end of February may be assumed to mark the end of the winter laying cycle. Just what length of pause should be chosen to mark the end of the winter laying cycle is purely arbitrary. Goodale (1918) suggested that a ten-day cessation of laying is sufficiently small to mark the end of the winter cycle. In the studies reported here, a four-day interval is considered as a winter pause because, in the flock studied, such a pause generally means the omission of one clutch* of eggs. The omission of one clutch of eggs really marks a distinct break in the functioning of the reproductive system and probably represents the termination of a laying cycle. Pauses due to broodiness or to injury or disease are not considered, and only pauses occurring between November 1 and February 28 or 29 are classed as winter pauses or as marking the end of the winter cycle.

Winter cycle may further be defined as total days from date of first egg to a pause of four or more days, the pause being considered only between the dates November first and March first. Winter cycle length can therefore be determined only for the pause class of birds, as Goodale (1918) pointed out. Winter cycle is probably inherited as a recessive, according to Goodale (loc. cit.); but he failed to discover a relationship between number of eggs laid in the winter cycle and duration of winter pause.

Winter pause may be defined as the period when egg production ceases, following the termination of the winter cycle and previous to the initiation of the spring laying cycle. Pearl (1912) and Goodale (1918) make reference to winter pause in relation to fecundity. Pearl (loc. cit.) found that the winter cycle in Barred Plymouth Rocks was characteristically terminated by a cessation of production. Goodale (loc. cit.), on the other hand, observed a cessation of production previous to March first in but a part of a Rhode Island Red flock. Goodale (1922) states that winter pause is due in part to inherited characteristics and in part to environmental conditions. He discovered a rather intimate relation between the time of beginning to lay in the fall and the appearance and duration of the winter pause.

Winter pause is usually associated with the shedding of some feathers, or partial molt, as Hays (1924) suggested. Furthermore, a cessation of production during broodiness or at any other time during the laying year is

* The term "clutch" refers to the number of eggs laid on successive days, which is more or less characteristic of the individual hen.

generally characterized by partial or complete molt. Apparently molting, which precedes the development of a new growth of feathers, is a phenomenon initiated by a cessation of active functioning of the reproductive system. A number of environmental influences as well as inherent fecundity thus appear to be concerned in the different pauses of the pullet laying year. The sum total of the winter pause may or may not be represented by a continuous period of non-production. In other words, there may be several pauses of four or more days with some production intervening. In these studies such pauses have been added together and such individuals placed in the same class with birds whose pause is unbroken.

The duration* of winter pause is recognized to be dependent upon environmental conditions such as hatching date, feeding and housing, weather conditions, and all other influences that may affect the physical condition and state of metabolism of the pullet. Since age at which sexual maturity is attained is modified by such controllable conditions as date of hatching, as Hays and Sanborn (1924) point out, and since age when sexually mature largely governs the time of beginning to lay, a complex relationship must exist between age at first egg and winter pause.

The presence or absence of winter pause depends upon inheritance, as Hays (1924) points out. Pullets that exhibit a winter pause of a week or more before March first are known to carry a dominant factor M, while non-pause pullets are recessive and lack factor M. This factor is transmitted equally by both males and females. In this connection, breeders should bear in mind that genetically non-pause pullets may exhibit a winter pause brought on by disease, abrupt changes of feed, moving to new quarters, and other environmental influences largely within control of the poultryman. In the breeding flock of the Massachusetts Agricultural Experiment Station extreme care has been exercised to keep environmental conditions constant from year to year in order that inherited traits affecting fecundity may be studied.

Character of Birds Used

This study includes all Rhode Island Red females, hatched from 1916 to 1924, on which pullet-year trapnest records are available. The flocks each year are made up of all the daughters from each individual female whose progeny was retained. Culling within the family has not been practiced. The major portion of birds in each flock belong to the fecundity experiment. There are, however, a limited number of birds bred for non-broodiness, some for intense broodiness, some for hatchability, some for color, and a few inbreds that are included. Pullet-year records alone are used in this study. The heterogeneity of the flock can scarcely be considered as a factor affecting the constants presented in this report.

Two possible methods are open for attacking these questions in a large population made up from nine years' breeding for fecundity. The first method is the use of the coefficient of correlation. The second possible mode of attack is through the presentation of actual data by families tracing to both foundation males and females through nine successive years. The possibilities of the two methods may be briefly considered.

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* In a small percentage of the flock the pause began late in February and such birds did not resume laying until some time in March or later. In these cases, duration of pause is calculated when production is actually resumed.

The Coefficient of Correlation.

A general survey of a series of individual egg records may lead to certain general deductions some of which may actually be true and others false. The breeder needs to know just how much stress to lay upon different characteristics associated with the traits concerned in high fecundity. The simple correlation coefficient affords a concise measure of the degree of association between specific traits and high fecundity as well as a measure of the relationship between the presence of particular traits and high fecundity. The correlation coefficient may thus be made use of by the breeder in two ways: first, for prediction purposes; and second, in the selection of breeding stock to obtain the most valuable combination of traits. Stated concisely, the correlation coefficient is the only direct and specific measure for degree of association of characteristics where large numbers of individuals are concerned. Fecundity records may be modified by a vast number of environmental conditions as well as by the five traits pointed out by Goodale and Sanborn (1922) which are shown to be inherited. Hays (1924). Only by the use of large numbers of records made over a period of years under uniform conditions of management and in a flock bred for uniformity can a true value of the relative importance of characteristics concerned with fecundity be approached. The coefficient of correlation thus becomes an invaluable tool in breeding for fecundity.

Presentation of Data by Families.

A study undertaken to consider the winter cycle and winter pause by separate families would necessitate the presentation of page after page of abstract data. Such data should be accompanied by detailed and complete discussions and such general deductions as would seem justified. No definite constants could be determined on numbers so small as the individual family. Possibly all the descendants of particular individuals could be considered as units, but from the genetic standpoint such a consideration should be classed as questionable. A general tabulation of the whole population, giving such information as mean hatching date, mean age at first egg, mean weight at first egg, percentage of birds pausing, mean length of pause, mean winter production, mean annual production, etc., by years could be made. Such a tabulation would again be open to the criticism of not furnishing specific information. Only general deductions could be made and no evidence would be furnished as to relative values. In view of the above facts, this method of handling the data is not considered feasible.

Winter Cycle

Winter cycle may be considered in three general categories: namely, (a) in its relation to environmental conditions, (b) in its relation to heritable characteristics concerned in fecundity, and (c) in its absolute relation to egg production.

(a) Relation of Environmental Conditions to Winter Cycle.

Hatching date belongs to the definitely controllable class of conditions in that it may be varied at will of the investigator. Date of first egg depends both upon environment and inheritance. The time when a group of pullets will begin to lay depends in part upon hatching date, method of feeding and management, and upon weather conditions—all of which may be classed as environmental. The dependence of date of first egg upon age when beginning to lay, however, is a relation to a heritable trait, since Hays (1924) has shown age at first egg to be inherited.

1. Correlation Between Hatching Date and Length of Winter Cycle.

Time of hatching is generally believed to hold an important relation to the time of appearance of winter pause. Since the appearance of winter pause marks the termination of the winter cycle, the possibility exists of a relationship between hatching date and length of winter cycle. The table presented below tends to substantiate a relation between date of hatching and length of winter cycle for the *total* population of birds actually manifesting a winter cycle terminated by a pause:

Hatches	Number of Birds	Mean Length of Winter Cycle
1	329	68.33 Days
2	267	62.54 "
3	286	59.56 "
4	281	51.91 "
5	258	47.05 "
6	237	42.00 "
7	225	36.21 "
8	195	38.78 "
Grand Average		52.26 "

The mean length of winter cycle is shown to consistently decrease as the hatching date advances, with but a single exception in the last hatch. There are eight hatches each year at one week intervals from March 25 to May 15. The total difference in age between the first and last hatches is 49 days, while the difference in mean winter cycle length is 30 days. The ability of the later hatched pullets to reach sexual maturity at a slightly earlier age than do early hatched pullets (Hays, Sanborn, and James, 1924) probably accounts for the minor inconsistencies in the above table. The means of the eight different hatches for the nine-year period covered by the table indicate a rather important relationship between date of hatching and length of winter laying cycle, which is determined by the onset of winter pause. In this connection, the reader should bear in mind that only winter pause birds are included in the tabulation because no winter cycle can be ascertained in non-pause birds.

The absolute relation between hatching date and length of winter cycle may be discovered by means of the coefficient of correlation. Available for study are 2078 birds. Class intervals of ten days are used for winter cycle in calculating the following constants:

Number of birds	2078
Mean hatching date (Apr. 17)	4.18
Hatching date standard deviation	± 2.26
Mean length of winter cycle	52.26
Winter cycle standard deviation	± 34.23
Coefficient of correlation	$-.3174 \pm .0133$
Regression of hatching date on winter cycle length .	$-.021$
Regression of winter cycle length on hatching date .	-4.811

A significant negative coefficient of correlation informs that, in general, early-hatched pullets have a longer winter laying cycle than late-hatched pullets of the same flock. The magnitude of the constant does not establish an intimate relationship, however, and for this reason the influence of other forces is evident. An increase in length of laying cycle is important from the breeding standpoint, because it signifies a greater mean winter record, and winter production is intimately correlated with annual production (Hays, Sanborn and James, 1924).

2. Correlation Between Date of First Egg and Length of Winter Cycle.

Date of first egg is very important economically. Its significance biologically depends upon the influence of weather conditions on egg production. Specific data concerning the influence of weather on fecundity are not available, however. There is a considerable body of evidence pointing toward a seasonal periodicity of production which has led a number of workers to consider winter, spring, summer and autumn cycles of laying.

In this experiment 2078 pullets with definite winter cycles are available for study. Fifteen-day class intervals are used in grouping data of first egg, and the range in dates is August 24 to February 20. Below are the constants calculated:

Number of birds	2078
Mean date of first egg (Oct. 29)	5.93
Date of first egg standard deviation	±2.09
Mean length of winter cycle	52.26
Winter cycle standard deviation	±34.23
Coefficient of correlation	—.5307 ± .0106
Regression of date of first egg on winter cycle .	—.032
Regression of winter cycle on date of first egg .	—8.689

The date of first egg fluctuates widely in the population studied. The mean date of first egg for the 2078 birds studied is October 29. In breeding for fecundity this variability in time of beginning to lay may be reduced genetically and also by providing a more uniform environment.

A negative coefficient of correlation of substantial magnitude demonstrates that early laying makes for a long winter cycle. The relation that winter cycle length holds to egg production remains to be considered in sections 4 and 5 of this report.

(b) Relation of Heritable Traits to Winter Cycle.

Age at first egg is a definitely heritable trait (Hays, 1924). It has been shown by a number of workers to be intimately correlated with both winter and annual fecundity. This study shows how age at first egg is related to length of the winter laying cycle. Sexual maturity is the only heritable characteristic reported on in relation to winter cycle.

3. Correlation Between Age at First Egg and Length of Winter Cycle.

The same group of 2078 pullets has been studied to ascertain the correlation between age at first egg and length of the winter laying cycle. Class intervals of ten days have been used for age, and the respective ages of the individuals tabulated against their winter cycle length. The constants determined are as follows:

Number of birds	2078
Mean age at first egg	203.66
Age at first egg standard deviation	±25.92
Mean length of winter cycle	52.26
Winter cycle standard deviation	±34.23
Coefficient of correlation	—.4529 ± .0118
Regression of age on winter cycle	—.343
Regression of winter cycle on age	—.598

Age at first egg varies within moderate limits. Since genetically-early and genetically-late birds are concerned, and because environment probably modifies age and sexual maturity, the standard deviation of age is not excessive.

A significant negative correlation is shown, as might be anticipated from the constants obtained in section 2. Age of sexual maturity may be classified as a characteristic influencing the length of winter cycle as determined by the onset of winter pause. Here is an example of a heritable trait being negatively correlated with duration of winter cycle.

(c) Relation of Winter Cycle to Egg Production.

A knowledge of the relation of winter cycle length to winter fecundity and annual fecundity is of value for prediction purposes. If any short-time measure of fecundity that is reasonably accurate in predicting winter and annual production is discovered, it will be of much economic import. Proper culling enables the poultryman to raise mean flock production by disposing of mediocre layers. If a relatively short season of trapnesting gives a clue to probable production for the year, such information will greatly assist poultrymen. This section considers the correlation between length of winter cycle and winter production and length of winter cycle and annual production. Since the winter cycle length for each bird is tabulated against her egg record, a true measure of degree of correlation is arrived at.

4. Correlation Between Length of Winter Cycle and Winter Egg Record.

Both length of winter cycle and winter egg record are placed in class intervals of ten for the 2078 individual pullets studied. The following constants were determined:

Number of birds	2078
Mean length of winter cycle	52.26
Winter cycle standard deviation	±34.23
Mean winter production	56.99
Winter production standard deviation	±23.40
Coefficient of correlation	+.6538 ±.0085
Regression of winter cycle on production	+.956
Regression of production on winter cycle	+.447

Mean length of winter cycle is 52.26 days while mean winter production is 56.99 eggs. Winter production exceeds the production of the winter laying cycle because most of the pullets resume laying previous to March first following a pause. An arbitrary termination of the winter season at the close of February in all cases does not give a true measure of winter production and no definite calendar date will suffice.

The standard deviations of both winter cycle and winter production are excessive. This fact further establishes the variability as due to inheritance and environment.

The above constant discloses a very intimate positive correlation between length of winter cycle and winter production. Here is concrete evidence establishing an important relation between long winter cycle and high winter egg record.

The importance of optimum hatching date, age at first egg, and date of first egg in relation to the length of the winter laying cycle has been presented in sections 1, 2, and 3. Possibilities of shortening the pause period by breeding methods are to be handled in another publication. Probably the most important consideration is the correlation between length of winter cycle and annual egg production, studied in the next section.

5. Correlation Between Length of Winter Cycle and Annual Production.

Annual egg record depends upon a vast array of environmental forces and upon a series of Mendelian factors. Specific information concerning many of these influences has never been presented. This section attempts to present in concrete form the relation of length of winter cycle to annual production over a period of years. On 1314 pullets the following constants appear:

Number of birds	1314
Mean length of winter cycle	53.52
Winter cycle standard deviation	±34.87
Mean annual production	172.53
Annual production standard deviation	±41.13
Coefficient of correlation	±.4027 ± .0156
Regression of winter cycle on production	+ 341
Regression of production on winter cycle	+.475

This group of birds averaged slightly under 173 eggs during their pullet laying year of 365 days beginning with their first egg. The standard deviation in production illustrates a wide range of fluctuation. The actual range in annual egg production was from 35 to 275.

A positive correlation of substantial magnitude exists between winter cycle length and annual egg record. Length of winter cycle, therefore, furnishes a rather dependable short time measure of probable annual production for a population. Winter cycle length is discernable only for pullets exhibiting winter pause. By trapnesting during the first part of the laying year, it is possible to discover the length of the winter cycle and consequently the time of appearance of its complement, the winter pause.

Winter Pause

In the following table are given the number of pause and non-pause birds by years, together with the percentage of birds in the pause class.

Year	Number of Non-Pause Birds	Number of Pause Birds	Total	% With Pause
1916	120	159	279	56.99
1917	153	239	392	60.97
1918	115	248	363	68.32
1919	59	109	168	64.88
1920	48	133	181	73.48
1921	276	175	451	38.80
1922	201	376	577	65.16
1923	109	353	462	76.41
1924	160	340	500	68.00

The average length of pause for those birds pausing is as follows:

1916 flock	29.46 days
1921 flock	19.23 days
1924 flock	32.97 days

6. Correlation Between Length of Winter Cycle and Length of Winter Pause.

The range in cycle length was found to be from 5 days to 175 days. The class interval used was 10 days. Since winter cycle and winter pause are complementary to each other, it is important to discover their possible relation to each other. The coefficient of correlation will illustrate any tendency for length of winter cycle and length of winter pause to move in the same or in opposite directions. Such information will make clearer their physiological relationships and possible genetic linkage.

Number of birds	2078
Mean length of winter cycle	52.26
Length of winter cycle standard deviation	±34.23
Mean length of winter pause	31.91
Length of winter pause standard deviation	±21.68
Coefficient of correlation	—.1385 ± .0145
Regression winter cycle on pause	—.219
Regression pause on winter cycle	—.088

The length of winter cycle as measured in these studies is subject to wide fluctuation as indicated by the relative magnitude of the mean and its standard deviation. Such fluctuations are to be anticipated in a population highly variable for the seven pairs of inherited factors concerned in winter production, subjected to uncontrollable variation in environmental influences. The fact should be observed, however, that the mean length of winter cycle is about 63 per cent greater than the mean length of pause.

A small negative correlation coefficient indicates a very slight tendency for long-cycle birds to pause for a shorter period than do short-cycle birds. This constant is subject to error, however, in that any increase in length of winter cycle reduces the possible pause interval before March first. The coefficient of correlation as calculated is of value in that it gives the actual relationship between length of winter cycle and duration of pauses within the winter season. These data furnish very good evidence that the length of winter pause does not depend upon the length of the winter cycle of laying.

In this report consideration is given to the winter pause from three general standpoints, namely, (a) Environmental factors affecting duration of the pause; (b) Inherited characteristics concerned with fecundity in relation to winter pause, and (c) The absolute relationship of winter pause to egg production.

(a) Environmental Factors Affecting Duration of Pause.

Much concern should be given to the relation of environmental factors affecting the duration of the winter pause since these conditions are more or less under the control of the poultryman. In the group of environmental factors the following have been placed: hatching date and time of beginning to lay in the fall. The time of year when pullets begin to lay is clearly dependent both upon management and inheritance. Management is a factor when the hatching date remains constant because housing, range, and feeding may either retard or accelerate sexual maturity. Just how significant these environmental influences are on time of beginning to lay in comparison with inherited early or late sexual maturity remains to be determined. At any rate, hatching date can be definitely controlled and time of beginning to lay may be considered as partially controllable.

7. *Correlation Between Hatching Date and Length of Winter Pause.*

A very common observation among poultrymen is that early-hatched pullets are more likely to exhibit winter pause than are late-hatched birds of the same flock. In other words, the belief is prevalent that the earlier the hatching date, the longer the winter pause. Such observations have naturally led to the assumption that the pullet possesses capacity to lay a certain number of eggs in the fall and winter and if this number is laid early there will be a cessation of laying until the spring season. That hatching date is only one of several conditions operating to affect the onset and duration of winter pause has been shown by Hays (1924) and Hays, Sanborn, and James (1924). Age at sexual maturity has been pointed out as an inherited characteristic, and as a characteristic having greater effect than hatching date upon winter egg production. Furthermore, winter pause of seven or more days' duration is an inherited characteristic. The importance of knowing just how intimate a relationship exists between date of hatching and duration of winter pause becomes apparent and may be discovered by means of the coefficient of correlation.

A total of 2134 birds exhibited a pause of four or more days and are included in these calculations. The winter pause class interval is ten days in all cases. Constants obtained from this study follow:

Number of birds	2134
Mean hatching date (Apr. 17)	4.15
Hatching date standard deviation	±2.26
Mean length of winter pause	32.26
Winter pause standard deviation	±21.92
Coefficient of correlation	—.2480 ± .0137
Regression of hatching date on winter pause . .	—.026
Regression of winter pause on hatching date . .	—2.404

The mean length of the winter pause over the entire nine-year period amounts to 32.26 days for the pause birds, but a striking fluctuation in the duration of the pause is revealed by its standard deviation. Environmental influences may be considered as largely responsible for the fluctuations. Any possible changed environment to shorten the pause would be advantageous economically.

The coefficient of correlation measuring the degree of association between time of hatching and duration of winter pause is negative, of moderate magnitude, and certainly significant. Clearly, a reduction in the range of hatching dates would tend to reduce the length of the period of non-production during the winter season. The mean length of winter pause of the eight different hatches studied follows:

Hatches	No. of Birds	Mean days Paused
1	353	39.41
2	271	37.35
3	293	36.46
4	289	33.84
5	261	28.22
6	245	25.99
7	227	25.85
8	195	24.32
Grand Average		32.26

8. Correlation Between Hatching Date Earlier Than The Mean and the Presence of Winter Pause For Entire Population.

Yule's short method as cited by Davenport (1907) is used in this study. This tabulation includes the total population, 3375 Rhode Island Reds classified as pause and non-pause individuals.

Hatching Date	Pause	Non-Pause
Earlier than Population mean	1206	555
Later than Population mean	928	686
Totals	2134	1241

Coefficient of correlation . . . . +.2326 ± .0110

This positive coefficient of correlation is of sufficient magnitude to establish a definite relationship between early hatching and the appearance of winter pause. This being the case, the assumption must be made that inheritance is not the sole controlling force concerned in the manifestation of winter pause.

9. Correlation Between Date of First Egg and Length of Winter Pause.

The date on which a pullet lays her first egg is dependent upon many factors. Among the most important of these are hatching date and age at first egg. Environmental influences such as character of ration, amount of free range, and weather conditions may, to some extent, hasten or retard the date of first egg. Date of first egg is important economically if not biologically.

The relation between date of first egg and duration of winter pause has been determined by means of the coefficient of correlation on the same group of 2134 birds studied in section 7. The birds were again classified as to winter pause into class intervals of ten days. The class interval used for date of first egg was fifteen days. Constants calculated are as follows:

Number of birds	2134
Mean date of beginning to lay (Oct. 29) . .	5.88
Date of beginning to lay standard deviation . .	±2.13
Mean length of winter pause	32.26
Winter pause standard deviation	±21.92
Coefficient of correlation	—.3205 ± .0131
Regression of date of first egg on winter pause . .	—.031
Regression of winter pause on date of first egg . .	—3.297

The date on which the birds began to lay ranged from August 16 to March 29 making 15 class intervals. Its standard deviation may be expected to be of considerable magnitude in relation to the mean as is shown above.

A negative coefficient of correlation of .3205 ±.0131 between time of beginning to lay and pause duration stresses an important relation between the two. Early laying, on the average, tends to increase the duration of the pause.

10. Correlation Between Time of Beginning to Lay Earlier Than the Mean and the Presence of Winter Pause for Total Population.

Time of Beginning to Lay in the Fall	Pause	Non-Pause
Earlier than Population mean	1210	456
Later than Population mean	924	785
Totals	2134	1241

Coefficient of correlation . . . . +.3854 ± .0099

A definite and significant correlation exists between early laying and the presence of winter pause. This fact suggests the importance of breeding for a specific age at first egg, and hatching on some special date to meet conditions of environment.

(b) Inherited Characteristics Concerned With Fecundity In Relation to Winter Pause.

In the category of inherited fecundity traits that may be considered in their relation to winter pause, the following may be grouped: age at first egg, weight at first egg, winter rate or intensity, length of winter cycle, size of winter clutch, annual rate or intensity and annual persistency. A study of the relative degree of correlation between these inherited characteristics and duration of winter pause as well as its presence or absence furnishes constructive information in breeding for high egg yield. Such analyses bring out important relationships as well as pointing out possible cases of genetic linkage.

11. Correlation Between Age at First Egg and Length of Winter Pause.

Age at first egg marks sexual maturity in the pullet. Age at first egg is inherited in Mendelian fashion according to Hays (loc. cit.). The importance of early laying to high winter and annual egg yield has been stressed in our publications as well as in those of other workers. The significance of knowing if there is a correlation between age at first egg and duration of winter pause is therefore very evident, since both are inherited traits and both are concerned in winter and annual egg yield. A study was therefore made on the 2134 pause birds already considered in sections 7 and 9. Age at first egg class intervals of ten days are used and the same class interval used for length of winter pause. The following constants were calculated:

Number of birds	2134
Mean age at first egg	203.26
Age at first egg standard deviation	±26.28
Mean length of winter pause	32.26
Winter pause standard deviation	±21.92
Coefficient of correlation	—.2329 ± .0138
Regression of age at first egg on winter pause . .	—.279
Regression of winter pause on age at first egg . .	—.194

The above coefficient of correlation is almost identical with that between hatching date and winter pause duration given in section 7. The range in hatching date covers 49 days, while the range in age at first egg covers 180 days. The fact therefore becomes evident that a slight change in hatching date would cause a greater change in winter pause duration than would the same change in age at first egg, as brought out by their respective regression coefficients. Herein lies the reason for emphasizing hatching date as of greater significance in relation to winter pause than age at first egg when they exhibit identical coefficients of correlation to winter pause duration.

12. Correlation Between Age at First Egg Below the Mean and the Presence of Winter Pause for the Total Population.

Age at first egg	Pause	Non-Pause
Earlier than Population mean	1337	549
Later than Population mean	797	692
Totals	2134	1241

Coefficient of correlation . . . . $+.3578 \pm .0101$

Attention should be called to the fact that time of beginning to lay and age at first egg each show almost identical correlation coefficients to the presence of winter pause. The interpretation is that age at first egg is the chief determinant of time of beginning to lay when the hatching dates are constant from year to year.

13. Correlation Between Weight at First Egg and Length of Winter Pause.

Available for this study are the records of 2106 birds, classed as pause birds, on which the body weight on the day of laying their first egg was secured. Thus a very small number of the 2134 birds previously considered is omitted from this study. The class interval used for body weight was the half pound and the ten-day class interval was again used for winter pause. The following constants were determined:

Number of birds	2106
Mean weight at first egg	5.55
Weight at first egg standard deviation . . .	$\pm .72$
Mean length of winter pause	32.32
Winter pause standard deviation	± 22.01
Coefficient of correlation	$+.0161 \pm .0147$
Regression of weight on winter pause . . .	$+.0005$
Regression of winter pause on weight . . .	$+.4908$

A range in body weight from 3.25 to 8.25 lbs. occurs in the population studied. The magnitude of the standard deviation in weight indicates, however, that extremely small or extremely large birds are the exception, since the coefficient of variability for body weight is only about 13 per cent.

The coefficient of correlation between body weight and winter pause duration is mathematically insignificant. This furnishes rather concrete evidence that a pullet's body weight when she lays her first egg bears no relation to the length of her winter pause.

14. Correlation Between Body Weight at First Egg Lower Than the Mean and the Presence of Winter Pause for Entire Population.

Weight at First Egg	Pause	Non-Pause
Below Population Mean	1139	655
Above Population Mean	967	544
Totals	2106	1199

Coefficient of correlation . . . . —.0110 ± .0117

The complete independence between weight at first egg and the presence of winter pause is shown by the above correlation coefficient. Evidently body weight is not a factor in either the manifestation of winter pause or its duration.

15. Correlation Between Winter Rate and Length of Winter Pause.

The group of 2134 birds exhibiting winter pause is used in these calculations. Winter rate or intensity was calculated for each individual bird in the following manner:—

The total number of eggs from first egg to March first was divided by the number of days from first egg to March first, less all pauses of four or more days in duration from November first to March first. By this method of calculation the actual net rate of laying is arrived at if the assumption is correct that a cessation of laying for four or more days during winter actually constitutes a winter pause. A four-day cessation of laying may generally be assumed to necessitate the omission of one clutch of eggs for the average bird and such omissions suggest the manifestation of winter pause. The following constants were calculated:

Number of birds	2134
Mean winter rate	65.69
Winter rate standard deviation	±8.74
Mean length of winter pause	32.26
Winter pause standard deviation	±21.92
Coefficient of correlation	—.1023 ± .0144
Regression of rate on winter pause	—.041
Regression of winter pause on rate	—.257

The above mean winter rate expresses the net rate of laying of all birds exhibiting winter pause. This rate of laying is compared in section 16 with that of the total population and that of the non-pause group above. The standard deviation for rate is of moderate magnitude compared with the standard deviation of many other fecundity characteristics.

A small but significant negative correlation suggests a very moderate tendency for high-rate birds to pause for a shorter period than do low-rate birds. Such a relationship is important from the breeding standpoint in that it hints at some linkage relation between the dominant genes for high winter intensity and the recessive gene for non-pause.

16. Correlation Between Winter Rate Below the Mean and the Presence of Winter Pause for the Total Population.

Winter Rate	Pause	Non-Pause
Below Population Mean	1688	784
Above Population Mean	446	454
Totals	2134	1238

Coefficient of correlation . . . . . . +.3734 ± .0100

Winter rate as used in all the calculations is the net rate of laying with all pauses of four or more days deducted. The above table shows the relation of net rate of laying to the presence of winter pause. This table displays a moderately intimate relation between low net rate and the presence of winter pause.

17. Correlation Between Size of Winter Clutch and Length of Winter Pause.

Size of clutch represents the number of eggs laid on successive days. In very extreme cases a pullet may lay as many as fifty eggs in succession previous to March first and the same bird may exhibit a few clutches of one. In order to arrive at a constant to represent the clutch size of an individual bird, it has been necessary to calculate mean clutch size during the winter. Such calculations have been made on all pause birds. The range in mean clutch size of individuals was found to be from 1 to 11.9. The class interval used was 1. Only one bird was omitted from this study because its class range fell between 15 and 15.9. Clutch size is really a measure of intensity of laying. Its relation to winter pause duration is of marked significance in breeding for fecundity.

Constants obtained in this correlation study are as follows:

Number of birds	2133
Mean winter clutch size	2.41
Winter clutch standard deviation	±1.11
Mean length of winter pause	32.27
Winter pause standard deviation	±21.92
Coefficient of correlation	—.0674 ± .0145
Regression of winter clutch on winter pause . .	—.003
Regression of winter pause on winter clutch . .	—1.325

On the average, winter clutch size closely approaches 2.5 but the magnitude of its standard deviation indicates considerable variability in clutch size. A small negative correlation was discovered between clutch size and winter pause duration. While this correlation is significant as judged by its probable error, it is of such small magnitude as to indicate practical independence between the characteristics being considered.

18. Correlation Between Winter Clutch Size Below the Mean and the Presence of Winter Pause for Entire Population.

Winter Clutch	Pause	Non-Pause
Below Population Mean	1425	616
Above Population Mean	709	624
Totals	2134	1240

Coefficient of correlation . . . . . . +.3412 ± .0103

A significant positive correlation between small winter clutch and the presence of winter pause appears above. In general, there is a greater tendency for birds that lay in small clutches to pause than for birds laying in larger clutches. The rate of functioning of the reproductive system must therefore bear a relation to winter pause.

19. Correlation Between Annual Rate or Intensity and Length of Winter Pause.

Annual rate represents or approximates the intensity of each individual bird for the pullet laying year. Inasmuch as this constant has been discussed in Technical Bulletin No. 7 of this station, space will not be occupied here by further discussion. Since winter pause represents a period of non-production, there must of necessity exist a negative correlation between annual rate and length of winter pause unless pause birds lay at a higher net rate than non-pause birds. This last point is, in part, discussed in section 16 of this report, where the net winter rate of the total population in relation to the pause and non-pause groups is considered. The important positive relation between annual rate and annual egg record makes the correlation between annual rate and length of winter pause of importance. Included in this study are the 1348 birds exhibiting winter pause and having complete annual records. The following constants were determined:

Number of birds	1348
Mean annual rate	53.79
Annual rate standard deviation	±9.07
Mean length of winter pause	32.29
Winter pause standard deviation	±21.77
Coefficient of correlation	—.4091 ± .0153
Regression of annual rate on winter pause . .	—.170
Regression of winter pause on annual rate . .	—.982

The mean annual rate of laying is lower than the mean winter rate of laying, which is 65.69. This difference may be attributed largely to the fact that in calculating annual rate no account is taken of winter pause or of broody pauses. In the winter rate calculations, winter pause days are not included and very few birds become broody before the end of the winter season. The standard deviation in annual rate is relatively small and suggests uniformity in annual rate of laying.

The coefficient of correlation is negative and of such magnitude as to indicate a significant relation between rate and length of pause. In other words, low annual rate and long winter pause tend to move together. In breeding for high annual intensity, winter pause must certainly be reduced in duration.

20. Correlation Between Annual Rate or Intensity Below the Mean and the Presence of Winter Pause for the Total Population.

Annual Rate	Pause	Non-Pause
Below Population Mean	858	209
Above Population Mean	490	593
Totals	1348	802

Coefficient of correlation . . . . +.6649 ± .0081

The substantial magnitude of the above coefficient of correlation points to a pronounced tendency for low annual rate to occur with winter pause. The table above also shows that 80 per cent of the low-rate birds are pause birds while only 45 per cent of the high-rate birds are in the pause group. The conclusion, therefore, seems justified that winter pause operates very significantly to lower the annual rate of laying.

21. Correlation Between Annual Persistency and Length of Winter Pause.

Annual persistency represents the number of days of laying from the first egg to a pause of thirty or more days after March first. If no thirty-day pause occurs between March first and the date 364 days after the first egg, the bird is given a persistency of 365 days on ordinary years and 366 days on leap years. A cessation of laying for a period of thirty days or more during summer is a rather dependable indication of the onset of complete molt, which always signifies the conclusion of the biological laying year.

Persistency as indicated by time of molting has long been recognized as affecting egg yield, and poultry investigators have recommended the use of late molting birds for breeding purposes. Hurst (1921) was the first to offer a definite hypothesis concerning its mode of inheritance. He believes high persistency is transmitted as a single factor recessive. If a rest period in winter enables the bird to lay later in the fall than does the bird without the rest period, then persistency must depend in part upon the previous physiological activity of the reproductive organs, or possibly there is linkage between winter pause and high persistency. The same group of 1348 birds used in the two previous sections is studied below. Persistency range lies between 67 and 366 days with class intervals of 15 days. Following are the constants:

Number of birds	1348
Mean annual persistency	309.03
Annual persistency standard deviation . . .	±54.89
Mean length of winter pause	32.39
Winter pause standard deviation	±21.77
Coefficient of correlation	+.1017 ± .0182
Regression of persistency on winter pause . .	+.256
Regression of winter pause on persistency . .	+.040

Mean annual persistency closely approaches ten months, but the range of variability is rather wide as shown by its standard deviation. This variability is no doubt due in part to many environmental influences as well as to differences in the inherited capacities of the birds. Only about five per cent of the population fall below 200 days in persistency so that the range 200 to 366 is a close approximation of the actual range. A study of frequency distribution for persistency does not reveal a bimodal curve as might be expected for a population made up of genetically early and late molting birds. Such information suggests two possibilities, namely, that environmental influences completely obscure the genetic phenotypes, or else that high persistency is not inherited in simple Mendelian fashion. The mode of inheritance of persistency is out of the scope of this report.

A small but significant positive correlation coefficient exists between persistency and winter pause duration. Thus there is a very slight tendency for birds with long winter pause to lay later in the fall than do short pause birds. Relatively little significance should be attached to a constant of such small magnitude, however.

22. *Correlation Between Annual Persistency Greater Than the Mean and the Presence of Winter Pause for the Total Population.*

Annual Persistency	Pause	Non-Pause
Above Population Mean	855	423
Below Population Mean	493	378
Totals	1348	801

Coefficient of correlation . . . . +.2156 ± .0139

A moderate degree of correlation is shown between the presence of winter pause and high persistency. There is thus a slight tendency for pause birds to lay later in the fall than do non-pause birds. Possibly the functional ability of the reproductive organs is somewhat extended by a period of non-production in winter. The relation does not appear to be pronounced, however.

(c) The Absolute Relationship of Winter Pause to Egg Production.

The duration of winter pause may be considered a factor affecting the number of eggs laid before March first as well as for the entire year. Since winter fecundity alone depends upon the inheritance of seven pairs of Mendelian factors (Hays, 1924), it is desirable and necessary to know something of the relation of winter pause to winter and annual egg record. Although fecundity is very complex in its mode of inheritance, its manifestation depends in part upon environmental conditions as division (a) of this report shows. The correlation between size of winter clutch and winter egg yield is first considered, then the correlation between winter pause and winter egg record, and finally the correlation between winter pause and annual production is studied.

23. Correlation Between Size of Winter Clutch and Winter Egg Yield.

The relation of winter clutch size to winter pause has already been considered in sections 17 and 18. In this section the relation of winter clutch size and winter egg production are studied. Since size of winter clutch is so often used as a criterion for selection by poultrymen, knowledge of its relation to winter fecundity is important. Records are available on 3376 birds upon which the following constants were ascertained:

Number of birds	3376
Mean size of winter clutch	2.57
Winter clutch standard deviation	±1.23
Mean winter production	61.08
Winter production standard deviation . . .	±25.79
Coefficient of correlation	+.4725 ± .0090
Regression of winter clutch in production . .	+.023
Regression of production on winter clutch . .	+9.884

The fact will be observed that the mean winter production above is greater than the mean length of winter cycle given in section 6. The mean length of winter cycle is less than mean winter production because the end of the winter cycle is determined by a four-day pause before March first while winter egg record does not cease until February 28 or 29. Winter egg record is highly variable on account of the complexity of its inheritance.

The magnitude of the above correlation coefficient emphasizes an important tendency for clutch size and winter production to move together. As a criterion of winter fecundity large clutch size is very important.

24. Correlation Between Length of Winter Pause and Winter Egg Record.

Winter pause represents a definite period of non-production, but the tendency of winter pause and winter production to move in opposite directions can only be measured by means of the coefficient of correlation. The group of 2134 pause birds has been tabulated to give this relationship. The following are the constants obtained:

Number of birds	2134
Mean length of winter pause	32.26
Winter pause standard deviation	±21.92
Mean winter production	56.87
Winter production standard deviation . . .	±23.51
Coefficient of correlation	—.2873 ± .0134
Regression of winter pause on production . . .	—.268
Regression of production on winter pause . . .	—.308

Mean winter production is lower in the above group of pause birds than for the total population given in section 23 because non-pause birds tend to have higher winter records than do pause birds. About the same degree of variation in winter records occurs in both cases.

A rather significant negative correlation coefficient shows that in general an increase in length of pause is associated with a decrease in number of winter eggs. A coefficient of much greater magnitude would appear if the time element were the only consideration. There is the possibility that pause birds tend to possess desirable fecundity traits that are lacking in non-pause birds.

25. Correlation Between Winter Production Below the Mean and Presence of Winter Pause for Total Population.

Winter Production	Pause	Non-Pause
Below Population Mean	1273	463
Above Population Mean	861	777
Totals	2134	1240

Coefficient of correlation . . . . +.4255 ± .0095

The above table illustrates a rather pronounced correlation between low winter egg production and the presence of winter pause. Winter pause has, therefore, proven to be a trait inimical to high winter egg record throughout the nine-year period of the experiment here reported.

26. Correlation Between Length of Winter Pause and Annual Production.

There are available for study 1318 pause birds with annual egg records. Tabulations have been made to discover how the length of winter pause affects annual egg production. Following are the constants:

Number of birds	1348
Mean length of winter pause	32.39
Winter pause standard deviation	±21.77
Mean annual production	172.51
Annual production standard deviation	±41.07
Coefficient of correlation	—.2107 ± .0176
Regression of winter pause on production	—.112
Regression of production on winter pause	—.398

The mean annual record of the pause birds throughout the period is about 173 eggs. The range of variation in annual egg yield is wide, as is shown by its standard deviation. Greater homogeneity in heritable factors concerned in fecundity should reduce such variability.

The magnitude of the coefficient of correlation is sufficient to indicate that, in general, an increase in length of winter pause is accompanied by a decrease in annual egg production. The time lost in winter pause is not compensated for by heavier production either before or after the pause in any class of pause birds.

27. *Correlation Between Annual Production Below the Mean and the Presence of Winter Pause for the Total Population.*

Annual Production	Pause	Non-Pause
Below Population Mean	715	301
Above Population Mean	633	501
Totals	1348	802

Coefficient of correlation . . . . +.3056 ± .0132

Low annual production is significantly correlated with the presence of winter pause as shown in the above table. Even though such a short period as a four-day pause is considered, this correlation coefficient is of appreciable magnitude. Winter pause must, therefore, be classed as inimical to highest annual egg yield, for the pause birds averaged but 173 eggs while the non-pause group averaged 189 eggs.

General Discussion and Summary.

The length of the winter laying cycle is unquestionably modified by a series of environmental influences. Some of these influences are within while others are beyond control of the poultry breeder. Winter pause is the complement of the winter laying cycle and is important in that it vitally affects total fecundity.

Two distinct classes of pullets appear in the flock studied, namely, pause and non-pause. A group of pause birds studied beside a group of non-pause birds, both groups hatched on the same date and both groups starting to lay at the same age, yet the first showing a distinct winter pause, places the difference in the groups as inherent. Such a study within the family gives definite ratios of pause and non-pause pullets as Hays (1924) points out.

The line of demarkation between genetically non-pause birds that exhibit winter pause due to environmental influences and birds carrying the dominant factor (M) for pause cannot be drawn. The present paper is devoted to a consideration of the non-heritable and some heritable factors that may or may not affect winter cycle and winter pause. Genetic factors concerned with the inheritance of winter cycle length and winter pause duration have not been dealt with.

The major teachings of this study may be summarized:

1. In general, early-hatched pullets have a longer laying cycle than late-hatched pullets of the same flock.

2. Date of first egg exhibits a rather intimate negative correlation to length of winter cycle.

3. Age at first egg shows an appreciable negative correlation to length of winter cycle.

4. The winter egg record is intimately positively correlated with length of winter cycle.

5. Annual egg production is significantly correlated with length of winter cycle though less intimately than is winter record.

6. A minor though significant degree of negative correlation appears between length of winter cycle and length of winter pause.

7. Hatching date bears a significant but not intimate negative correlation to length of winter pause in the pause population.

8. Early hatching is positively correlated with the presence of winter pause in the total population of pause and non-pause birds.

9. Time of beginning to lay is significantly negatively correlated with length of winter pause in the pause population.

10. Time of beginning to lay is appreciably positively correlated with early hatching in the total population.

11. Age at first egg shows the identical degree of negative correlation to length of winter pause that it shows to *length* of winter cycle.

12. Early sexual maturity is positively correlated with the presence of winter pause in the total population.

13. Weight at first egg is independent of length of winter pause.

14. Light weight at first egg is not correlated with the presence of winter pause in the total population.

15. The net winter rate of laying holds a very slight negative correlation to length of winter pause in the pause population.

16. Slow rate of winter laying is rather intimately positively correlated with the presence of winter pause in the total population.

17. The average size of winter clutch is but very slightly correlated with length of winter pause in the pause population.

18. Small size of winter clutch is moderately positively correlated with the presence of winter pause in the total population.

19. Annual intensity shows a considerable degree of negative correlation to length of winter pause.

20. A very intimate positive correlation exists between low annual intensity and the presence of winter pause.

21. Annual persistency is but slightly positively correlated with length of winter pause.

22. Birds that pause during winter show a tendency to lay later in the fall than non-pause birds.

23. The mean size of winter clutches is rather intimately positively correlated with winter fecundity. Clutch size is a very good measure of intensity.

24. Length of winter pause is negatively correlated with winter production.

25. Low winter production exhibits a considerable degree of correlation to the presence of winter pause in the total population.

26. Length of winter pause is negatively correlated with annual egg record in the pause population.

27. Annual production below the mean is substantially correlated with the presence of winter pause in the total population.

28. Although winter cycle and winter pause are complements of each other, they are practically independent in duration in the pause group.

29. Winter pause is definitely shown to be a characteristic detrimental to both winter and annual fecundity, and should therefore be eliminated from flocks bred for egg production.

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ANNUAL PERSISTENCY IN RELATION TO WINTER AND ANNUAL EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

This bulletin is the third in a series dealing with the five inherited traits in relation to fecundity. Those already published show the relation of broodiness and of winter pause to egg production; while a later publication will consider intensity in relation to fecundity.

The records show that high persistency is a trait much to be desired from the standpoint of production, and that there is no reason why it may not be combined with other desirable traits in the same individual.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

ANNUAL PERSISTENCY IN RELATION TO WINTER AND ANNUAL EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

Annual persistency, as terminated by the onset of complete molt, has been emphasized for more than the past three decades as of marked significance in the selection of breeding females for egg production. The cessation of egg production in summer or fall is generally accompanied by a complete change of plumage and this period of non-production may continue for 30 to 120 days. The exceptional hen may lay a considerable number of eggs while molting, but such individuals are of infrequent occurrence.

Hurst (1925) classifies laying hens into complete and partial-molt classes and states that there is complete cessation of laying in the first class while the second class sheds its feathers gradually and continues to lay for 13 or 14 months after the first pullet egg. According to Hurst, complete early molt depends upon the inheritance of a dominant Mendelian gene.

Goodale and Sanborn (1922) note that cessation of production in the summer or fall at the end of the pullet laying year has a genetic foundation as indicated by the behavior of families in this respect. Data collected on the Massachusetts Agricultural Experiment Station flock of Rhode Island Reds show that the biological laying year may extend to 14 or 15 months as a maximum with 6 or 7 months as the minimum for normal birds. A study of all factors affecting the duration of the pullet laying year in the flock in question has not yet been completed.

A flock bred for egg production should theoretically consist of two general classes of birds with respect to persistency, namely, a high persistent class and a low persistent class. In reality these two classes do not stand out distinctly to form a bimodal curve when all the birds with annual records for the nine-year period are tabulated in persistency classes using 15-day class intervals. (See chart 1.) The probability exists, however, that environmental forces largely obscure these expected classes. A tabulation of the 2179 birds with annual persistency records does give a frequency distribution that is indistinctly bimodal and furnishes the basis for classification of those birds laying for a shorter period than 315 days as low in persistency and those laying for 315 days or longer as high in persistency. Such a classification is largely arbitrary, however, and is used in these studies only as a working basis until the true genetic point of division may be discovered.

Scope of This Report

This study was undertaken for a three-fold purpose, namely, to show (a) the relation between controllable environmental conditions and persistency, (b) the relation between inherited characteristics concerned with fecundity and persistency, and (c) the relation between persistency and fecundity. From the practical breeding standpoint these considerations are of great im-

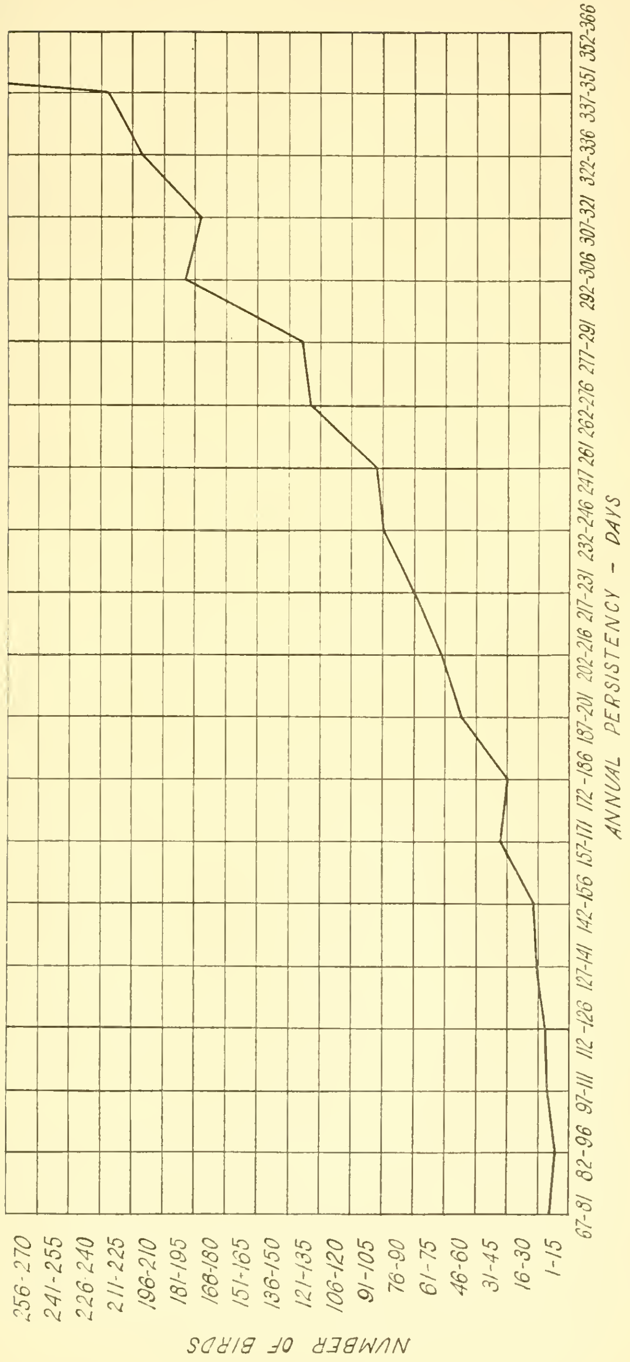

CHART 1. Frequency Distribution of Population with Regard to Persistency.

portance. A knowledge of the part played by environment as well as the part played by inheritance in limiting the manifestation of a desirable characteristic is well worth considering when breeding for egg production. Analytical studies on the complex nature of fecundity should further disclose valuable information that might otherwise be obscured.

Character of Birds Used

The birds used in this study are identical with those used in the two previous reports. Included are the records of all Rhode Island Red females hatched from 1916 to 1924 in the experimental flock upon which pullet-year trapnest records are available. The flock each year is made up of all the daughters of each hen whose progeny was retained. The major portion of the birds belong to the fecundity experiment. There are, however, a limited number of birds bred for non-broodiness, some for intense broodiness, some for hatchability, some for color, and a few inbreds that are included. Pullet-year records are used exclusively in this study.

The Coefficient of Correlation

The simple coefficient of correlation is subject to certain limitations in biological data yet it affords a basis upon which to select groups of breeders and also a basis for predicting future possibilities. The fact is self-evident that the simple coefficient of correlation is not an absolute measure of the degree of association between the variables being studied because each variable may be partially dependent upon other variables. For example, section 3 shows a negative correlation of $.6146 \pm .0090$ between age at first egg and annual persistency. It is a known fact that both the dependent variable, age at first egg, and the independent variable, annual persistency, are dependent upon hatching date and environmental conditions, and that persistency is also dependent upon weight at first egg and possibly upon length of winter pause. The true relation between age at first egg and annual persistency could only be arrived at by making the hatching date and environmental conditions constant, as well as by making weight at first egg and winter pause duration constant. Such procedure necessitates the use of partial coefficients of correlation which require the use of the simple coefficient in their calculation. Both the partial coefficient and the multiple coefficient will be employed in a concluding bulletin of the series. Simple correlations are of very significant practical value to the poultryman, however, in that they show him the relative importance of different environmental influences and inherited characteristics in relation to fecundity, and enable him to formulate his breeding program accordingly.

(A) Relation Between Environmental Conditions and Persistency

The only controllable environmental condition that will be considered in relation to persistency is hatching date. Extreme care has been exercised throughout the experiment to employ the same methods of feeding and brooding. Hatching dates have been kept constant each year, but there have been eight hatches each year at weekly intervals between March 25 and May 15. The range in hatching date thus amounts to 49 days. Hatching date, however, may be controlled at will by the poultryman.

1. *Correlation Between Hatching Date and Annual Persistency.*

The class interval for hatching date is seven days, and the class interval for annual persistency is 15 days with a range of from 67 to 366 days. The following constants were calculated on 2179 birds:

Number of birds	2179
Mean hatching date (April 18)	4.28
Hatching date standard deviation	±2.24
Mean annual persistency	300.47
Persistency standard deviation	±62.64
Coefficient of correlation	—.2208±.0137
Regression hatching date on persistency	—.008
Regression persistency on hatching date	—6.187

The above constants indicate that, on the average, the birds laid for 300 days before the onset of complete molt. This figure is somewhat lower than it would be if maximum persistency had not been placed at 366 days, because some of the birds laid for a greater time interval. The standard deviation in persistency amounts to almost 63 days and furnishes statistical evidence of very marked variability in persistency.

The coefficient of correlation between hatching date and annual persistency is negative and statistically significant. While this is not an intimate correlation, it does demonstrate a tendency for early-hatched birds to lay longer than late-hatched birds. The fact should be kept in mind, however, that the earliest hatch was taken off each year about March 25 and that this date should not be considered very early in this latitude.

2. *Correlation Between Hatching Date Earlier than the Mean and High Persistency.*

As previously stated, the birds have been divided into two classes with regard to persistency, namely, high and low. All birds are classed as *high* in persistency when they lay for 315 days or more before molting. Birds laying for a shorter period than 315 days are classed as *low*. By dividing the population of 2179 birds into these two classes for persistency, and by again classifying these as hatched earlier or later than the population mean, an absolute measure of the correlation between early hatching and high persistency is obtained. The results of this classification follow:

Hatching Date	High Persistency	Low Persistency
Earlier than population mean	720	458
Later than population mean	416	585
Totals	1136	1043

Coefficient of correlation . . . . . . +.3771±.0124

The division of the population into high and low persistency groups in the above table rests on a possible genetic foundation as already stated. The mean persistency of the entire 2179 birds was found to be about 300 days as section 1 shows. When the point of division between high and low persistency birds is taken between 314 and 315 days, there are 1136 individuals classifying as high and 1043 as low in persistency. The low persistency class ranges from 67 to 314 days while the high persistency class ranges from 315 to 366 days. The wide range for the low class enables them to bring the mean persistency of the population down to 300 days even though there are more high-persistency birds than low-persistency birds in the above classification.

A positive coefficient of correlation .3771±.0124 signifies that early hatching is associated with high persistency. Possibly early hatching better equips the pullet for a long laying year because she begins to lay earlier in the fall and is also able to finish her laying year under more favorable weather conditions than is her late-hatched sister. These data signifiy, therefore, that hatching before the middle of April tends to increase persistency for the pullet year.

(B) Relation Between Inherited Characteristics Concerned with Fecundity and Annual Persistency.

In the class of inherited characteristics concerned with fecundity the following will be considered in relation to annual persistency: Age at first egg, weight at first egg, winter rate, length of winter pause, and total days broody, all records being based on the pullet year.

3. *Correlation Between Age at First Egg and Annual Persistency.*

Both age at first egg and annual persistency have been found by Goodale and Sanborn (loc. cit.) and by the writers to be of appreciable significance in breeding for egg production. Both early maturity and high persistency are essential in the high producer and for this reason their relation to each other should be known. The identical group of birds studied in section 1 is used to determine the following constants:

Number of birds	2179
Mean age at first egg	208.56
Age standard deviation	±31.28
Mean annual persistency	300.47
Persistency standard deviation	±62.64
Coefficient of correlation	—.6146±.0090
Regression age on persistency	—.307
Regression persistency on age	—1.231

Mean age at first egg is about 209 days, which is a figure falling within the limits of genetic early maturity. Age at first egg is a characteristic that fluctuates widely, and in this particular population the extremes are 140 and 379 days, respectively. Class intervals of ten days for age have been used in these correlation studies.

The mean annual persistency of the population is about 300 days. The extremes are 67 and 366 days, respectively. The standard deviation for persistency is very large and indicates that a number of factors is concerned.

The negative coefficient of correlation is of such magnitude as to suggest an intimate relation between age at first egg and annual persistency. Those pullets that lay at an early age appear to be much more persistent layers than those maturing later. Herein lies a partial explanation of the significant relation between early maturing and high annual production. These studies point to age at first egg as a criterion of importance for predicting persistency.

4. *Correlation Between Age at First Egg Below the Mean and High Persistency.*

The population has again been divided into the two possible genetically different classes for persistency as in section 2. These classes have been tabulated against age below the mean and age above the mean as follows:

Age at First Egg	High Persistency	Low Persistency
Below population mean	860	387
Above population mean	276	656
Totals	1156	1043

Coefficient of correlation . . . . . . +.6816±.0077

A very intimate correlation is shown by the above coefficient between early sexual maturity and high persistency. This relationship is very significant to the breeder, disclosing possible genetic linkage between two desirable inherited traits that may later be cleared up on a factorial basis.

5. *Correlation Between Weight at First Egg and Annual Persistency.*

Body weight is a convenient standard to use for selection purposes. Weight in poultry is inherited on a multiple factor basis according to Punnett and Bailey (1914). If weight should prove a criterion of persistency, its value for culling purposes soon after pullets begin to lay is very evident. Weight records are available on 2125 of the birds being studied, and when correlated with persistency give the following constants:

Number of birds	2125
Mean weight at first egg	5.58
Weight standard deviation	±.75
Mean annual persistency	302.64
Persistency standard deviation	±58.00
Coefficient of correlation	—.3225±.0131
Regression weight on persistency	—.004
Regression persistency on weight	—25.002

This group of birds averaged about five and one-half pounds at first egg and the extremes are 3 and 9.5 pounds, respectively. Class intervals of .5 pound were used in making these studies. Weight shows a coefficient of variability of about 13 per cent.

The coefficient of correlation exhibits something of a tendency for light weight and high persistency to move together. Such a coefficient might have been anticipated from the fact that weight and age at first egg are positively correlated (Hays, Sanborn and James, 1924), and because hatching date and weight at first egg are negatively correlated (Hays, Sanborn, and James, loc. cit.). In view of these facts, it is doubtful if weight at first egg is a true criterion of persistency.

6. *Correlation Between Body Weight at First Egg Below the Mean and High Persistency.*

Weight at First Egg	High Persistency	Low Persistency
Below population mean	714	468
Above population mean	417	526
Totals	1131	994

Coefficient of correlation . . . . . $+.3161 \pm .0132$

The above table presents the absolute correlation between weight at first egg below the population mean and high persistency. Those birds weighing less at first egg than the mean of the whole population may be considered small while the high persistency class includes only those individuals laying for 315 days or more before molting.

The coefficient of correlation is positive and of statistical significance. There is a tendency for the persistent class to weigh less at first egg than does the low persistency class. Although the correlation is significant, it is not pronounced and probably does not imply that factors for rapid growth are inimical to high persistency.

7. *Correlation Between Net Winter Rate and Annual Persistency.*

In order to discover if there is any association between the net rate of laying throughout the winter season and persistency of laying the following fall, a correlation table was made between winter rate and persistency, using the 2147 birds with records for both characteristics. The constants are as follows:

Number of birds	2147
Mean winter rate	67.41
Winter rate standard deviation	± 8.87
Mean annual persistency	302.98
Persistency standard deviation	± 59.03
Coefficient of correlation	$+.1835 \pm .0141$
Regression winter rate on persistency . . .	$+.028$
Regression persistency on winter rate . . .	$+1.222$

A slight but significant correlation is found to exist between winter rate of laying and persistency. This correlation indicates that, in general, there is some tendency for the more intense winter layers to persist in laying later in the fall than do less intense layers.

8. *Correlation Between Winter Rate Greater than the Mean and High Persistency.*

By classifying all birds with higher winter rates than the mean of the whole population as high for rate, and by classing as highly persistent all individuals laying for 315 days or more, the following table gives the correlation between high winter rate and the presence of possible genetically high persistency:

Winter Rate	High Persistency	Low Persistency
Above population mean	651	466
Below population mean	484	546
Totals	1135	1012

Coefficient of correlation . . . . . . $+.2236 \pm .0138$

The above tabulation presents a moderate degree of positive correlation between two inherited characteristics concerned in high fecundity. The very significant fact is brought to light that high winter rate and high persistency are partially complementary, and there is no evidence of antagonism between the two.

9. *Correlation Between Length of Winter Pause and Annual Persistency.*

The presence or absence of winter pause has been shown by Hays (1924) to depend upon genetic factors. The duration of the pause, however, may depend upon environment as well as inheritance. Most environmental forces affecting the duration of pause are probably beyond control of the breeder and may not properly be considered in this report. This section is devoted to a study of the correlation between length of pause and persistency as has already been done by Hays and Sanborn (1926b). In the population being studied there were 1348 birds with winter pause records which were divided into ten-day class intervals and the following constants arrived at:

Number of birds	1348
Mean length of winter pause	32.39
Pause standard deviation	± 21.77
Mean annual persistency	309.03
Persistency standard deviation	± 54.89
Coefficient of correlation	$+.1017 \pm .0182$
Regression persistency on pause	$+.256$
Regression pause on persistency	$+.040$

Winter pause duration is subject to extreme fluctuations. Its range extends from 4 to 130 days. The magnitude of its standard deviation indicates that its duration is affected by a considerable number of variables.

The above coefficient of correlation gives a statistically significant yet far from pronounced correlation between length of winter pause and annual persistency. There is but a very slight tendency for long-pause birds to persist longer than do short-pause birds.

10. *Correlation Between Annual Persistency Above the Mean and the Presence of Winter Pause.*

This section is devoted to a consideration of the presence of winter pause and annual persistency above the population mean of 303.20 days. Such a correlation will bring out any possible association between the heritable characteristic, winter pause, and high persistency which, in this instance, means persistency greater than the mean of the population studied. The classification follows:

Annual Persistency	Pause	Non-Pause
Above population mean	855	423
Below population mean	493	378
Totals	1348	801

Coefficient of correlation . . . . . . +.2156±.0139

The correlation coefficient is significant though of only moderate magnitude. Possibly winter pause birds tend to lay for a slightly longer period than do non-pause birds because the former are more likely to be early-hatched (Hays and Sanborn 1926b), and early-hatched birds tend to be more persistent than late-hatched birds. The exact relation between pause and persistency can only be discovered through the partial coefficient of correlation and will be reported in a later publication.

11. *Correlation Between Total Days Broody and Annual Persistency.*

The heritable trait, broodiness, will next be considered in so far as its intensity as measured by total days broody is correlated with persistency. Only the pullets that exhibited broodiness during their first laying year are used to obtain the constants below:

Number of birds	1037
Mean total days broody	42.69
Broody standard deviation	±27.33
Mean annual persistency	294.05
Persistency standard deviation	±64.82
Coefficient of correlation	+.0532±.0209
Regression days broody on persistency	+.022
Regression persistency on days broody	+.126

Intensity of broodiness, as measured by the total days spent in broodiness during the pullet year is subject to wide fluctuations. Its standard deviation shows marked variability in the population. In view of this fact, it seems probable that intensity of broodiness depends on a number of variables.

The small and statistically insignificant coefficient of correlation indicates practical independence between degree of broodiness and annual persistency.

12. *Correlation Between Annual Persistency Above the Mean and the Presence of Broodiness.*

This section deals with the absolute relation between the presence of the inherited characteristic, broodiness, and persistency greater than the mean of the population studied. Herein lies a definite basis for selection which may or may not be useful in breeding for high persistency. The following results appear:

Annual Persistency	Broody	Non-broody
Above population mean	566	715
Below population mean	471	390
Totals	1037	1105

Coefficient of correlation . . . . —.2081±.0139

The above negative correlation coefficient is statistically significant though it does not reveal an intimate correlation. Eliminating the broody characteristic should in some measure increase annual persistency.

(C) The Relation Between Persistency and Fecundity

Since high annual persistency appears to be a desirable characteristic to develop from several standpoints, it is highly desirable that its relation to both winter and annual egg record be ascertained. Both relations may be considered first from the quantitative standpoint and then from the qualitative standpoint by use of long and short correlation tables, respectively.

13. *Correlation Between Winter Production and Annual Persistency.*

Winter production during the pullet year is represented by the number of eggs laid from first egg to the end of February. It has already been pointed out by many workers as a valuable criterion of annual production. Class intervals of ten have been used to make the correlation table for the 2151 birds with winter records. Constants computed follow:

Number of birds	2151
Mean winter production	62.49
Winter production standard deviation . . .	±25.44
Mean annual persistency	302.82
Persistency standard deviation	±59.32
Coefficient of correlation	+.4551±.0115
Regression production on persistency . . .	+.195
Regression persistency on production . . .	+1.061

The degree of correlation between winter production and annual persistency is positive and of appreciable magnitude. Selection for persistency based on winter records should be of considerable value. Such a condition might be anticipated in view of the high correlation between early maturity and winter production and between early maturity and persistency.

14. *Correlation Between Winter Production Greater Than the Mean and high Persistency.*

In the tabulation below the population is classified into four qualitative groups, namely, high winter producers, low winter producers, possible genetically highly persistent, and possible genetically low persistent. The correlation is then determined between production above the mean and high persistency.

Winter Production	High Persistency	Low Persistency
Above population mean	712	345
Below population mean	424	670
Totals	1136	1015

Coefficient of correlation . . . . +.5306±.0104

This coefficient of correlation demonstrates a positive relation between high winter egg record and high persistency. In other words, selection based on winter records greater than the average should increase the percentage of late-molting or persistent birds.

15. *Correlation Between Annual Production and Annual Persistency.*

Other conditions being equal, any increase in persistency should be accompanied by an increase in annual egg yield. These are purely quantitative relations and in this manner some information concerning the value of high persistency from the fecundity standpoint may be ascertained. The same population of 2179 individuals is tabulated, using ten-day classes for production, to obtain the following constants:

Number of birds	2179
Mean annual production	177.46
Production standard deviation	±44.73
Mean annual persistency	300.47
Persistency standard deviation	±62.64
Coefficient of correlation	+.7082±.0072
Regression production on persistency . . .	+.506
Regression persistency on production . . .	+.992

The above coefficient reveals an intimate correlation between annual egg yield and annual persistency or the length of the laying year. These data furnish definite evidence to commend the practice of emphasizing late molting in breeding for high fecundity. On the average, any increase in persistency within the limits of the pullet laying year is advantageous.

16. *Correlation Between Annual Production Above the Mean and High Persistency.*

By classifying all birds as high producers if they laid more eggs than the population mean of 177.46, and as high in persistency those birds that laid for not less than 315 days before molting, a definite relation between high production and high persistency may be established.

Annual Production	High Persistency	Low Persistency
Above population mean	872	280
Below population mean	264	763
Totals	1136	1043

Coefficient of correlation . . . . . . +.8000±.0052

The above coefficient of correlation establishes a very intimate relation between the presence of possible genetic high persistency and annual egg yield above the average of the total population. This fact points to high persistency as being closely associated with high annual fecundity. High persistency must, therefore, be classed as a trait of vital importance in breeding for fecundity and one that should be stressed greatly by the breeder. Should high persistency breed as a true recessive, it would be a comparatively simple matter to establish the characteristic in the laying flock.

Discussion and Summary.

Annual persistency is a characteristic bearing a vital relationship to fecundity. Its duration is affected by environmental influences and by inherited traits concerned in fecundity. No conclusive evidence is presented in this report to indicate that high persistency behaves as a simple recessive in inheritance as has been suggested by Hurst (loc. cit.). In this climate persistency may be increased to some extent by hatching before April 15, with such birds as are studied here. Early sexual maturity, non-broodiness and high winter rate probably show some linkage with high persistency. At any rate, there is no evidence of antagonism in attempting to combine these desirable traits in the same individual. Valuable information for selection purposes has been disclosed by these studies. Partial correlation coefficients will be used in a later publication to remove some complications.

The general relation of persistency to winter and annual production for the whole population studied is shown in the following table:

Character of Birds	Winter Production	Annual Production
Persistency above population mean	69.84	198.59
Persistency below population mean	51.57	145.67
Persistency of 315 days or more (Mean 347 days)	71.13	201.98
Persistency below 315 days (Mean 249 days)	52.83	150.75

Mean Persistency by Years

Year	Number of Birds	Average Persistency
1916	278	247.53
1917	347	280.74
1918	194	285.49
1920	125	325.29
1921	314	301.00
1922	379	329.67
1923	317	316.33
1924	225	320.47
Total and average	2179	300.19

The chief findings of this report may be summed up as follows:

1. Early hatching is moderately correlated with high annual persistency.

2. Age at first egg is very intimately negatively correlated with high persistency.

3. Weight at first egg shows significant negative correlation to persistency.

4. Winter rate of laying is moderately correlated with persistency. The two traits appear to be partially complementary.

5. Length of winter pause is but slightly positively correlated with persistency.

6. Total days broody is not significantly correlated with persistency.

7. The presence of broodiness shows a fair negative correlation to high persistency.

8. Winter production and persistency are rather significantly positively correlated.

9. Annual production is pronouncedly correlated with persistency.

10. Persistency behaves as a trait much to be desired from the production standpoint.

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AGRICULTURAL EXPERIMENT STATION

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THE THERAPEUTIC EFFICIENCY OF AVIAN DIPHTHERIA, ROUP, AND BIRD POX VACCINES AND BACTERINS

By Norman J. Pyle

Avian diptheria, roup and bird pox cause serious loss to Massachusetts poultrymen by decreasing egg production during the season when eggs are bringing the highest prices. In this bulletin the Department of Veterinary Science and Animal Pathology reports results of their study of the problem. A filtrable virus was found to be the cause of all three types of the disease. None of the commercial vaccines produced immunity, neither did they effect a cure when the disease was present, although they caused a slight improvement in the general condition of the birds. Autogenous bacterins, when used in the early stages of the disease, caused an improvement in the general health of the birds, but were not of sufficient value to make their use economically profitable.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE THERAPEUTIC EFFICIENCY OF AVIAN DIPHTHERIA, ROUP, AND BIRD POX VACCINES AND BACTERINS

By NORMAN J. PYLE

Introduction

Avian diphtheria, roup, and bird pox have caused serious financial losses to the poultry industry of Massachusetts during the fall and winter months of past years. Diphtheritic roup has been the predominating form of the disease. It has not been attended with great mortality, but has become of grave economic importance because it has caused a decrease in production, occurring at a time of the year when poultry products bring maximum prices.

Two biological products, a powdered pox virus vaccine and an avian mixed infection bacterin, have been used extensively in an attempt to control the disease. The results obtained following the use of the preparations have been confusing. Some reports claim the vaccine to be 100 per cent efficient, while others claim it to be an absolute failure.

Many factors contribute towards the efficiency of the vaccine and bacterin. It is of primary importance to ascertain the nature of the causative micro-organism or virus and whether it is incorporated in either of the preparations. When this is accomplished, it is assured that either the vaccine or bacterin is the logical product to develop specific antibodies against the disease.

It is also necessary to determine whether avian diphtheria, roup, and bird pox are separate etiological entities or various manifestations of a common cause. On the answer to this problem depends the need for one common vaccine or bacterin or for separate ones for each entity.

Historical.

Moore (1), a pioneer American worker on avian diphtheria and roup, isolated a non-motile, pathogenic bacillus from lesions of the disease. He claimed that this organism was "apparently the etiological factor". He was unable, however, to determine its specificity for the affection. Harrison and Streit (2) demonstrated that *Bacillus pyocyaneus* would produce typical lesions of avian diphtheria and roup. These authors also found a second virulent bacterium associated with the diseases, which they called the roup bacillus or *B. cacosmos.* Hausser (3), Bordet and Fally (4), Beach, Lothe and Halpin (5), and Crofton (6) have all added specific organisms to the long list of causative factors.

Bird pox or contagious epithelioma has not been studied from the standpoint of its etiology to the extent that has avian diphtheria. Marx and Sticker (7) reported investigations wherein they found a filtrable virus to be the cause of bird pox. Schmid (8) and Sigwart (9) confirmed this work. V. Betegh (10), De Blieck and V. Heelsbergen (11), and others advanced the theory that all forms of the disease are caused by one and the same virus.

Several references in the early literature maintain that the various poxes, skin eruptions, and variola affecting animal life are all caused by a common virus, which adapts itself over a period of successive generations to a specific host. If this were true, vaccinia or cowpox would have an etiological relationship to bird pox.

Lowenthal, Kadowaki, and Kondo (12) were able to transmit vaccinia to the fowl through five successive generations, but the affections became less and less pronounced and finally died out. Fowls recovering from vaccinia were immune to vaccinia, and those recovering from bird pox were immune to bird pox. They were unable to produce a neutral or combination immunity and concluded that the causes of vaccinia and bird pox were very different.

Experimental Data on the Etiology of Avian Diphtheria Roup, and Bird Pox.

Bacteriological examinations of diphtheritic patches were made and many organisms were isolated, the majority of which were contaminating invaders. In order to avoid this the patches were aseptically removed and the bacteriological examination made directly from the underlying, denuded surface. The same technic was employed in the pox form of the disease; that is, bacteriological cultures were made from the pitted areas after removal of the pox scabs.

Pseudomonas aeruginosa (*Bacillus pyocyaneus*) was found associated with pox and diphtheritic lesions. This organism has been previously observed in diphtheritic roup by Harrison and Streit (2), Hausser (3), Jackley (13), Kaupp (14), and others. Various other pyogenic bacteria were isolated, namely, *Staphylococcus aureus*, *Gaffkya* (*Staphylococcus*) *tetragena*, and *Staphylococcus albus*. A *Pasteurella avicida*-like organism was isolated from infected birds suffering with avian diphtheria, also one similar to the roup bacillus or *Bacillus cacosmus* of Harrison and Streit (2).

These organisms are at least prominent secondary invaders, but their ability to cause diphtheritic roup is in doubt. *Pseudomonas aeruginosa,* when found in an infected flock, was readily isolated from the heart blood, liver, and spleen of those birds dead of the disease. The organism was injected into the wing veins of several healthy birds and death ensued in from fifty-six to eighty-four hours. The germ was recovered from the dead fowls, especially from exudates in the nasal passages, indicating that the organism was associated with roup. Other experiments with the organism, such as injection beneath the skin and application to scarified wounds of the comb, wattles, and membranes of the mouth, failed to produce any type of the disease.

Fresh pox scabs obtained from a Massachusetts infected flock were dried, passed through a coffee mill, and finally pulverized in a ball mill. One gram of this powdered virus was macerated for twelve hours and afterwards triturated in 100 cc. of physiological salt solution. It was then passed through a controlled Berkefeld filter of medium porosity. The filtrate was vigorously rubbed into the scarified comb and wattles of healthy birds and failed to reproduce the disease in forty-three days. These birds were susceptible to avian diphtheria and bird pox for they later succumbed to inoculation with the unfiltered virus. The experiment was repeated, using scab virus from two other States, and again using a filter of medium porosity. The results were the same. The experiments were controlled by the respective unfiltered scab viruses which produced typical pox lesions in the usual incubation period.

It is known that the filtrable virus of smallpox will not pass through a filter of fine porosity, but will pass through one of coarser porosity. Accordingly, Berkefeld filters No. V (coarse) were next used and the results recorded in the following table. The filtrate proved "sterile" upon cultural examination.

Table 1. Filterability of Pox Virus with a Coarse Berkefeld Filter.

Bird	December 17	December 23	December 29	January 4	January 12	January 28	January 30
No. 1 (healthy)	Comb and wattles scarified. Filtrate applied by vigorous rubbing.	No pox	Several well formed pox nodules.	Pox nodules markedly developed.	Lesions still persistent.	Condition same.	Destroyed.
No. 2 (slight cold)	Comb and wattles scarified. Filtrate applied by vigorous rubbing.	No pox	No pox	No pox	Few well defined "cankers" roof of mouth.	Condition same.	Destroyed.
No. 3 (healthy)	Comb and wattles scarified. Filtrate applied by vigorous rubbing.	No pox	No pox	Small pox nodules on comb and eyelids. 1st stage of roup in evidence	Pox nodules still present. Few "cankers" on membranes of pharynx.	Condition same.	Destroyed.
No. 4 (healthy)	Comb and wattles scarified. Filtrate applied by vigorous rubbing.	No pox	No pox	Several small pox nodules on comb. 1st stages of roup in evidence.	Pox and roup clearing up.	Condition same.	Destroyed.
Control No. 5 (healthy)	Comb and wattles scarified. Unfiltered virus applied by vigorous rubbing	Pox well developed.	Pronounced pox production.	Maximum pox development.	Pox nodules mature.	Condition same.	Destroyed.
Control No. 6 (healthy)	Comb and wattles scarified. Unfiltered virus applied by vigorous rubbing	Pox well developed.	Pronounced pox production.	Maximum pox production.	Pox nodules mature.	Condition same	Destroyed.

Interpretation

1. The filtered virus produced pox, roup, and avian diphtheria, indicating that one and the same virus is capable of causing all forms of the disease.
2. Bird No. 2 had a simple catarrh when inoculated. This evidently lowered the resistance of mucous membrance surfaces and avian diphtheria followed.
3. The incubation period of the filtered virus was from twelve to eighteen days, while in the case of the unfiltered virus it ranged from seven to nine days. The filtered virus also produced a less pronounced form of the infection than did the unfiltered virus. These latter two points confirm the work of Schmid (8) in 1909.

A bacteriological examination of the unfiltered powdered virus revealed several secondary invaders, such as *Pseudomonas aeruginosa* and various Staphylococci. These organisms undoubtedly assisted the unfiltered virus in causing a shorter period of incubation and a more pronounced form of the disease.

The Uniformity of the Virulence of Commercial Viruses.

Before studying the efficiency of the powdered pox virus vaccines, it was desirable to ascertain the strength of the viruses which make up these commercial products.

Four groups of birds were inoculated on October 5th with four different strains of powdered pox virus. The course of the disease subsequent to the inoculation is represented by the respective lines A, B, C, and D in the following graph. Virus A was obtained on October 1 from a natural infection in Massachusetts and viruses B, C, and D were of commercial origin.

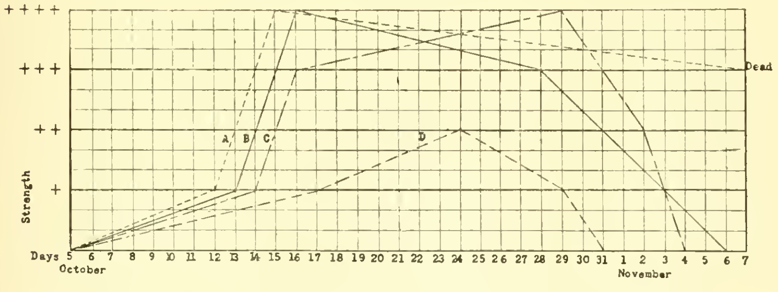

Chart I. Variance in Strength of Powdered Pox Viruses.

-|- Period of incubation.
-|--|- Appearance of a few or several well formed pox nodules.
-|--|--|- Appearance of many pox nodules of mature development.
-|--|--|--|- Maximum development of pox nodules.
Downward curves—Periods of recovery.

Virus A showed the greatest potency. The period of incubation was seven days, the disease reaching its maximum development three days later, and death following within twenty-three days with no appreciable evidence of recovery.

Virus B showed the greatest potency of the three commercial stock viruses. The period of incubation was eight days, maximum development four days later, and complete recovery in twenty-two days more.

Virus C presented an incubation period of nine days, maximum development fifteen days later, and complete recovery within an additional six days.

Virus D was very weak. The period of incubation was twelve days. There was practically no further development of pox and recovery soon took place.

Interpretation.

The degree of efficiency of the powdered pox virus vaccine depends upon the potency and antigenicity of the virus of which it is composed. The following conclusions are then evident:—

1. The viruses, being non-uniform in potency, would produce vaccines of varying efficiency.

2. A method of standardizing the virus and vaccine, which is lacking at the present time, would be essential to the efficiency of the vaccine.

3. An autogenous virus would produce a vaccine of greater value than one composed of a stock virus.

The Efficiency of Powdered Pox Virus Vaccines.

The powdered pox virus vaccine was first used by Manteufel (15) and by Hadley and Beach (16). The vaccine as commercially distributed to-day is a development of the original methods of these workers.

Scabs collected from pox nodules are the source of the virus. In order to produce large quantities of scabs it is necessary to maintain a flock of young cockerels, preferably white leghorns. The combs and wattles are scarified and the powdered scab virus after being "emulsified" in physiological salt solution is vigorously rubbed into the wounded areas. Typical pox scabs will develop and mature on susceptible birds in from seven to twelve days. The scabs are then collected, thoroughly dried, passed through a coffee mill, and finally pulverized in a ball mill. The product is stored away as the stock virus.

The vaccine is made by taking 1 gram of the powdered virus and thoroughly triturating it in 100 cc. of physiological salt solution. It is then attenuated at 55° C. for one hour in a water bath. Finally it is filtered through sterile cheesecloth into vaccine bottles, and after cooling is ready for use. The entire procedure should be handled in as sterile a manner as possible. The vaccine should be used within ten to fifteen days after it is manufactured because it deteriorates rapidly.

In the following experiments having to do with the efficiency of the powdered pox virus vaccines each bird was housed in a separate compartment. The final conclusions are based on a repetition of experiments and the average reaction of a group of birds. The vaccine used was manufactured as described by J. R. Beach (17), a brief description of which is given above.

Experiment 1.

Part A.

A freshly made vaccine, composed of virus B, was administered subcutaneously to a group of six healthy birds, 1 cc. being given to each bird beneath the skin of the breast under the right thigh. The group was divided into three lots of two birds each.

Lot 1. Fourteen days after vaccination both birds were inoculated on comb and wattles with virus B. Pox nodules developed eight days later and reached a maximum growth in an additional ten days.

Lot 2. Twenty-six days after vaccination both birds were inoculated on comb and wattles with virus B. A mild pox developed eight days later, but soon disappeared without further development.

Lot 3. Forty-two days after vaccination both birds were inoculated on comb and wattles with virus B. Pox was pronounced eight days later, one bird showing diphtheritic patches in mouth as well as pox.

Control: two non-vaccinated birds inoculated with virus B. Incubation period of eight days, maximum development four days later.

Part B.

Two injections of a virus B vaccine were given a second group of six birds in the same manner. The second injection was given six days after the first. The group was likewise divided into three lots of two birds each, and inoculated with virus B fifteen, thirty, and forty-two days respectively after the second injection.

Lot 1. Incubation period of ten days, pox becoming pronounced five days later.

Lot 2. Slight pox developed in eight days in only one bird, clearing up within the next seven days. Second bird showed no evidence of the disease.

Lot 3. Pox developed in ten days, persisting for three weeks in a mild form.

Control: two non-vaccinated, healthy birds inoculated with virus B. Pox developed in eight days, reaching a maximum development four days later.

Part C.

Three injections of a virus B vaccine were given a third group of six birds at intervals of six days. The group was again divided into three lots of two birds each, and inoculated with virus B sixteen, thirty-one, and forty-two days respectively after the third injection.

Lot 1. Pox developed in eleven days and persisted in mild form.

Lot 2. Pox developed in eight days and became pronounced in another week.

Lot 3. Pox developed in twelve days and persisted in mild form for three weeks.

Control: two non-vaccinated, healthy birds inoculated with virus B. Pox developed in eight days, reaching a maximum development three days later.

Result.

One, two, and three injections of the vaccine failed to produce an absolute protection against artificial infection with homologous virus B.

Experiment 2.

Part A.

This experiment was similar to Experiment 1, except that the vaccine was made of virus C and the check inoculations were made with virus B. The first group of six birds was given a 1 cc. injection of the vaccine, divided into three lots of two birds each, and inoculated with virus B seventeen, twenty-six, and forty days respectively after the vaccine injection.

Lot 1. Pox developed nine days later, grew worse, and death followed in one bird.

Lot 2. Pox developed within eight days, but in weak form, and cleared up in two weeks.

Lot 3. Pox developed within eight days in one bird and diphtheritic roup within ten days in the other.

Control: two non-vaccinated, healthy birds inoculated with virus B. Pox developed in nine days, reaching a maximum development four days later.

Part B.

A second group of six healthy birds was given two injections of a virus C vaccine of 1 cc. each at five day intervals. The group was divided into lots 1, 2, and 3 and inoculated with virus B sixteen, thirty, and forty days respectively after the second vaccine injection.

Lot 1. Pox developed in ten days and persisted in a mild form.

Lot 2. Pox developed in eight days in both birds and avian diphtheria in one bird of the lot.

Lot 3. Pox developed in eight days, becoming pronounced, and complicated with roup.

Control: two non-vaccinated, healthy birds inoculated with virus B. Pox developed in eight days and reached a maximum development three days later.

Part C.

A third group of six healthy birds was given three injections of a virus C vaccine of 1 cc. each at five day intervals. The group was divided into lots 1, 2, and 3 and inoculated with virus B fifteen, thirty, and forty-one days respectively after the third vaccine injection.

Lot 1. Pox developed in ten days and persisted in severe form for three weeks.

Lot 2. A slight pox developed in eight days, persisting in a mild form.

Lot 3. Pox developed in eight days, becoming severe and persisting as such.

Control: two non-vaccinated, healthy birds inoculated with virus B. Pox developed in eight days and reached a maximum development four days later.

Result.

One, two, and three injections of the vaccine failed to produce an absolute protection against artificial infection with heterologous virus B.

Other vaccine and virus combinations were used, such as a vaccine made of virus B, and its immunizing ability checked with virus C. The results were comparable to experiments 1 and 2.

Infection by Contact.

A healthy, young cockerel was added to each lot of the foregoing experiments after the disease developed in the supposedly immune birds. This addition of a strange bird to each lot of birds instigated fights, and minor wounds of the comb followed. This allowed a point of entrance for the virus which contaminated the food, water, and litter. Pox developed in about 50 per cent of those birds in contact with the diseased ones. The infection persisted in a mild form, never reaching the severity evidenced in those birds with which they were in contact.

Experiment 3.

An effort was made to determine the curative value of the vaccine. A group of twelve birds was inoculated with virus C. Pox nodules appeared in nine days and a moderate degree of development, which proved to be the maximum, followed in seven days. The group was then divided into two lots of six birds each and placed in separate pens. A virus C vaccine, in a 1 cc. dose was administered to each bird of one lot, the other lot being used as the control. No apparent decrease in number and severity of the pox nodules followed the injection of the vaccine. The injected lot, however, appeared brighter and more active, and loss of flesh was arrested after seven days following the injection. The non-injected lot steadily lost flesh for two weeks, but from then on gained in general appearance and physical conditions.

Results.

The use of the vaccine as a curative measure resulted in a slight improvement in the general condition of the treated birds, but did not cause any diminution in number or extent of the lesions.

One Attack of Bird Pox Confers an Immunity.

All birds recovering from the infection during the experiments were held over for future use. Approximately fifty days following complete recovery from both types of the disease, a group of such birds was inoculated wtih viruses B and C. Lesions of the disease failed to develop, indicating that one attack of the disease, whether of avian pox or diphtheritic type, confers an immunity of at least fifty days' duration. Four healthy birds which served as controls developed pox in eight days with virus B, and in nine days with virus C.

This actively acquired immunity is undoubtedly of greater duration than that demonstrated by the above experimental data. Evidence indicates that it lasts from two months to two years, depending upon the virulence of the infection among the birds which acquire this protection.

The Efficiency of Bacterins.

Several infected flocks were available during the fall and winter of the past year for treatment with bacterins. Autogenous bacterins were resorted to for the control of the outbreaks. Eleven different organisms, aside from the common *Subtilis* group, etc. contaminators, were isolated from diseased birds obtained from five outbreaks of bird pox and avian diphtheria. These organisms were not constantly present in all cases of the disease, and as has been previously stated, they are secondary invaders only. It appears, therefore, that an autogenous bacterin is indicated in preference to a stock bacterin. Also, such a preparation is limited to the control of secondary complications. of the disease.

Commercial avian mixed infection bacterins were not used. Their bacterial content does not correspond to the specific bacteria isolated from lesions of birds affected with the disease as it exists in Massachusetts. McNutt (18) in referring to experimental data on the use of such a biologic concludes, "In every case the death loss among the treated equaled or exceeded the loss among the untreated. Usually the loss was greater among the treated."

Flock 1.

A pen, consisting of 112 birds affected with both pox and avian diphtheria, the latter predominating, was treated with an autogenous bacterin. Several of the worst cases of both forms of the disease were examined bacteriologically and the following organisms isolated: *Staphylococci aureus* and *albus*, *Gaffkya* (*Staphylococcus*) *tetragena*, and an unknown, gram negative, short, rod-shaped organism of the colon group. The bacterin, composed of these organisms, was standardized so that one dose of 1 cc. contained 2,000,000,000 organisms.

An initial injection of 1 cc. was given to 80 birds of the pen, selected promiscuously, and 32 birds remained uninjected as controls. All birds were laying well prior to the outbreak of the infection. Both the injected and control groups averaged 43 per cent production at the time the first symptoms of the disease were noticed. Three days prior to the first injection the egg production of both groups dropped to 18 per cent. Fifty per cent of the total number of birds showed symptoms of one or more forms of the disease. There was no appreciable decrease in number or extent of lesions or increase in egg production of both groups during the next few days. The infection appeared to be arrested, however. Nine days following the first injection, a second one of the same dose was given. Three days afterward the injected group of layers improved in general condition and the egg production began to increase gradually. The condition and production of the control group remained at a standstill. These results were evident in the same proportions for the following two weeks, at the end of which time the last reading was taken. The injected group had reached 41 per cent egg production and the control group averaged 35 per cent. Lesions of the disease persisted, however, in all birds, but were somewhat less extensive in type.

In estimating the percentage of egg production care was taken to consider factors other than disease, which would tend to influence it.

Results.

The administration of the autogenous bacterin was followed by an improvement in the general condition and production of the injected group. No diminution in number or extent of the lesions was noted. Local treatment of the lesions would probably have served the purpose.

Flock 2.

An autogenous bacterin was administered to a second flock affected with avian diphtheria. The following organisms, which were used to make the bacterin, were isolated from typical cases of the affection: *Staphylococci aureus* and *albus, Gaffkya* (*Staphylococcus*) *tetragena,* a gram negative, short rod, bi-polar staining bacillus, and an organism of the *Escherichia* group, typical of *Escherichia schaefferi.*

A severe infection of a similar nature had existed in these same pens during the previous season. At the time of the injection a moderate degree of the infection was present in the birds of houses 1, 2, and 3. One injection of 1 cc. of the bacterin, having a concentration of 2,000,000,000 organisms per cc., was given each bird. Previous to the treatment the egg production had dropped to 40 per cent. From four to six weeks later when final readings were made the production had increased to 66 per cent. House 1 contained 2.8 per cent injected birds showing mild symptoms of the disease as opposed to 11 per cent of the non-injected birds or controls in the same condition. House 2 showed 12.3 per cent infection in injected birds and 30 per cent infection in the controls. House 3 showed 5.4 per cent infection in injected birds and 41.7 per cent infection in the controls. No attempt was made to treat the symptoms of the disease.

Results.

One injection of the autogenous bacterin arrested the course of the infection and brought about an increase in egg production.

Flock 3.

A third flock of 2,000 birds was injected, each bird receiving 1 cc. of an autogenous bacterin consisting of *Staphylococci aureus* and *albus,* and *Pseudomonas aeruginosa.* The bacterial concentration in this instance was but 500,000 organisms per cc. Complete data on the results of the treatment were not obtainable. An early report from the owner showed an improvement in egg production and but a few mild cases of the disease among the treated birds. It was questionable, however, whether the increase in production was due to recovery from the disease or from an existing neck moult. No data were available concerning the controls. No conclusion can be drawn from the use of the bacterin in this instance.

Flock 4.

A fourth flock of 300 cockerels was injected with an autogenous bacterin composed of *Staphylococcus aureus,* a *Pasteurella avicida*-like organism, and a bacillus similar to the roup bacillus or *B. cacosmus* of Harrison and Streit (2). The infection had practically run its course at the time of the treatment. Two injections were given, the first of 0.5 cc. containing 500,000 organisms, and a second six days later of 1 cc. containing 1,000,000 organisms. The disease entirely cleared up during the following three weeks. No difference was noted between the injected and control groups.

Summary.

1. Several organisms were isolated from the lesions of avian diphtheria, diphtheritic roup, and pox. They proved to be of no causative significance, but were prominent secondary invaders. A filtrable virus was found to be the common cause of all types of the disease.

2. Commercial stock powdered pox viruses varied markedly in ability to produce the disease. The need of a method of standardizing the virus and vaccine was indicated.

3. One, two, and three injections of the powdered pox virus vaccines failed to produce an absolute protection against artificial infection with homologous and heterologous viruses.

4. Infection by contact occurred in 50 per cent of all cases.

5. The powdered pox virus vaccine caused a slight improvement in the general condition of diseased birds when administered as a means of bringing about recovery from the infection.

6. One attack of either or both types of the disease conferred an immunity of at least fifty days' duration against both types.

7. Autogenous bacterins, when administered in the early stages of the disease, caused an improvement in the general health of the birds. As avian diphtheria and pox advance in severity the egg production of hens decreases. With the injections of these bacterins, data at hand indicate that the egg production is increased. While all these observations are interesting and point to a certain degree of therapeutic efficiency; the time consumed in the manufacture, standardization, and administration of these bacterins would work against their use as an economic practice.

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