Soil Disinfestation by Plastic Tarping

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Plant Protection, Faculty of Agriculture , University of Jordan .

By

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" بسم اللـــــه الرحمن الرحيم "

ملخص بالعربيـــــة

تعقيم التربه باستخدام الاغطية البلاستيكية

تم اختيار اربعة مواقع في الغور الاوسط لاجراء تجربة التعقيم بالبلاستيك في كل من كريمة ومحطة دير علا الزراعية حيث استعمل الرى بالتنقيط خلال فترة التغطية وفي مزرعة جميل فقد غمرت الارض بالماء مرة واحدة قبل وضع اغطية البلاستيك أما في مزرعة قعوار حيث لم ترو التجربه نهائيا خلال فترة التغطية . استعملت اربعة انواع من اغطية البلاستيك المحلي ، ثلاثة منها بسمك ٣٠ مليمكرون وهي الاســـــود والشفاف والاصفر أما الرابع فهو بلاستيك قديم استعمل لمدة موسم زراعي واحد في انفاق البلاستيكية وبسمك ٨٠ مليمكرون . وقد دام وضع الاغطية لمدة اسبوعيـــن ، اربعة ، سته أو ثمانية اسابيع ابتدا من منتصف شهر تموز وذلك على شكل اسطـــر بطول ٢١ متر وبعرض متر واحـــد .

تم عزل نوعين من فطر Fusarium من تربة المواقع الاربعة احدهما يسبب الذبول والآخر يسبب تعفن الجذور كما تم عزل فطرين ايضا يسببان تعفن الجذور من بعض المواقع هما Rhizoctonia solani و Pythium. اخذت عينات من التربة . قبل التغطية وبعد انتهاء فترة التغطية مباشرة وذلك لتعيين اثر الحرارة الناجمة عن استخدام الاغطية البلاستيكية على نسبة تناقص الجراثيم المرضيـــه ،

وقد وجد ان التعقيم بالبلاستيك الشفاف في حالة استعمال الرى بالتنقيـــط يعطي نتائج جيدة وهي تقريبا تشابة نتائج البلاستيك القديم . كانت افضل معاملـــة هي تغطية التربة لمدة ثمانية اسابيع حيث أدت الى تخفيض نسبة الفطريات المذكورة سابقا بنسبة تتراوح ما بين ٨٠ - ١٠٠٪ على عمق ٢٠ سم . وكان اثر التعقيم واضحا في تقليل نسبة الذبول واصفرار النباتات بعد زراعتها في التربه التى تم تعقيمهـــا بالبلاستيك . ويكون اثر البلاستيك اما بقتل الجراثيم نهائيا في الطبقة العليـــا أو بتقليل كمية الجراثيم المرضية والتى لا تشكل خطرا على النبات وخاصة في المراحـــل الاولى من حياتـــــه .

يتم تحضير التربه بشكل يكون جاهزا للزراعة بعد انتهاء عملية التغطية وعـــدم حراثة التربه نهائيا بعد ازالة غطاء التعقيم وفرش البلاستيك الاسود على خطـــوط الرى وزراعة البذور مباشرة في الفتحات المعمولة بالبلاستيك الاسود وفي حالة وجـــود بعض الاعشاب بعد عملية التغطية اما تزال باليد أو باستعمال مبيدات الاعشـــاب . والافضل تغطية ارضية البيت البلاستيكي بكاملة بالبلاستيك الشفاف بسمك ٨٠ مليمكرون حيث يمكن استعماله مرتين أو سمك ٤٠ مليمكرون حيث يستعمل مدة واحـــــدة .

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Soil Disinfestation by Plastic Tarping

I. Introduction :

Successive cropping leads to accumulation of inoculum of soil-borne pathogens which cause root rots , wilts and numerous other plant diseases .

Fusarium spp , other soil-borne fungi (which cause root rots and wilts)and nematodes constitute major disease problems under conditions of intensive cropping in the Jordan Valley, especially under plastic covers . The search for nonhazardous and inexpensive methods for controlling diseases caused by soil-borne pathogens is continuous. Rotation and flooding are nonchemical measures employed with varying degrees of success on some diseases (43, 45). The use of soil fumigants is widespread, but it is expensive, hazardous, and the benefits are often of short duration. Steam is widely used for disease control in glasshouses, but the method is probably not economical under normal field conditions(4).

Recently the use of plastic tarps during the hottest part of the year is promising in areas where such a procedure can raise the temperature in the upper 5 cms of soil to 50 - 55 ^{o}C (27) .

The purpose of this research was to investigate the effect of the type and thickness of plastic tarps, the length of tarping periods and soil moisture on the incidence and survival of soil-borne pathogens under plastic tarps .

II. Review of literature :

Soil disease problems are most frequently due to the fungi commonly associated with roots and hypocotyls of seedlings. It is reported by Sumner (36) that in commercial fields of crucifers in Georgia, U.S.A. Fusarium oxysporum (Schlecht) Snyd. and Hans., Rhizoctonia solani Kuehn, Pythium irregulare Buis.M, F. solani (Mart.) App. and Wr., Phoma spp. and F. roseum (Lk) em. Snyd. and Hans. were the most important pathogens. The most virulent pathogen was R. solani regardless of soil temperatures; P. irregulare at low temperatures, and F. oxysporum and F. solani at high temperatures caused significant reductions in stands of crucifers.

F. solani f. phaseoli Snyd. and Hans. occurs as chlamydospores in naturally infested field soil. In sterilized field and virgin soils seeded with conidia, and planted to beans, chlamydospores of F. solani were gradually formed within the conidia on bean debris after harvesting of the beans. As the soil gradually dries, chlamydospores are formed in the tissues of diseased plants, and then released into the soil with the disintegration of the diseased host tissue (34, 35). Oospores are the sole surviving structure of Pythium aphanidermatum (Edson) Fitzp. in naturally infested

field soil (13). Rhizoctonia survives from season to season as sclerotia on propagative plant parts, i.e potato tubers, and as sclerotia in the soil (3).

Qasem(43)reported that a four year crop rotation was effective in controlling root rot of cucumber caused by Fusarium solani f. cucurbitae Snyd. and Hans. If susceptable cucurbits were avoided in the rotation, large quantities of the overwintering structures that infest the soil in the Jordan Valley were destroyed during the rotation. The same author reported that planting beans after wheat resulted in low severity of root rot on beans. Adding wheat or barley straw to the soil reduces the severity and incidence of Fusarium root rot of beans. He also reported that crop rotation with wheat or alfalfa in the infested soil is helpful in reducing the population of the overwintering structures of F. solani f. phaseoli, which causes root rot of leguminasea but crop rotation does not eliminate all persistant pathogenic structures. Crop rotation was found ineffective in controlling Fusarium oxysporum f. lycopercisi Sayd. and Hans. which causes Fusarium wilt of tomato, since the pathogen normally survives for long periods in the soil even in the absence of the host. Cucumber and tomato are important cash crops grown in increasing quantities in plastic houses and plastic tunnels in the Jordan Valley .

The 1978/1979 survey showed an area of 741 dunums was planted with vegetable crops under plastic houses and 6015 dunums under plastic tunnels (personal contact with Dr. Steitieh). These crops are continuously grown because they provide substantial financial returns, and utilizing a crop rotation consisting of tomato, wheat, squash, ..., is not profitable for the farmers. Thus crop rotation is not employed under these circumstances, and other effective means for the control of such soil - borne diseases must be practiced.

Flooding for long periods was introduced by the United Fruit Company (45) to eradicate Fusarium oxysporum Schlecht var cubense (E.F.Sm) Dr. Flooding reduces the oxygen tension to a degree at which aerobic fungi are killed. This procedure is not practical in Jordan because of the water shortages which are encountered even during the growing season .

Fumigation of soil by chemicals results in good control of most pathogens in the soil because most of these chemicals work as biocides. Fumigants such as methyl bromide, chloropicrin, carbon bisulfide, etc often do not become uniformly distributed in the soil because their concentration decreases progressively outward from the point of injection , with excess amounts persisting at the point of injection and undertreatment occuring at the margins (5). Phytotoxic symptoms

often developed on rooted carnation when planted in soil previously fumigated with methyl bromide (29). Methyl bromide fumigation of soil is potentially hazardous. The chemical accumulates in fruit and in the foliage. Mature fruit of tomato from plants grown in soil fumigated at the commercial rate of 1.5 lb/100 ft^2 (73 g/m^3) contained up to 45 µg of bromide per gram of fresh tissue (28). Most of the soil fumigants currently used are expensive. Less costly means of eliminating soil-borne pathogens would be used much more intensively in the Jordan Valley.

Soil may be treated thermally by dry heat, moist heat (steam) or hot water (4). Treatment of soil by steam for the purpose of destroying microorganisms was first demonstrated in 1888 by Frank (4) in Germany and was used commercially in 1893 in the United States. Heating the soil by steam up to 60 °C for 30 minutes has been known for over 30 years to kill plant pathogenic fungi, bacteria and nematodes and will inactivate nearly all soil-borne viruses (5). R. solani has been found not to survive treatment with aerated steam at 54.4 °C for 30 minutes (37) while heating naturally infested soils to 60 °C for 10 - 30 minutes eliminated attack by both R. solani and another unknown pathogen which caused brown root rot of lettuce and tomato (14). Various organisms reacted differently to heat treatments. Mitchell et al (33)

reported that populations of Pythium spp., R. solani, Fusarium spp. and other fungi were eliminated from field soils after exposure to 80 ± 2 °C for 30 minutes. Pythium myriotylum Drechs. and R. solani were eliminated from an infested potting mixture treated at 60, 70 or 80 °C for 30 minutes. However, Aspergillus niger V. Tiegh. was recovered from the mixture after heat treatment at any of the mentioned temperatures. Heating soil for 10 minutes at 50 °C kills Pseudomonus spp., but heating the soil up to 80 °C for 10 minutes is required to kill Streptomyces spp. Bacillus spp. survive heat treatments due to their sporulation and encapsulation , and Bacillus spp. are important as an element of biological control of Pythium diseases (11). Heating soil up to 100 °C reduces the population of nitrifying bacteria much more than that of the ammonifiers (17). Most pathogenic fungi are inactivated by lower temperatures than are saprophytic microorganisms (4). Ascomycetes, especially cleistothecia forming Penicillium and Aspergillus spp, are among the relatively heat resistant fungi (7).

Heat can be used to control nematodes. The nematodes are normally killed by exposuring them to temperatures between 40 - 55 °C. Temperature of 55°C donaturates animal enzymes (25) .

Although heating soil has many advantages, it also has many drawbacks. Treatment of some soils with high temperatures produces phytotoxic materials which may persist for long periods of time unless they are broken down by microorganisms or leached from the soil (5). Treating soil at temperatures above 80 °C retards lettuce growth. The reduction in growth was found to be associated with high soil concentrations of water soluble and exchangeable manganese ions and nitrites , 30 and 23 p.p.m. respectively (14) . amounts of ammonia were greatly increased at 52 °C , compared with unheated controls, but manganese (the water soluble and exchangeable) and nitrite were not significantly increased at temperatures less than 65 °C . For good potato growth, the level of soluble Mn in soilsshould not exceed 1 p.p.m. (5). Williams et al. (14) reported that the damage caused by subsequent recontamination with plant pathogens may sometimes be greater in steamed than in unheated soils due to the absence of biological control agents. This disadvantage can be avoided by heating soils to temperatures only just above those lethal to pathogens, i.e to 60 °C, a temperature which many saprophytes can survive (14). Heating the soil to 60 °C for 30 minutes in order to eliminate plant pathogens is less harmfull to biological control agents because it leaves an effective antagonistic microflora which suppress subsequent pathogen build up and hence delay recontamination (11).

Nelson (36) reported that the minimum exposure to lethal temperature in hot water for isolates of Verticillium albo-atrum Reinke and Berth. from rose and tomato growing on previously sterilized uniform pieces of flower stalks of Plantago lanceolata L. was 5 minutes at 47 °C for the hyphae and the conidia, and 10 minutes at 50 °C for the microsclerotia. Hot water immersion technique for 10 minutes at 50 °C controlled Rhizoctonia and Fusarium fungi on the surface of sweet potato roots (22).

The amount of heat gained by soil depends on its moisture content and on the humidity of the air just above the soil surface (42). It was found that keeping the soil at field capacity was effective for the purpose of increasing thermal sensitivity of resting structures and improving heat conduction. As a result of increased hydration by high moisture levels in the soil, the external layers of these overwintering propagules were broken and the heat tolerance of propagules was severely diminished (4).

Katan et al .(27) reported that soil moisture greatly affects sensitivity of the resting structures to heat. An incubation period of one hour at 50 °C killed 100% of the sclerotia of Verticillium dahliae Klebahn and 95 - 100 % of the chlamydospores of F. oxysporum f. lycopersici added to soil subsequently moistened prior to heat treatment. In air dried soil , viability of V. dahliae was reduced only

partially either by 50 °C for 6 hours or 55 °C for one hour. Viability of Fusarium was not affected by 55 °C for one hour in air dried soil. These various experiments were carried out in a controlled temperature water bath.

Because of the disadvantages of other means of soil sterilization, plastic tarps were tested and found to be a promising means of raising soil temperature. The soil must be moistened to a good planting tilth for three days preceding treatment in order to increase thermal sensitivity of spores and weed seeds to acheive an effective control with plastic tarping (5). Soil temperature was markedly increased in irrigated soils mulched with transparent(0.03 mm thick) plastic sheets during the months of July and August when the highest air temperatures (37 - 39 °C) were recorded (27). Clear plastic tarps were reported to increase soil temperatures at 2.5 cm depth up to 8.5 °C higher than those in unmulched soil. Under black plastic tarps temperatures were appreciably higher than in unmulched soil but not as high as under clear plastic (19). The mean temperature was higher by 5.8 °C at 5 cm depth under a colourless plastic film and by 3.2 °C under a black one compared to uncovered soil (42).

The aim of plastic tarping is to raise temperatures to a degree which could destroy the structures of pathogens present in the soil as dormant propagules. Infective propagules which can remain dormant for considerable periods

include: resting spores resulting from sexual reproduction such as the oospores of the Oomycetes, thick walled chlamydospores formed within hyphae and conidia, sclerotia or multicellular resting bodies and ascospores . Sclerotia have much higher levels of reserve nutrients , especially of carbon compounds than other resting structures(17) . Populations of plant-parasitic nematodes, Pythium spp., Fusarium spp., Enlogone spp. and R. solani are greatest in the top 18 cm of soil (23). Population densities were particularly high near plant roots. High densities of R. solani are confined almost entirely to the upper 15 cm of soil (38, 47). Plastic mulching with clear plastic raised the soil temperature at 20 cm depth up to 44 °C which could be very effective in controlling the pathogens if it was maintained for 31 days (18).

Since plastic tarps produce higher temperatures in the upper soil layers, it would be desirable to keep the roots of plants subsequently grown in treated soils in the upper layer of the soil. The use of black plastic mulch during the growing season looks promising in this regard. Roots of tomato, squash and muskmelon plants grown under clear polyethylene were similar to those produced in unmulched plots. In contrast, roots of these three crop plants that were mulched with either black film or black paper were very shallow and

considerably longer than the roots of unmulched plants (32). Under black plastic mulch, the roots grow more laterally and stay near the soil surface where the moisture level is high. The major portion of the root system was located in the top 20 - 25 cm of the soil (23, 31, 44).

Thermal killing of microorganisms could be due to denaturation of their enzymes (4). Fungistasis in soils which keeps fungus propagules at passive resistant stage is partially nullified at 45 to 56 °C (5, 27). Temperatures below 35 °C are generally in the range of microbial activity (27). Higher, but sublethal temperatures, may weaken the resting structures rendering them more vulnerable to the antagonistic microflora as was shown when Armillaria mellea (Vahl.) Quel. was exposed to chemicals at sublethal thermal treatments (6).

Using plastic materials to control diseases is less costly than fumigation, leaves no toxic residues and is non hazardous. Furthermore, it facilitates biological control (27). Another side advantage of mulches is that they have been used to reduce loss of nitrogen by leaching. Nitrogen levels are higher in mulched soils compared to nonmulched plots

because of either a reduction in leaching of nitrate nitrogen or an increase in nitrogen mineralization(48). Microbial activity was probably high underneath the black plastic mulch where moisture and temperature were at the optimum levels for nitrification and carbon dioxide release (32).

Plastic has been widely used for some years as a mulch to control soil-borne pathogens. In 1956 black and clear plastic were used to control certain diseases of lettuce: bottom rot (caused by Rhizoctonia spp.), drop (caused by Sclerotinia spp.)and slime rot (caused by Pseudomonas spp.). Plastic covers were used during the growing season, so that no part of the lettuce head touched the soil. Both types of mulch gave good control of slime rot. There was 16.3% disease with the white mulch, 17.2% with the black mulch and 52.7% in the untreated controls (21).

Soil temperatures at 5 cm below clear plastic were usually 7-10 °C higher during the day than in soil with no plastic mulch. This increase in temperature resulted in practical control of Thielaviopsis root rot of sesame during planting. Sesame growth is favoured by relatively high soil temperature (30 - 35 °C). Mulching caused sesame plants to be less severely diseased, taller, and heavier than plants grown without plastic mulch(1). Katan et al (27) reported that after two weeks under clear plastic (0.03 mm thick), V. dahliae

was eliminated from soil at depths of 0 to 25 cm, while the population of F. oxysporum f. lycopersici at 5 cm was reduced by 94 - 100 %; at 15 cm 68 - 100% and at 25 cm 54 to 63%. The maximum soil temperatures underneath the mulch at depths of 5 and 15 cm were 49 - 52 °C and 42 °C, respectively , and 38 °C at 20 cm. Irrigating soil and tarping with 0.04mm thick clear plastic for 31 days gave good control of V. dahliae and nematodes. The treatment resulted in 96% disease control and 80 - 100 % reduction in the population of Pratylenchus thornei Sher and Allen, also increased the yield of potatoes by 35% compared to the untarped. Tarping was carried out from July 13 till August 13, 1977(18). R. solani was eliminated from the top 18 cm of soil after two weeks of tarping with clear plastic (0.1 mm thick) in California . V. dahliae, Pythium spp. and Thielaviopsis basicola(Berk.& Br.) Ferr. were essentially eradicated to a depth of 45 cm in areas tarped for four weeks. The soil was irrigated before and during the tarping. Tarping soil can be an effective non-chemical method for the control of soil-borne plant pathogens (41). Under clear plastic tarp high temperatures in moist soil lead to more germination of weed seeds, and the heat at the surface kills them as they emerge. Under black plastic mulch where 3800 - 7800 A° wave lengths were eliminated , little photosynthesis occurs and thus growth of plants is stopped (16).

The density of pathogenic propagules in the soil is calculated from the number of colonies developing on agar plates. The most widely used technique for estimating the number of fungi, bacteria and actinomycetes in soil is the dilution plate method (12). A known weight of soil is placed in a measured quantity of sterile water and the suspension shaken to ensure thorough dispersion of the soil. Preliminary experiments must be conducted to ascertain the optimal dilutions for counting the colonies which develop in the Petri dishes. Another method for pathogen assessment is direct plating (Warcup method) (12). Five to thirty mg of soil are put in a sterile petri dish and cooled, melted agar added. Burying the soil particles in the agar prevents the spread of bacteria in the film of water which soon surrounds soil particles placed on the surface of fresh agar. This method is more convenient to use and makes the isolation of Phycomycetes particularly much easier. Issaac (24) used a dilution method to estimate the propagule density of V.dahliae in soil. A 10 ml aliquot of a soil suspension formed by adding eight gm of soil to 100 ml of distilled water was shaken for 15 min and then filtered through a Whatman paper number 5 (pore size 10 A^{o}). The filter paper with the propagules retained was then transfered to a sterilized Petri dish and 10 ml of potato dextrose agar (PDA) (2%) poured over it. The Petri dish was then incubated at 20 ^{o}C for two weeks .

Antibiotics are added to many selective media used for isolating particular pathogenic fungi from soil. Bacteria and actinomycetes can readily be suppressed in dilution plates by adding combinations of such antibiotics as streptomycin and aueromycin (26, 39). Penta. Chloro nitro benzene(PCNB) inhibits the growth of Mucorales in general (20). Nash and Snyder (35) found that PCNB @ 750 ppm and streptomycin @ 300 ppm in PDA facilitated the isolation of F. solani f. phaseoli and other Fusarium spp. by suppressing other fungi. Kerr(30) found that adding PCNB @ 100 ppm, streptomycin @ 50 ppm,rose bengal @ 60 ppm, and nystain @ 100 units/ml provided a selective medium for recovering Pythium spp. from naturally infested soil. Boosalis and Scharen (8) reported that streptomycin @ 270 ppm in 2% PDA provided a selective medium for the isolation of R. solani from particles of plant debris in soil. Ausher et al. (2) developed a selective medium for the isolation of Verticillium spp.

III. Materials and Methods:

A. Locations and Soil preparation of experiments.

Tarping was done during the months of July and August which are normally the hottest months of the year according to the climatological records which were obtained from Deir Alla Agriculture Experimental Station(personal comunication).Four locations were chosen: Kraimeh, Deir Alla, Kawar Farm and Jameel Farm (in the Jordan Valley). In Kraimeh the soil was flooded for 24 hrs and then manure fertilizer was added at a rate of 800 kg/ 1,000 m^2. The soil was then plowed and disked in so as to have a smooth surface and to avoid the presence of clods. Then the drip system was laid down to permit repeated irrigation (24 hrs twice a week) without removing the tarps. The tarping was installed on July 16, 1978 and the experiment was completed after 8 weeks. The same procedure was followed at Deir Alla Station. The tarps remained in place for 0, 2, 4, 6 or 8 weeks from August 1, to September 25, 1978. Land preparation at the Deir Alla station was not completed until the first of August. In flood tarping at the Jameel Farm, the soil was flooded for 24 hrs and subsequently plowed on July, 19, 1978 and the tarps were installed for

0, 2, 4 or 6 weeks from July 20. to September 1, 1978. In dry tarping at Kawar Farm the soil was plowed and then disked, but many clods still remained in the three houses that were used. The tarping was done on July 15, 1978 and continued until September 9, 1978 without any irrigation. The lack of water during the summer at Kawar Farm in the Middle Gohr made it impossible either to flood initially or to resaturate these plots periodically. These houses had been planted with cucumber for several years previously, and Fusarium wilt was reported to be a serious problem.

B. Application of tarps:

Three types of local plastic, 0.03 mm thick and 120 cm wide, were used: black, clear and yellow. In addition old (some what opaque) plastic was obtained from a stock that was previously used for plastic tunnels during a period of one season. The old plastic was 0.08 mm thick and 150 cm wide .

Plastic strips 21 m in length were centered over the drip lines. The edges of the plastic tarps were fastened by placing one edge in 20 cm deep furrows which were covered with soil over the edges. Then tarps were pulled snugly across the drip line, avoiding any large air pockets by assuring good contact between the plastic tarp and the soil surface. Soil was heaped on the second

edge. Care was taken to avoid tears or holes in the plastic. All treatments were replicated three times in a factorial randomized complete block design where the two main variables were the type of the plastic and the period of tarping. Tarps were left in place for 2, 4, 6 or 8 weeks with an uncovered control for each treatment. Three plastic houses were used, each house being a replicate with four types of plastic and five periods of tarping. Thus each replicate consisted of 20 experimental treatments. Treatments were randomized in each replicate .

Each experimental treatment was 21 m long and one meter wide, so the total area actually covered with plastic at each location was 1008 m^2 . The plants would be planted later 30 cm apart on each side of the drip line. The tarped area in each house was approximately 45% of the total area of the house. The plastic tarps were applied in the morning from 6 - 10 a.m to avoid high temperatures. High temperature leads to plastic expansion, while at night the plastic cools and shrinks and may break if the strips have been pulled too tightly .

C. Measurement of air and soil temperatures :

Thermographs were placed at Deir Alla and Kraimeh in order to record the air temperatures; charts of the thermographs were replaced each week. After the soil was

tarped and irrigated, soil thermometers (of Casella London type) were carefully placed in each treatment at 5, 10, 20 and 30 cm depth. The thermometers were placed in the middle of the strips near the drip line. Temperatures were recorded once daily between 2-4p.m when the maximum air temperatures occured. Temperatures were recorded from two days after starting the drip irrigation until the experiments were finished.

D. Effect of pathogen reduction on crop development:

D.1. In greenhouse pots:

As each period of tarping terminated, soil samples were taken from the center of each plot at 0 - 5, 5 - 10 and 10 - 20 cm depth were placed in pots (20 X 20 cm). Samples taken at 10 - 20 cm depth were placed in the bottoms of the pots first, those from 5 - 10 cm in the middle and lastly the samples from 0 - 5 cm placed on the surface of the pots.

Sixty pots containing soils from tarped plots at Kraimeh were planted to tomato (Claudia R.F) on Dec. 3, 1978 under greenhouse conditions. The percentages of yellowed plants and damping off were recorded.

Pots containing soils from tarped plots at Jameel Farm were planted to cucumber (Beit Alfa) on Jan 5, 1979. The percentages of wilted plants and those showing root rot and the number of days required to develop initial wilting symptoms were recorded .

Pots containing soils from tarped plots at Kawar Farm were planted to cucumber (Beit Alfa) on Dec. 23, 1978. The percentages of plants showing root rot were recorded.

Pots containing soils from tarped plots at Deir Alla were planted to tomato (Claudia RAF) on Dec. 15, 1978. The percentages of yellowed and damped-off plants were recorded. Oven dry weight of foliage and plant height were also recorded.

To ascertain the effects of plowing on the distribution of pathogen propagules, further soil samples were collected from the pots at 0 - 5, 5 - 10 and 10 - 20 cm depth 2½ months after planting. The propagules were assessed by direct plating (12) and populations compared with densities previously determined immediately after tarping . The same procedure was followed for field samples collected after plowing and 3½ months after planting .

D.2. In the tarped plots:

The tarps were removed from the experimental plots, then the soil in each plastic house was plowed and disked by the cooperating farmers. The drip systems was laid down and covered with black plastic. The tomato variety (Claudia RAF) was directly seeded in holes that were made in the plastic mulch, 30 cm apart in two rows, one on each side of the drip line. Planting was performed on Oct. 7, 1978 at Kraimeh location, one month after completion of the longest (8 weeks) tarping period .

The cucumber, Beit-Alfa variety was planted in the second location, Kawar Farm. Planting was performed on Nov. 6, 1978, two months after the end of the longest tarping period .

Potatoes and tomatoes (Claudia RAF) were planted in the third location, Deir Alla. Planting was performed on Jan. 16, 1979, 3½ months after tarpind had been completed. Here the plots were hand weeded but not plowed before planting nor mulched. Also only one row was planted along each drip line, so a minimum of soil distrubance occured between treatment and planting even though this interval was the longest at any location.

E. Soil sampling for pathogen propagules assessment:

Three samples were taken from the center of each plot at 0 - 5, 5 - 10 and 10 - 20 cm before tarping was performed. Each sample was thoroughly mixed prior to subsampling. Most samples were taken by soil auger. A hand trowel was used when soil was damp. Each field sample, about 1 kg in weight, was transferred to a clean plastic bag which was tied to avoid moisture loss. Total number of samples that were taken before tarping was one hundred eighty from each location. Soil samples were stored in the dark at room temperature for two weeks prior to sub-sampling to stabilize dormant propagules of pathogenic fungi (12). As each period of tarping terminated, a second series of soil samples was collected. These samples were examined for counting the propagules of different pathogens.

Two methods were used to isolate and count propagules : direct plating and dilution plating (12). Dilution plating was used for the two locations with drip irrigation (Deir Alla and Kraimeh) beside the direct plating method. In the other two locations (Kaw ar and Jameel Farms) the propagules were counted by direct plating method only.

After thorough mixing and sieving of the bulk soil samples and storage for two weeks, for dilution plating one gram of soil was transferred from each sample to a sterile dilution bottle (100 ml) and sterile distilled water was added to give 100 ml total solution. After one hour of mechanical shaking on electic shaker, one ml aliquot was transferred to another sterile dilution bottle and the process was repeated. Dilutions of 1 X 10^{-2} , 10^{-3} , 10^{-5} and 10^{-6} were prepared. Four Petri dishes were plated from each dilution by transfering one ml aliquots from each diltuion to the sterile Petri dishes. Ten ml of ccoled, unsolidified selective medium were added to each Petri dish. Plates were incubated at room temperature for 5 - 7 days. The numbers of colonies were counted after the incubation period. The propagules in samples collected after tarping were counted by dilution plating method at 1 X 10^{-2} dilution with five replicates. A soil sample of 15 gms was weighed and then oven dried in order to determine the soil moisture content. The counts of propagules were corrected and expressed in terms of counts per gram of oven dry soil. Direct plating was performed as described by Warcup(12). Five to 30 mg of soil was placed in a sterile Petri dish. Sterile distilled water (1-2ml)was added to the soil sample in order to evenly distribute the soil over the whole plate. The plate was shaken and rotated to disperse the soil, and 10 ml of 2% potato sucrose agar poured into each

dish. The number of propagules in samples that were collected after tarping were counted with a minimum of five replications.

The selective medium developed by Katan (2) and used for Verticillium counts consists of: agar - 20 g, PCNB-0.05g, sucrose-7.5 g, chloramphenical-0.25g, $NaNO_3$-2.0g, KCL-0.5g, $MgSO_4 \cdot 7H_2O$-0.5g, K_2HPO_4-1.0g and $FeSO_4 \cdot 7H_2O$-0.01g. The media was autoclaved at 15 psi for thirty min, and then cooled to 45°C. Streptomycin (0.1g) and ethanol (5 ml) were added to each liter of media. Plates were incubated in the incubator at 18°C for 4-7 days; then they were checked for Verticillium. A known culture of V. dahliae was grown on this media in order to test its suitability. Another method employed to isolate Verticillium was developed by Issaac (24). Ten g of soil were incorporated into 100 ml sterile distilled water; an aliquot of 5ml was shaken for 30 minutes then filtered through Whatman paper No 5. The paper supposedly retained all propagules; it was then transferred to a sterile Petri-dish and the same selective medium for Verticillium was used. Plates were incubated in the incubator at 18 °C for one week and checked after the incubation period.

Potato sucrose agar (PSA) medium was used for isolating Fusarium spp. It consisted of; 20g agar, 20g sucrose, potatoes (100g) were boiled in 500 ml distilled water for 20 minutes and filtered through cheesecloth. The medium was autoclaved; then it was cooled to 45 °C. The antibiotics (PCNB at 0.75g

and streptomycin at 0.5g per liter of medium) were added. The medium was shaken vigorously, and then was immediately poured in the sterile plates. Inoculated plates were incubated in the incubator at 25 °C for 5-7 days. Colonies were counted after five days; and counted a second time after seven days. Fungi were identified according to Booth's key (9, 15).

F. Pathogenicity tests:

Five isolates of Fusarium and one each of Rhizoctonia solani and Pythium sp. were tested for pathogenicity. For each isolate twenty Petri dishes containing potato sucrose agar were prepared and inculated. The Petri dishes were incubated at room temperatures in the incubator for one month. The cultures obtained from the twenty Petri dishes were mixed with a Waring blender and added to one liter of sterile distilled water. Pots (12 cm depth) were filled with soil previously sterilized with methyl bromide and then inoculated with aliquots of the inoculum by pouring 20 ml into each pot. Tomato (Marmand variety) and cucumber (Beit alfa), three seeds per pot, were planted one week after inoculation to ascertain the pathogenicity of the different isolates.

A total of seventy pots were employed for seven isolates times two crops replicated five times. Half of these pots was planted to tomato and the others to cucumber. Five uninoculated pots were also planted to cucumber and five pots to tomato as control treatments.

Yellowing, wilting and root roting symptoms were recorded. Reisolations were also attempted by placement of root sections in Petri dishes containing PSA medium.

G. Tarping of artificially infested soils in pots:

Cultures of F. solani, F. oxysporum and Verticillium sp. obtained from the culture collection at the University of Jordan were mixed with soil previously fumigated with methyl bromide, so as to give initial densities of 1136, 656 and 1042 propagules/g of oven dry soil, respectively, as determined by direct plating, irrigated once, then the pots were tarped for 2, 4 and 6 weeks with yellow, black and clear plastic (0.03 mm thick). The plastic on each pot was tightly tied in place with string. The pots (12 cm deep) were kept in the greenhouse and tarped on May 3, 1978. The Fusarium and Verticillium cultures had been isolated previously from diseased plants from the Jordan Valley.

Rhizoctonia cultures were isolated from infected stems of French beans (Phaseolus vulgaris L.) from the University Farm. The bean stems

containing microsclerotia were ground with a Waring blender and then mixed thoroughly into soil previously fumigated , so as to give an initial density of 732 propagules/g of oven dry soil. After the tarping period was completed, the pots were planted to beans. Observation on damping off and yellowing were recorded. Tarping was started on July 17 , 1978 in pots (12 cm deep) kept in the greenhouse.

IV. Results :

1. Identification of the fungi isolated.

The following fungi have been isolated and identified from the soils involved in these experiments : Fusarium solani (Mart.) Appel & Wor, F. oxysporum. Schlecht. (9), Rhizoctonia solani Kuehn (15), and Pythium sp. (15). Pure cultures were prepared from most of the types of colonies observed in the Petri-dishes. Colonies were selected for isolation on the basis of pigmentation, rate of growth, appearance of the mycelium and presence of propagules on potato sucrose agar. Descriptions based on the isolates obtained during this study follow.

A. Fusarium oxysporum.

Colonies 4.5 cm in diam after three days, grey to purple or violet: macroconidia abundant , generally 3-5 septate, 27 - 60 X 3 - 5 µ , microconidia oval-ellipsoid, straight or curved , 5 - 12 X 2.2 - 3.5 µ ; both are produced from simple, short, lateral phialides. Chlamydospores globose, formed singly or in pairs intercalary or on short lateral branches .

B. Fusarium solani.

Colonies 3.2 cm in diam after three days, greyish-white to blue or bluish-brown; microconidia 8 -16 X 2 - 4 µ cylindrical to oval, some becoming one septate, borne on long lateral phialides 45 - 80 X 2.5 - 3 µ or laterally on branched conidiophores, macroconidia inequilaterally fusoid, widest point above the center , 1 to 5 septate, 35 - 55 X 4.5 - 6 µ. Chlamydospores globose, smooth to rough walled, 9 - 12 X 8 - 10 µ borne singly or in pairs on short lateral branches or intercalary .

C. Pythium sp.

Hyphae large, branching irregularly, septate in older portions of cultures, sporangia spherical or oval, terminal and intercalary; oogonia usually numerous and formed frequently in culture. Oospores shperical, germinating by a branching hypha .

D. Rhizoctonia solani .

Mycelium septate, turning dark brown with age , branching approximately at right angles, lateral branches constricted at their bases; forming black sclerotia four days after incubation. The mycelium has constrictions at the base of each branch .

The following fungi were consistently isolated from the soil: F. solani and F. oxysporum from both Kraimeh and Deir Alla and R. solani from Kraimeh . Other fungi (Pythium sp. and Penicillium) isolated were either nonpathogenic or so infrequently encountered as to be considered unimportant in this work. Verticillium spp. were not isolated from any samples, not even from the control samples. These soils were either free from Verticillium spp., or the density of Verticillium was extremly low .

The following fungi were isolated from the soils used in the experiments at Jameel Farm: F. solani , F. oxysporum and Pythium sp.

The following fungi were consistently isolated from the soil at Kawar Farm (prior to tarping): F. solani , F. oxysporum, R. solani and Pythium sp.

2. Effect of plastic tarping on the population of soil infesting fungi .

It was originally planned to perform the same experiments at four locations, but the conditions at each location and the availability of water were so different that it is unrealistic to average the data, Detailed results are presented for one location only, namely Kraimeh .

A. Kraimeh location :

High fluctuations were observed in the incidence of pathogens when isolations were attempted immediately after sampling. This was considered due to the presence of short-lived propagules (= hyphal fragments) which either became converted to resting propagules or were eliminated in one to two weeks. Results were much more uniform when subsamples for isolations were taken after two weeks of storage.

Table 1 presents the levels of these three pathogens as percentages of reduction from their initial densities as determined by direct plating. Table 1 A in the appendix presents the same information as in Table 1, but as originally determined (i.e raw data). The reductions in the pathogen levels indicated by the dilution method are presented in Table 2.

Both direct plating (Tab. 1) and dilution methods (Tab. 2) gave comparable results for F. solani and F. oxysporum. However, the dilution method was not suitable for the siolation of R. solani . The results were erratic, probably associated with the difficulty in keeping microsclerotia (the propagules of this fungus) in suspension. The number of colonies developing in the 1 X 10^{-2} dilution plates could be counted most easily.

Table 1. Effect of tarping on the populations of common soil infesting pathogens at Kraineh; Jordan Valley.[1]. Reduction in (%) at different soil depths.[2]

Type of Plastic	Duration of tarping (wks)	*Fusarium solani*			*F. oxysporum*			*Rhizoctonia solani*		
		0 - 5 cm	5 - 10 cm	10-20 cm	0 - 5 cm	5 - 10 cm	10-20 cm	0 - 5 cm	5 - 10 cm	10-20 cm
Clear	2	100 a	83 b	59 bc	100 a	100 a	96 a	100 a	100 a	80 a
	4	100 a	84 ab	73 ab	100 a	100 a	100 a	100 a	100 a	85 a
	6	100 a	86 ab	79 a	100 a	100 a	100 a	100 a	100 a	87 a
	8	100 a	91 ab	80 a	100 a	100 a	100 a	100 a	100 a	94 a
Old	2	97ab	88 ab	50 c	100 a	100 a	100 a	100 a	100 a	78 a
	4	100 a	92 ab	77 a	100 a	100 a	100 a	100 a	100 a	85 a
	6	100 a	93 ab	78 a	100 a	100 a	100 a	100 a	100 a	85 a
	8	100 a	95 a	83 a	100 a	100 a	100 a	100 a	100 a	94 a
Yellow	2	80 b	68 c	42 cd	100 a	94 a	24 d	100 a	9 b	2 b
	4	87ab	81 b	43 c	100 a	94 a	42 c	100 a	10 b	4 b
	6	100 a	85 ab	45 c	100 a	100 a	43bc	100 a	10 b	5 b
	8	100 a	85 ab	55 c	100 a	100 a	56 b	100 a	11 b	5 b
Black	2	24 e	26 e	18 e	66 b	61 b	24 d	6 b	4 b	3 b
	4	32de	30 e	27 de	98 a	96 a	23 d	7 b	5 b	4 b
	6	43cd	33 e	32 d	100 a	97 a	29 d	9 b	5 b	5 b
	8	59 c	50 d	48 c	100 a	98 a	30 d	10 b	7 b	6 b
None	2	1.0 f	1.5 f	1.6 f	2.1 c	1.1 c	0.7 e	1.2 b	1.7 b	1.4b
	4	1.3 f	2.1 f	1.9 f	1.7 c	1.6 c	0.8 e	1.0 b	2.0 b	1.0b
	6	3.1 f	3.4 f	2.0 f	1.8 c	2.0 c	0.9 e	1.0 b	2.7 b	1.9b
	8	2.0 f	1.9 f	3.0 f	2.7 c	1.7 c	1.9 e	1.0 b	.0 b	2.4b

1) Soil constantly kept close to saturation by drip irrigation for 12 hours twice each week. Soil samples assessed by direct plating .

2) Percent reduction was calculated for each treatment from the propagule count determined for that treatment prior to tarping. All percentages are the average of three replications. Treatments in each column with the same letter are not significantly different at the 5% probability using Duncan's multiple range test.
($P = 0.05$) , DUNT).

Table 8. Effect of tarping on the populations of two common soil infesting pathogens at Kraimeh; Jordan Valley[1]. Reduction in (%) at different soil depths[2].

Type of plastic	Duration of tarping (Wks)	*Fusarium solani* 0 - 5 cm	5 - 10 cm	10-20 cm	*Fusarium oxysporum* 0 - 5 cm	5 - 10 cm	10-20 cm
Clear	2	96 a	80 a	48cd	100 a	100 a	100 a
	4	100 a	87 a	75ab	100 a	100 a	100 a
	6	100 a	92 a	80ab	100 a	100 a	100 a
	8	100 a	93 a	84a	100 a	100 a	100 a
Old	2	93 a	46 b	41cde	100 a	95 ab	84 b
	4	100 a	83 a	49cd	100 a	100 a	92 ab
	6	100 a	88 a	59bc	100 a	100 a	100 a
	8	100 a	96 a	73ab	100 a	100 a	100 a
Yellow	2	58 b	76 a	37cde	100 a	88 b	9 ef
	4	94 a	82 a	37cde	100 a	100 a	11 ef
	6	100 a	83 a	43cde	100 a	100 a	17 e
	8	100 a	83 a	44cd	100 a	100 a	31 de
Black	2	40 d	21 c	18ef	88 a	13 e	17 e
	4	51 d	26 c	24def	97 a	39 d	19 e
	6	61 c	33 bc	29 de	100 a	49 c	33 d
	8	65 c	46 b	48cde	100 a	55 c	46 c
None	2	3.9 e	2.3d	1.3 f	9.4 b	4.5 f	3.8 f
	4	1.6 e	3.1d	4.1 f	6.7 b	4.9 f	2.4 f
	6	3.1 e	1.9d	8.6 f	6.5 b	3.1 f	1.9 f
	8	8.1 e	1.6d	0 f	0 b	8.1 f	0.8 f

1) Soil constantly kept close to saturation by drip irrigation for 12 hours twice each week. Soil samples were assessed by dilution method .

2) Percent reduction was calculated for each treatment from the propagule count determined for that treatment prior to tarping. All percentages are the average of three replications .

Treatments in each column with the same letter are not significantly different at $P = 0.05$, DMRT .

There was no significant difference between clear and old plastic treatments, but there was a highly significant difference between these two treatments and all other treatments (yellow, black and control = not treated). The results also showed that the longer the period of tarping the higher was the reduction in propagule counts for all treatments. The greatest reductions were obtained with old and clear plastic tarps, followed by yellow and black. The effectiveness of the treatments was less at greater depths. Complete elimination of F. solani was acheived from the upper 5 cm of soil after six weeks of tarping with yellow, clear, and old plastic in all samples assessed by either direct plating or dilution method. The direct plating method indicated that R. solani was eliminated completely from the upper 10 cm of soil tarped with clear and old plastic for two weeks. Black mulch was very poor in causing reduction of levels of R. solani at any depth, but yellow plastic effectively caused elimination of the pathogen from the upper 5 cm of soil. No significant reduction was observed in the control treatment during the whole period.

The reduction in pathogen levels was asseciated with soil temperature (Tab. 3). Soil temperature was raised 12 to 16 ^{o}C under old plastic above that of the controls at the 5 cm depth; clear tarps raised the temperature from 8 to 14 ^{o}C

Table 3. Maximum temperatures of soils and air in °C under different types of tarps at Kraimeh; Jordan Valley from July 16 to September 8, 1973.

Type of Plastic	Soil depth cm	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Old	5	53.9	49.3	49.8	51.1	49.9	49.7	47.6	50.7
	10	46.8	43.7	44.8	45.4	44.3	42.7	41.5	44.0
	20	38.9	37.8	38.2	37.3	37.0	36.1	36.3	35.0
	30	35.3	35.7	37.3	36.4	36.0	35.6	35.5	34.3
Clear	5	51.9	46.4	47.1	47.8	45.4	44.7	44.3	46.6
	10	43.8	41.5	42.6	42.8	42.8	41.8	37.6	37.9
	20	38.4	37.3	39.1	37.2	35.8	36.1	37.8	33.7
	30	37.1	36.3	37.5	36.6	35.1	35.0	35.6	33.7
Yellow	5	45.3	43.8	41.9	42.7	42.4	42.3	39.8	37.3
	10	40.8	38.6	39.1	39.5	39.1	37.7	36.3	35.9
	20	37.3	35.7	36.9	35.4	35.3	34.8	34.5	33.0
	30	35.6	34.7	36.3	35.0	34.3	34.3	34.3	32.8
Black	5	43.3	39.6	41.3	38.2	39.8	39.1	38.5	36.7
	10	37.9	37.1	37.3	35.5	36.8	34.8	34.8	34.2
	20	34.3	34.4	34.3	33.3	35.4	33.8	33.1	32.8
	30	33.1	33.9	33.6	32.3	32.1	32.0	32.6	32.0
None	5	37.4	36.4	36.6	37.0	36.6	35.3	35.3	35.9
	10	36.3	36.3	36.1	36.5	36.4	35.5	35.1	34.8
	20	32.4	32.4	33.5	34.7	34.6	34.0	33.3	31.7
	30	31.4	31.0	33.1	33.7	33.6	33.1	32.5	31.0
Max Air Temp		41.4	36.7	37.1	38.4	36.7	36.6	36.2	37.5

compare with the controls . Yellow tarps raised the soil temperature from 5 to 8 °C higher than the controls at 5 cm soil depth while black tarp raised the temperature from 1 to 4°C higher at the same depth . The maximum rise in temperature was obtained under old plastic followed by clear , yellow and black tarps at all soil depths . The maxima in soil temperatures were correlated with increased air temperatures (Tab . 3). Soil temperatures changed slowly during the whole tarping period (Tab 3). The old and clear tarps were effective in raising soil temperatures in the upper 10 cm to 40°C or more during most of the treatment period . Even at 30 cm the old and the clear plastic raised the soil temperature 2-5 °C above the controls . The temperature increases under clear and old plastic at depths of 20 cm and more were probably not solely responsible for reduced propagule counts obtained at 20 cm . In moist soil held at these slightly elevated temperatures , there was an opportunity for marked biological activity . There is no comparble biological activity in dry soil (4) .

B. Deir Alla location :

Results comparable to those from Kraimeh were obtained for both F. solani and F. oxysporum at Deir Alla location in terms of reduction in the propagule levels after tarping with different types of plastic .

Therefore the results are not tabulated. A lower percentage of reduction in pathogen levels was observed in most of the treatments than at Kraimeh. The drip system at Deir Alla was not working well and the water available was not enough at any time to saturate completely the treated plots. Clear and old tarps resulted in higher percentages of reduction in pathogen levels than other tarps. The best results were obtained by tarping with clear and old tarps for eight weeks.

C. Jameel Farm Location :

The tarping period was for six weeks at this location. There was insufficient old plastic available to be used at this location. The tarps were inadventantly destroyed after six weeks and data for eight weeks could not be obtained .

The levels of the three pathogens found here as percentages of reduction from their initial densities as determined by direct plating are presented in Table 4. Prior to treatment, the population density was highest for F. solani (900 - 1000 propagules per gram of oven dry soil). The densities of F. oxysporum and Pythium sp. were originally much lower, being 250 - 350 propagules per gram of oven dry soil in the tarped area at 5 cm

Table 4. Effect of tarping on the populations of three common soil infesting pathogens at Jameel Farm; Jordan Valley [1].

Type of plastic	Duration of tarping (Wks)	Reduction in (%) at different soil depths [2]. *Fusarium solani* 0 - 5 cm	*Fusarium solani* 5 - 10 cm	*Fusarium solani* 10-20 cm	*Fusarium oxysporum* 0 - 5 cm	*Fusarium oxysporum* 5 - 10 cm	*Fusarium oxysporum* 10-20 cm	*Pythium* spp 0 - 5 cm	*Pythium* spp 5 - 10 cm	*Pythium* spp 10-20 cm
Clear	2	98.ab	58.bc	41.ab	100 a	55bc	37. a	64.	49.	45.
	4	100 a	57 ab	57 ab	100 a	75ab	48. a	83.	55.	52.
	6	100 a	67.a	64.a	100 a	95a	68. a	99.	70.	65.
Yellow	2	66.b	45 c	24bc	69.b	15df	13. b	49.	47.	40.
	4	76.ab	45.c	25b	81ab	35cdf	13. b	57.	51.	45.
	6	82.ab	46.c	27bc	82.ab	39cd	15. b	60.	56.	54.
Black	2	18.c	13.e	12c	18.c	25cdf	14. b	37.	31.	28.
	4	19.c	17.de	16c	26.c	25cdf	15. b	42.	37.	31.
	6	87.c	83.d	18c	65.b	89cdf	19.b	56.	55.	55.
None	2	0 c	1.2 f	0c	1.2c	0 f	0 c	4.0	1.7	1.1
	4	1.7 c	0 f	2.1c	1.7c	1.0 f	0.7c	7.0	1.2	0.7
	6	1.3 c	0 f	3.1c	0 c	1.9 f	1.2 c	2.0	0.9	2.1

1) Soil flooded once before tarping. Soil samples were assessed by direct plating method .

2) Percent reduction was calculated for each treatment from the propagule count determined for that treatment prior to tarping. All percentages are the mean of three replications, except for *Pythium* sp.

* Treatments in each column with the same letter are not significantly different at $P = 0.05$, DMRT .

soil depth. For all types of plastic the longer the period of tarping the greater was the reduction in propagule counts. Both F. solani and F. oxysporum were completely eliminated from the upper 5 cm of soil after four weeks of tarping with clear plastic. Pythium spp. were less affected by tarping for any duration period than the Fusarium spp. In the control plots there were slight increases and some decreases in the concentrations of the three pathogens during the entire tarping period .

Duncan's multiple range test at the 5% probability showed that the reduction in pathogen levels was increased by clear plastic tarping for four or six weeks at 10 and 20 cm depth. There was a significant difference between the yellow plastic treatment and black plastic treatment at any depth in controling Fusarium solani. There was no significant difference between the black plastic treatment and the control (= not treated). The best results were obtained by tarping with clear tarps for six weeks.

D. Kawar Farm Location :

The reductions in the levels of four pathogens as percentages of reduction from the initial densities as determined by direct plating are presented in Table 5. Tarping dry soil with clear and old plastic was fairly effective in reducing the pathogen levels in the upper 5 cm of soil , but the percentage reduction did not

Table 5. Effect of tarping dry soil on the populations

Reduction i

Type of plastic	Duration of tarping (wks)	F. solani			F.oxyspor
		0-5	5-10	10-20 cm	0-5
Clear	2	94 abc	15 bc	13 bc	100 a
	4	96 abc	16 bc	13 bc	100 a
	6	100 a	21 bc	17 bc	100 a
	8	100 a	45 a	42 a	100 a
Old	2	40 efg	13 bc	12 bc	43 bc
	4	66 bcde	17 bc	16 bc	55 bc
	6	66 bcde	30 ab	27 ab	71 ab
	8	97 ab	32 ab	28 ab	72 ab
Yellow	2	55 def	4 c	4 c	13 cd
	4	68 bcde	4 c	4 c	14 cd
	6	71 abcde	6 c	5 c	18 cd
	8	84 abcd	8 c	6 c	21 cd
Black	2	16 hi	4 c	1 c	7 d
	4	30 fghi	5 c	2 c	19 cd
	6	33 fgh	6 c	3 c	34 bcd
	8	55 def	7 c	5 c	38 bcd
None	2	7 i	2 c	2 c	0 d
	4	9 i	4 c	2 c	7 d
	6	12 i	3 c	3 c	11 d
	8	16 i	2 c	2 c	13 d

1) Soil remained dry without any irrigation . Soil s

2) Percent reduction was calculated for each treatme to tarping. All percentages are the mean of three

* Treatments in each column with the same letter ar

exceed 51% for any pathogen in the 5 - 10 cm soil layer even when the tarping period was eight weeks. Clear plastic gave better results than old plastic in the upper 5 cm of soil for both Fusarium solani and F. oxysporum. R. solani was less affected by the heat obtained from dry tarping than were Pythium spp. especially at the lower soil depths (10 - 20 cm). In the control plots no significant reductions were observed in the population densities at any soil depth during the entire tarping period. Yellow tarps reduce R.solani more than does black for any time period, but at soil depths of 5 - 20 cm both types fail to reduce the pathogen levels any significant amount. Yellow and clear tarps became cracked late in the period of tarping. Tarps were more adversely affected in this location than in Kraimeh where the drip system was used .

3. Effect of plastic tarping on the population of fungi introduced artificially into soil.

A. Artificial infestation with F. solani, F. oxysporum and V. dahliae.

The soil moisture before tarping was 10% of the oven dry weight in all pots. After tarping the moisture had dropped to 1.5 - 5% of the oven dry weight.The pots were not rewetted during the tarping period . The reduction of these pathogens in

pots (12 cm deep) tarped for various periods of time are represented as percentages in Table 6. V. dahliae was completely eliminated in all experiments, even in the control, due to the high air temperatures occuring in the greenhouse. The average air temperatures were 39.9 , 43.7 and 44.2 °C two, four and six weeks after the start of the experiments, respectively. The soil temperature increased with time in all treatments. The average soil temperature at 5 cm depth was 37.4 °C after two weeks in the control pots. The soil temperature at 5 cm averaged 50.3 °C under clear plastic after four and six weeks. Clear plastic tarping for six weeks almost completely eliminated Fusarium spp. from the pots.Yellow tarps were less effective in reducing the pathogen levels than clear tarps. Black tarps for six weeks reduced the pathogen densities 50% or more but not significantly different from yellow tarps for two weeks. Even in the control pots the densities of both Fusarium spp. were reduced by 33% due to the high air temperature.

B. Artificial infestation with R. solani.

The soil moisture was 12% of oven dry weight when the experiment started and 1.6 - 4.4% at the end (after six weeks). The percentage reductions of this pathogen resulting from different treatments are presented in

Table 6. Effect of mulching on populations of three pathogens in artificially infested soils tarped with different colored plastics [1].

Type of plastic	Duration of tarping (wks)	% Reduction in population of *Fusarium solani* from cucumber	*Fusarium oxysporum* from tomato	*Verticillium* for tomato	Average soil temp at 5 cm [2]
Clear	2	82. b	66. bc	100 a	48.1
	4	87. b	75. b	100 a	50.3
	6	96. a	94. a	100 a	50.3
Yellow	2	66. c	57. cd	100 a	46.2
	4	80. b	57. cd	100 a	48.0
	6	89. b	67. bc	100 a	48.5
Black	2	25. d	43. ef	100 a	44.4
	4	64. c	47. de	100 a	47.1
	6	86. c	50. de	100 a	47.6
None	2	3. e	30. g	100 a	37.4
	4	81. d	32. g	100 a	39.5
	6	94. d	33. g	100 a	41.7

1) Mulching performed in the greenhouse from May 3 to June 14, 1978 in pots 12cm in depth. Pots were not rewatered during tarping. Samples were assessed by direct plating. Data are the average of three replicates .
Treatments in each column with the same letter are not significantly different at $P = 0.05$, DMRT .

2) Average soil temperatures at 5 cm for 2, 4 and 6 weeks .

Table 7. Clear plastic gave the highest reductions but these were not significantly different from those obtained with other types of plastic. The population density was reduced 75% under clear plastic tarped for six weeks .

4. Effect of pathogen reduction on crop development .

4.i. In greenhouse pots: (Relatively undisturbed soil)

A. Kraimeh location:

Soil samples collected at the end of each tarping period were placed in pots (20 cm in depth) and planted with tomato (Claudia RAF). The percentage yellowed plants counted 5 to 7 weeks after planting are presented in Table 8. Fusarium sp. was isolated from yellowed plants. The lowest percentages of yellowed plants were obtained in pots containing soil from plots tarped with clear and old plastic in place for eight weeks. Results from plots tarped with black plastic were not statistically different from the control. The percentage of yellowing decreased in the second count and then increased in the third count from pots having soil tarped with clear and old plastic tarps. This was due to thining operation.

Table 7. Effect of mulching on Rhizoctonia solani in soil artificially infested with sclerotia.[1)]

Type of plastic	Duration of tarping (wks)	Reduction % of pathogen[2)]	No of propagules/g of oven dry soil	Average soil temperature at 5cm 1st week	2nd week	3rd week	4th week	5th week	6th week
Clear	2	48. ab	374	49.7	46.3	50.0	42.4	44.5	47
	4	60. a	288						
	6	75. a	176						
Yellow	2	43. ab	413	49.2	45.0	49.0	40.9	43	45
	4	48. ab	375						
	6	66. a	242						
Black	2	20. b	581	48	43.3	46.0	40.4	42.3	44
	4	41. ab	426						
	6	48. ab	376						
None	2	12. b	638	44	41.2	45.0	40	41.5	44
	4	17. b	605						
	6	19. b	587						

1) Samples were assessed by direct plating. Mulching performed from July 17 to August 28, 1978 under greenhouse conditions in pots 12 cm in depth. Initial density 732 propagules/ g soil .

Treatments with the same letter are not significantly different at P = 0.05 , DMRT.

Table 8. The percentages of yellowed tomato plants in greenhouse pot experiments containing relatively undisturbed soil from tarped plots at Fraish; Jordan Valley[1].

Type of plastic	Duration of tarping (wks)	8.1. 79[2]	22.1. 79[3]
Clear	8	32 efg	22 def
	4	25 efg	11 ef
	6	16 g	11 ef
	8	14 g	0 f
Old	2	31 efg	44 bcdef
	4	28 efg	33 cdef
	6	33 efg	11 ef
	8	18 fg	0 f
Yellow	2	39 defg	77 abc
	4	25 efg	55 abcde
	6	19 fg	22 def
	8	16 g	11 ef
Black	2	82 a	77 abc
	4	78 a	66 abcd
	6	51 bcde	44 bcdef
	8	49 cde	33 cdef
None	2	83 a	99 a
	4	71 abc	88 ab
	6	65 abcd	77 abc
	8	45 cdef	66 abcd

1) The smallest plants were removed from pots for thinning purposes.

2) Data recorded prior to thinning; at this time the number of seedlings per pot ranged form 2 - 7 plants.

3) Plants thinned to 3 per pot.

Treatments in each column with the same letter are not significantly different at $P = 0.05$, DMRT .

The percentage of damping off observed in tomato plants grown in pots containing soils treated with different colored plastic for various time periods are shown in Figure 1 . The longer thr tarping period (up to eight weeks) the less the subsequent amount of damping off for all treatments . Damping off declined in pots with soils tarped with yellow plastic for six weeks or more . Damping off declined after four weeks in soils taken from plots tarped with clear and old plastic . Greater percentages of damping off was observed in soils taken from plots tarped with black plastic than in soil taken from plots tarped with yellow plastic .Tarping with old plastic for four weeks caused more reduction in percentage of damping off than did clear plastic tarps used for the same period .

Plant heights and the oven dry weights of foliage of tomato crop did not differ significantly in these greenhouse pot experiments .

B. Deir Alla Location:

Soil samples collected at the end of each tarping period were placed in pots and planted with tomato (Claudia F1)under greenhouse conditions .

The percentage of wilted plants in pots containing soils tarped with different plastics for various time periods are shown graphically in Figure 2 . In the control (not tarped) pots all plants showed wilting . This

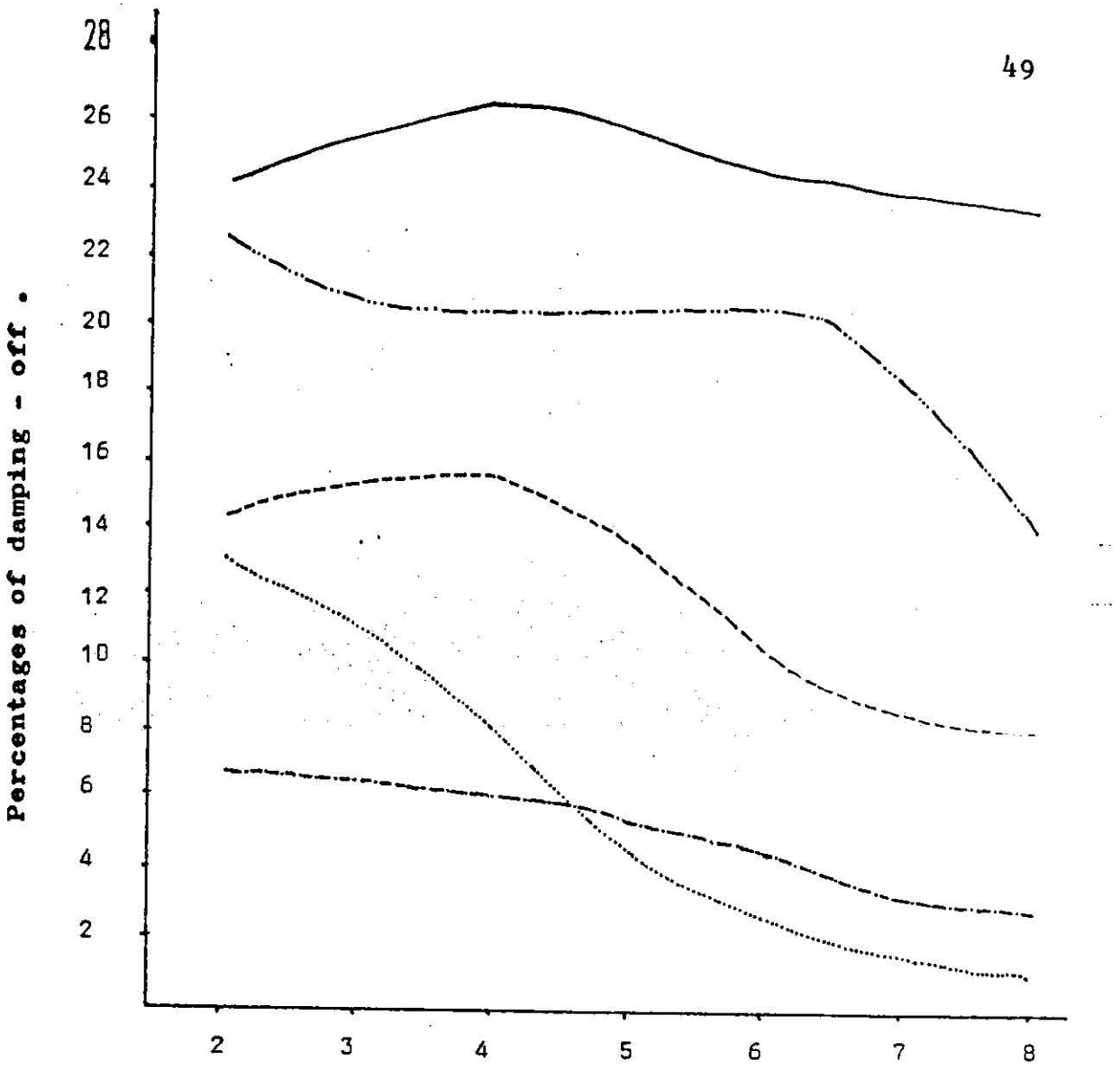

Figure (1). Damping off of tomato seedlings five weeks after planting in a greenhouse inpots containing soil from tarped plots at Kraimeh .

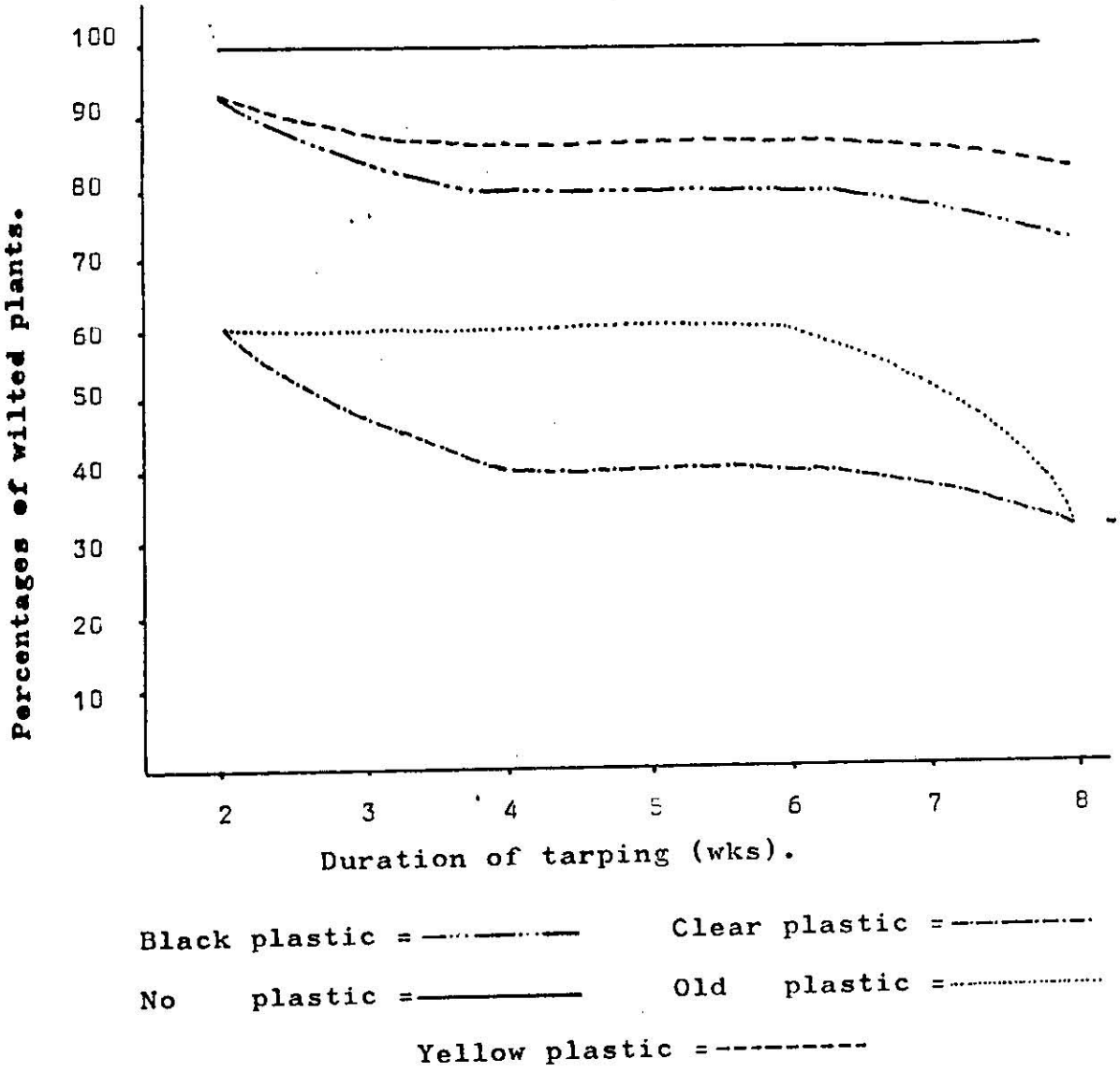

Figure (2). The percentages of wilted tomato plants observed in a greenhouse in pots containing relatively undisturbed soil from tarped plots at Deir Alla . Counted 12 weeks after planting .

observation was done 12 weeks after planting the tomato seed, The longer the tarping period (up to eight weeks), the lower was the percentage of wilted plants. The lowest percentages were observed in pots containing soils from plots tarped with clear plastic for different time periods. Tarping with old plastic gave similar results. There were no sighificant differences between black and yellow plastic treatments for any time period .

The percentages of yellowed plants as observed after 7, 9 and 13 weeks from planting are presented in Table 9. Fusarium spp. were isolated from yellowed plants. The lowest percentages of yellowed plants were obtained in pots contaning soil from plots tarped with clear and old plastic for eight weeks. Results obtained in the first observation from pots containing soils from plots tarped with yellow plastic did not significantly differ from those which were obtained from both clear and old plastic . The percentages of yellowed plants were increased in all treatments during crop development. In the third observation, the percentages of yellowed plants in pots containing soils from plots tarped with yellow and black plastic did not significantly differ from the control pots .

Table 9. The percentages of yellowed tomato plants in greenhouse pot experiments containing relatively undistrubed soil from tarped plots at Deir All[1)].

Type of plastic	Duration of tarping(wks)	Data collected on 6.2. 1979	17.2. 1979	12.3. 1979
Clear	2	6 cd	46 def	53 cde
	4	6 cd	40 defg	40 def
	6	0 d	33 efg	40 def
	8	0 d	6 h	33 ef
Old	2	0 d	40 defg	66 bcd
	4	0 d	26 fgh	53 cde
	6	0 d	20 gh	53 cde
	8	0 d	13 h	20 f
Yellow	2	13 bcd	60 bcd	86 ab
	4	13 bcd	60 bcd	86 ab
	6	13 bcd	53 cde	80 abc
	8	0 d	53 cde	73 abc
Black	2	53 a	86 a	93 ab
	4	40 ab	73 abc	80 abc
	6	33 abc	73 abc	73 abc
	8	20 bcd	73 abc	73 abc
None	2	60 a	86 a	100 a
	4	60 a	80 ab	86 ab
	6	60 a	80 ab	80 abc
	8	53 a	73 abc	73 abc

1) Plants thinned to five per pot. Figures in the counts made on Feb 17, and March 12 represent the accumulative numbers of yellowed plants in the previous counts.

c. Jaweel Farm location :

Soil samples collected at the end of each tarping period were placed in pots (20 cm in depth) and planted to cucumber (Beit Alfa) on Jan 5, 1979 under greenhouse conditions. The percentages of wilted plants observed 10 weeks after planting are presented in Table 10. Symptoms included cracking of the stems above the soil surface. Infected plants had poor growth; the height of the plants was less than 15 cm after 10 weeks and roots were obviously rotted. Wilted plants first became obvious at different periods after seeds were planted (Tab. 10). The shortest time required for wilting symptoms to develop was 20 to 25 days in the control. Pots containing soils tarped with clear plastic for four weeks or more did not show wilting symptoms until two months after planting. Symptoms were observed somewhat earlier after tarping with black than with yellow plastic . The lowest percentage of wilting was observed in pots with soil tarped for six weeks with clear plastic. The percentages of the wilted plants was greater in pots with soil tarped with yellow plastic than with soil tarped with clear plastic. The percentage of plants showing root rot after being grown in soils tarped with different plastics are presented in Table 10.

Table 10. The percentages of wilted cucumber plants and those showing root rot and the number of days required to develop initial wilting symptoms in pots containing soils tarped for various periods after a single flood irrigation.

Type of plastic	Duration of tarping(wks)	% of wilting on 16.3.1979[1)]	Days from planting required for first wilt symptoms to develop	% of plants having root rot on 16.3.1979
Clear	2	66 bc	30 b	50 ab
	4	45 d	60 a	0 c
	6	41 d	60 a	0 c
Yellow	2	62 c	34 b	50 ab
	4	50 d	60 a	45 b
	6	41 d	60 a	37 b
Black	2	100 a	25 b	50 ab
	4	50 d	34 b	50 ab
	6	49 d	60 a	50 ab
None	2	100 a	25 b	66 a
	4	75 b	20 b	66 a
	6	50 d	20 b	50 ab

1) The number of plants per pot varied from 2 to 5. The percentages were determined 10 weeks after planting .

Treatments in each column with the same letter are not significantly different at $\underline{P} = 0.05$, DMRT .

These data were collected 10 weeks after planting. F. solani was isolated from these rotted roots.Root rot was not observed in pots containing soils treated with clear plastic for four weeks or more.No significant differences between black, yellow treatments and the controls were observed. The highest percentage of root rot was observed in the control pots.

D. Kawar Farm location:

Soil samples collected at the end of each tarping period were placed in pots (20 cm in depth) and planted with cucumber. After eight weeks there was 100% root rot in all treatments with yellow and black plastic and in the controls. The percentages of plants having root rot was 85 - 95 % and 97% in pots containing soils treated with clear and old plastic for eight weeks, respectively (data not tabulated).

4.ii. In tarped plots in the Jordan Valley:

A. Kraimeh location:

The percentage of holes with no tomato plants resulting from dampped-off small seedlings or non emerging seeds are presented in Table 11.The first data were collected two weeks after planting tomato seeds and data were collected monthly until Jan 20, 1979. The percentages of missing holes decreased.

markedly from the first to the second observation because of replanting. The percentages of missing holes increased in all treatments from the second to the third date of observation, because some of the newly germinated seedlings also damped-off. Results observed in January(not presented in Tab. 11) were similar to those observed in December primarily because no further replanting occured after mid December. The lowest percentage of missing holes was observed in plots tarped with clear or old tarps for eight weeks. There were no significant differences between black and yellow treatments in reducing the percentage of missing tomato plants, although there were obviously decreasing trends in the data. Slightly higher percentages of missing holes were observed in plots tarped with yellow plastic than in plots tarped with black plastic .

The percentages of holes having only one plant after different color treatments are shown in Figure 3. The data were collected only once, two weeks after planting tomato seeds. The percentage of holes with only one seedling dropped from 4.3 to 1.1 by extending the tarping from two to eight weeks, in plots tarped with clear plastic. Similiar results were obtained with old plastic, the percentage dropping from 4.9 to 1.9 . While there were some differences in the numbers of holes with only one plant after tarping for two or four weeks with black ,

Table 11. Percentages of holes with no tomato plants in tarped plots at Kraimeh .

Type of Plastic	Duration of tarping (wks)	Dates of observation 20.10. 1978 1)	20.11. 1978 2)	20.12.1978 3)
Clear	2	29.7 a	2.7 abc	17.3 a
	4	24.3 b	2.5 abc	9.5 bcd
	6	14.5 de	2.3 bc	8.4 cd
	8	13.3 e	0.8 c	4.1 d
Old	2	21.3 bc	2.7 abc	8.2 cd
	4	15.7 de	1.7 bc	6.2 d
	6	16.6 de	1.6 bc	5.6 d
	8	15.4 de	0.9 c	4.1 d
Yellow	2	24.2 b	6.1 a	17.1 ab
	4	23.2 b	5.4 ab	16.2 ab
	6	23.1 b	5.4 ab	14.9 abc
	8	22.6 bc	3.3 abc	14.9 abc
Black	2	25.3 b	4.7 ab	15.7 abc
	4	24.4 b	4.5 abc	14.3 abc
	6	22.2 bc	4.1 abc	14.2 abc
	8	18.3 cd	3.2 abc	10.3 abcd
None	2	23.7 b	4.7 ab	17.2 ab
	4	23.3 b	4.6 abc	16.9 ab
	6	21.7 bc	4.5 abc	15.5 abc
	8	20.9 bc	4.5 abc	14.6 abc

1) Observed two weeks after planting tomato seeds.

2) Observed one month after the first observation .

3) Observed two months after the first observation.

4) Observed three months after the first obseration .

Means within column followed by the same letter are not significantly different at $\underline{P} = 0.05$. DMRT .

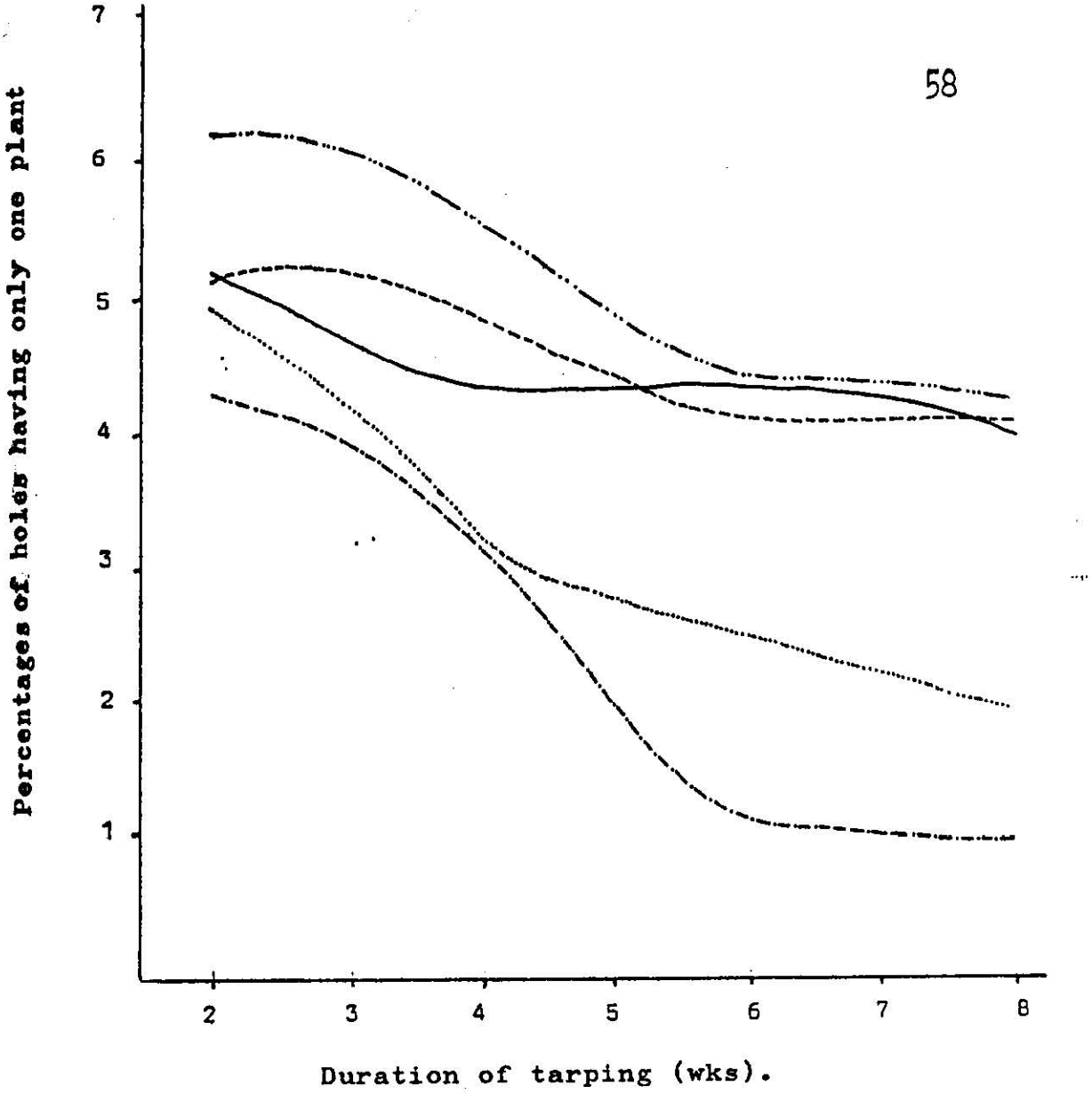

Figure (3). The percentages of holes having only one tomato plant each after tarping the soilwith different types of plastic at Kraimeh. Counted two weeks after planting .

yellow and no tarping, these differences were not significant. The numbers of holes with only one plant were essentially the same for these three treatments after tarping for six or eight weeks.

B. Kawar Farm location :

The percentages of holes having only one plant were checked two weeks after planting (Tab. 12) . The percentages of yellowed plants were determined 15 weeks after planting. Wilted plants were counted 10 and 15 weeks after planting (Tab. 12). Poor stands in Table 12 were due to the high survival rate of the different pathogens (Tab. 5) after dry tarping . The wilting percentages increased with time(Tab.12) and were correlated with higher population densities of different pathogens in the soil. The lowest percentages of wilted and yellowed plants were observed in the plots tarped with clear or old plastic for eight weeks .

The percentages of missing plants observed two, six and ten weeks after planting cucumber seeds in the tarped plots are presented in Table 13. The

Table 12. The percentages of holes having only one plant , yellowed and wilted cucumber plants in tarped plots at Kawar Farm on different dates during the growing season .

Type of plastic	duration of tarping (wks)	Percentage.[1] % holes with one plant 21. 11. 1978	% yellowed plants 20.2. 1979	% of wilted plants 16.1.1979	% of wilted plants 20.2.1979
Clear	2	13.5 abc	13.1 abcde	12.4	19.2
	4	11.5 abc	8.2 cde	10.1	8.2
	6	11.4 abc	7.4 de	8.2	7.2
	8	11.1 abc	7.3 e	4.1	7.1
Old	2	16.9 ab	13.1 abcde	11.4	16.2
	4	14.5 abc	12.4 abcde	10.7	14.3
	6	14.2 abc	12.2 abcde	10.2	11.4
	8	11.3 abc	8.9 bcde	9.6	6.3
Yellow	2	13.3 abc	19.7 a	16.4	19.6
	4	11.2 abc	16.2 ab	12.4	16.3
	6	9.6 bc	15.4 abcd	13.2	15.8
	8	8.9 c	14.6 abcde	7.5	15.2
Black	2	13.2 abc	19.2 a	17.2	20.4
	4	12.4 abc	17.2 a	14.7	17.9
	6	10.2 abc	16.4 ab	14.3	16.2
	8	7.3 c	15.9 abc	10.1	14.5
None	2	18.0 a	20.0 a	15.9	29.4
	4	14.3 abc	18.9 a	15.2	27.3
	6	10.7 abc	17.9 a	14.7	25.9
	8	14.5 abc	17.2 a	14.2	23.2

1) All percentages are the average of three replicates, except for wilted plants .

Treatments in each column with the same letter are not significantly different at $\underline{P}$ = 0.05 , DMRT .

percentage of missing plants decreased from the first to the second and from the second to the third counts because of replanting done by our cooperating farmer. Nevertheless, poor stands occured in all treatments. There were no significant differences between treatments in the first and second counts. Old and clear tarping for six to eight weeks and two replantings reduced the percentage of missing plants in the third count.

5: Effect of cultural practices on pathogen densities.

The actual pathogen densities in soil samples collected before tarping, immediately after tarping (i.e before plowing) and thirteen weeks after planting for selected treatments are presented in Table 14. Cultural practices, including the actual growing of a crop (with but few exceptions) did not greatly modify the population densities of F. oxysporum and R. solani. R. solani and F. oxysporum were each reintroduced only once after being eliminated by the tarping. Indeed in several cases these

Table 13. Percentages of holes with no cucumber plants in tarped plots at Kawar Farm on different dates during the growing season

Type of plastic	Duration of tarping (wks)	Percentages collected on [1] 21. 11.1978[2]	19. 12.1978[3]	16.1. 1979[4]
Clear	2	33.7 a	23.1 a	12.5 abc
	4	30.1 a	22.4 a	9.7 abc
	6	28.9 a	21.7 a	8.3 abc
	8	28.7 a	20.3 a	5.8 bc
Old	2	30.5 a	26.6 a	14.6 abc
	4	29.5 a	17.3 a	7.8 abc
	6	24.2 a	15.3 a	6.7 abc
	8	23.9 a	14.0 a	4.8 c
Yellow	2	34.8 a	25.2 a	16.1 ab
	4	33.6 a	23.0 a	9.8 abc
	6	33.1 a	19.4 a	9.8 abc
	8	21.6 a	18.6 a	8.4 abc
Black	2	32.9 a	27.5 a	14.8 abc
	4	32.4 a	26.9 a	12.5 abc
	6	27.8 a	18.9 a	12.1 abc
	8	20.1 a	16.2 a	10.3 abc
None	2	33.4 a	27.4 a	16.9 a
	4	30.1 a	26.9 a	16.3 ab
	6	28.4 a	25.8 a	15.7 abc
	8	22.2 a	19.6 a	15.2 abc

1) All percentages are the average of three replicates .

2) Observed two weeks after planting .

3) Observed six weeks after planting .

4) Observed ten weeks after planting .

Treatments in each column with the same letter are not significantly different at $P = 0.05$, DMRT .

Table 14. Pathogen densities in field soil samples collected from tarped plots at Kraimeh before tarping, immediately after tarping and 3½ months after plowing and planting .

Treatment / Pathogen		Actual densities at different soil depths.[1] 0 - 5 cm			5 - 10 cm			10 - 20 cm		
		A^2	B^2	C^2	A^2	B^2	C^2	A^2	B^2	C^2
Clear plastic (6 wks)	F. solani	1866	0	138	2062	288	135	3379	709	98
	F. oxy	556[1]	0	0	495	0	0	304	0	0
	R. solani	200	0	0	400	0	0	160	20	0
Old plastic (6 wks)	F. solani	2266	0	1628	1875	131	490	2902	638	652
	F. oxy	400	0	0	309	0	0	270	0	0
	R. solani	290	0	0	409	0	75	210	31	0
Yellow plastic (4 wks)	F. solani	2266	294	1019	1975	375	735	2902	1654	1398
	F. oxy	356	0	0	313	18	0	304	218	0
	R. solani	271	0	0	550	495	0	209	200	0
Black plastic (6 wks)	F. solani	1816	1035	755	5837	3910	684	3414	2321	800
	F. oxy	340	0	256	271	8	0	289	150	0
	R. solani	271	246	52	461	437	152	289	274	67
None (4 wks)	F. solani	1799	1775	951	2062	2018	1906	3379	3314	988
	F. oxy	471	462	0	395	388	0	204	202	0
	R. solani	200	198	0	300	300	0	170	170	0

1) Density = No of propagules/g of oven dry soil as determined by direct plating of field samples .

2) A = Density prior to tarping
B = Density after tarping for the period indicated and before plowing .
C = Density in mid season (approximately 3½ months after plowing and planting).

pathogens could not be reisolated in mid season even though they had been present in reduced numbers at the end of tarping. In contrast, F. solani population fluctuated in density after soil preparation and planting or was reintroduced more frequently after having been eliminated by tarping. Portions of the soil samples collected at the time of removing the tarps were placed in pots (20 cm in depth) in the greenhouse with the least possible distrubance so as to maintain the original field profile. Tomatoes were then planted in these pots and soil samples were taken two and half months after planting from randomly selected pots. The population densities in field samples taken before and after tarping and for portions of the samples taken after tarping which were sampled two and half months after being potted and planted to tomatoes are presented in Table 15. If the propagule densities obtained in the greenhouse pot experiments (Tab. 15) are compared with those obtained in the field at mid-season (Tab. 14), there is generally less variation from the end of tarping(i.e from before plowing) to mid season in the greenhouse experiments than in the field experiments .

6. Pathogenicity of the isolates :

Five different Fusarium isolates , four of F. solani, one of F. oxysporum and one isolate of each R. solani and Pythium sp. were obtained from the tarped plots. Plants were checked for symptoms two months after seeding ; root sections were

Table 15. Pathogen densitites in soil samples collected from tarped plots at Kraimeh before tarping, before plowing and 10 weeks after being planted to tomatoes in the greenhouse.

Treatment / Pathogen		Actual densities at different soil depths.[1] 0 - 5 cm			5 - 10 cm			10 - 20 cm		
		A[2]	B[2]	C[2]	A[2]	B[2]	C[2]	A[2]	B[2]	C[2]
Clear plastic (6 wks)	F. solani	1866	0	123	2062	288	652	3379	709	1236
	F. oxy[illegible]	556	0	44	495	0	0	304	0	0
	R. solani	200	0	0	400	0	0	160	20	0
Old plastic (4 wks)	F. solani	2209	66	106	2166	259	102	3516	1758	1092
	F. oxy[illegible]	361	0	45	604	0	24	237	0	455
	R. solani	200	0	0	301	0	0	120	24	0
Yellow plastic (4 wks)	F. solani	2266	294	129	1975	375	748	2902	1654	1223
	F. oxy[illegible]	356	0	0	313	18	0	304	218	30
	R. solani	271	0	0	550	495	150	209	200	180
Black plastic (8 wks)	F. solani	2218	909	460	4683	2341	710	3496	1817	1140
	F. oxy[illegible]	302	0	0	464	9	43	505	222	51
	R. solani	131	117	80	338	314	0	224	210	200
None plastic (6 wks)	F. solani	2109	2043	2093	5179	5002	1541	3479	3409	1930
	F. oxy[illegible]	435	427	153	120	117	103	110	109	120
	R. solani	190	188	151	380	380	360	130	130	100

1) Density of propagules/g of oven dry soil as determined by direct plating.

2) A = Densities prior to tarping .
B = Densities immediately after tarping for the period indicated and before plowing .
C = Densities in B samples, 2½ months after they had been potted and planted to tomato .

randomly selected (one section per plant) and plated on PDA medium in order to isolate pathogens persent. It was not possible to distinguish infected roots on the basis of symptoms. All of the tomato and cucumber roots from pots artificially infested with R. solani and Pythium sp.yielded these pathogens when reisolation was attempted . R. solani or Pythium sp. developed from all root sections plated . All Fusarium isolates were also reisolated from infected roots but usually in smaller percentages. Thus all soil isolates tested proved to be pathogenic to both tomato and to cucumber (Table 16).

Table 16. Pathogenicity of fungi isolated from experimental plots.

No	Pathogen isolated	Percent reisolation from [1]	
		Tomato plants %	Cucumber plants %
1.	Pythium sp.	100	100
2.	Rhizoctonia solani	100	100
3.	Fusarium oxysporum	93	89
4.	Fusarium solani	100	100
5.	Fusarium solani	100	100
6.	Fusarium solani	37	62
7.	Fusarium solani	90	90

1) Percentage of plants yielding each fungus from their roots.

V. Discussion:

These results clearly demonstrate that clear and old plastic mulches during July and August provide a highly promising means of raising soil temperatures to 44.-53.9 °C in the upper 5 cm of soil depth and that this temperature range, if maintained for four or more weeks in moist soil is lethal to most pathogenic fungi present in the soil. Transparent plastic permits 80% of the daylight to pass into the soil layers, but black plastic permits only 50% of the rays to pass and reflects the other 50% . Consequently higher temperatures are induced under clear than under black plastic (16).

During the night the soil temperature drops under clear more than under black plastic because clear plastic has higher transparency to long, infrared radiation than does black. So there is less variation in temperature under black plastic from, but also lower average temperatures . The visible wavelengths in sunlight (from 3800 - 7800 A°) are somewhat effective in raising soil temperatures and some of the energy comes from wavelengths of 2800 - 3800 A° (ultraviolet rays), but the most energy comes from the infrared rays, with wavelengths of 7800-25000 A°. Soil temperature drops during the night due to radiation of wavelengths from 50000 - 350000 A° from the soil (16) .

The highest inoculum densities of pathogens have been observed in June, i.e after tomato and cucumber debris has been plowed into the soil. Tarping should commence only after the debris of the previous crop has either been removed or well mixed into the soil, and obviosuly should occur when air temperatures are at the highest.

Weather records for Jordan (Deir Alla Station) indicate that July and August have the maximum monthly average temperatures, and the average maximum daily temperature increases from June till August. Average maximum daily temperature is not the only factor. Obviously the total number of hrs of sunshine possible per day is also significant; the number of sunshine hours increases in June and during July; then it decreases in the middle of August . During July the daily mean sunshine lasts for 12.5 hrs; this period drops to 11.4 hrs after August 15 in Deir-Alla Station. Because of residual effects more heat is held in the soil once the temperature has been built up, i.e in July, than earlier (i.e in June). Conversely when the days begin to shorten appreciably in length, i.e in late August and early September, soil temperatures begin to decrease. Therefore, it is better to tarp in July and August than in September; July is probably better than August. However, the results clearly indicate that the longer the tarping period the greater the reduction in propagule survival, particularly if water is available to retain

high levels of moisture. So it is recommended that tarping be done wherever feasible after mid June and tarps be left in place until planting operations commence.

The following statistical analysis for column 1 in Table 1 as an example indicate that there were a significant differences between plastic types, between durations of tarping and between type-duration interactions.

Source of variation	df	SS	MS	Fc	F table 5%	1%
Blocks	2	147.35	73.6			
Treatments	19	96632.39	5085.9	49.8*	1.85	2.40
Plastic type	4	91464.21	22866	223.9*	2.62	3.86
Duration of tarping	3	1567.6	522.5	5.11*	2.85	4.34
Type - duration	12	3600.58	300	2.93*	2.02	2.69
Error	38	3881.9	102.1			
Total	59	100661.64				

* = significant difference

Fc = F calculated

The density of pathogen propagules tends to be lower during the middle of the growing season and to increase towards the end and after the plants die(12). As the temperatures become less favorable for disease development in Jordan Valley or under greenhouse conditions, hyphal cells of fungal pathogens are converted to long lived propagules(sclerotia or chlamydospores).

Both clear and old plastic tarps have been demonstrated to be effective in reducing the levels of pathogens. This reduces the number of yellowed plants appearing in the plots after planting and in pot experiments using soil samples from treated pots .

Yellow plastic was much more effective than black plastic in reducing pathogen levels. However, some tears and holes appeared in the yellow plastic after two weeks, and none of the yellow tarps remained intact through the 6 or 8 weeks tarping periods. The degradation of plastic mulch is the combined result of oxidation and the effect of ultraviolet light, which causes embrittlement. This damage can be avoided by careful control of the specific additives put in plastic during processing (10).

Clear and old plastic tarping are considered effective for complete elimination of some pathogens, and for reducing the density of others to levels that do not cause severe disease.

Reduction in the density level of R. solani after tarping is reported to be due to an antagonistic relationship with Pythium ultimum (40). We isolated an unidentified species of Pythium from three locations, but we do not have direct evidence that the reduction in Rhizotonia solani observed in our experiments was the result of an antagonistic reaction with

the Pythium sp. isolated. In contrast, a synergistic interaction has been reported between Pythium ultimum and F.solani under field conditions during the growing season (40). High densities of Pythium were accompanied by increasing levels of Fusarium spp. This was obvious in pots kept in greenhouse from the dry-tarped plots.

Direct plating was more suitable for pathogen assessment in this study than was dilution plating. Higher numbers of propagules have been recovered from the same soil weight by the former method. The latter method requires special care during mechanical shaking for accurate results, especially with pathogens producing sclerotia. Some colonies recovered may have resulted from fragments of mycelia. In the case of direct plating there is no breaking of hyphae into smaller fragments. Thus each colony results from a single propagule. Also direct plating is satisfactory in detecting low densities of pathogens, while dilution plating techniques works best in the case of high density levels of pathogens. The differences obtained between direct and dilution plating suggest that a period longer than 2 weeks may be necessary for the number of propagules of some pathogens to become stabilized. Also for maximum uniformity shaking the dilution bottle vegorously is recommended immediately prior to withdrawal of the sample by the pipette in case of dilution plating .

Effective control of pathogens has been acheived by either old or clear plastic where tarping was performed with a drip system previously installed. This permits the soil to be rewetted without removing the tarps. Watering the soil to the field capacity improves heat conduction by filling the air spaces. Air is a poor conductor of heat. Also high temperature accompanied by high soil moisture apparently induced weakening of resting propagules. Such propagules are more subject to attack by other micro-organisms. Soil saprophytes are enhanced in numbers by high temperature and high moisture. Some saprophytes initiate attacks on pathogens, and thus provide biological control (4).

The aim of soil preparation is to have a fine tilth. By rolling , air pockets under plastic tarp are reduced as better contact results between the plastic tarp and the soil surface. Less reduction of pathogen level is acheived by a single flooding followed by tarping than by plastic tarping of soils that can be remoistened periodically. Similarly,dry tarping where no water is applied is also less effective. For example, a high linear regression coefficient was acheived between reduction percentages of the pathogen, E. solani, at 10 cm in all four locations and the percentage of moisture, 0.86, 0.89, 0.94 and 0.97 under clear , yellow, black, and old plastic tarps respectively. This means that irrigation

during tarping operation is necessary to acheive effective results.

In the West-Bank the reduction in propagules of F. solani varied from 95, 68 and 63% at 5, 15 and 25 cm depth with clear plastic tarped for two weeks(27), while it was 96, 80 and 48 at 5, 10 and 20 cm depth with our clear tarp for two weeks. So better control was obtained by oxtending the length and the width of the tarped plots (our tarped plots were 21 long and one meter in width while they were 15 m and 70 cm in width in the West-Bank). The wider and the longer the plots the less heat loss through the edges and higher heat will be built up in the soil.

We obtained better results in reducing the pathogen level at Kraimeh than at the Deir-Alla location. The drip system in the second location was poor and not enough water was available to wet the whole tarped area. In contrast the jet type drip system in Kraimeh did the job easily and water was available to resturate the soil.

There were no significant differences recorded between treatments for 2, 4 or 6 weeks with each color of plastic in the number of wilted plants found in tarped plots. The farmer at the Kraimeh location plowed the soil to remove the weeds present between the plots, and organic manure was added to the whole house before our tarps were spread.

The number of missing tomato plants was less in the second count six weeks after initial planting than in the first because of replanting. Subsequently, the number of missing holes increases in the third count because most of the seedlings replanted do not become established in the missing holes after two successive direct seedings have failed. The numbers do not change in the fourth count because no further replanting occured and no additional plants became wilted. The percentage of holes having one plant in the first 2-4 weeks after planting is also considered a weak link in stand establishment because if that single seedling is attacked by some pathogen, a missing hole results. The number of holes with one plant decreased as the period of tarping increased, In greenhouse pots containing soil samples from Kraimeh, the percentage of yellowed plants increases with time (Tab. 8) because with each count the number of yellowed plants in the same pot is increasing. Old and clear tarping for eight weeks resulted in the lowest percentage of yellow plants.

Tarping after a single flood irrigation was effective in reducing pathogen levels in the upper 5 cm and relatively effective in the next 15 cm below. Thus flooding will delay infection for certain periods. Equally important during this additional time period plants become more resistant to disease.

Even dry tarping in the absence of water was effective in eliminating pathogens from the upper 5 cm of soil. At greater depths the reduction was not significant. Because of poor soil conductivity due to the absence of water, little heat penetrated below the upper 5 cm. The air in the soil is a good insulator. Here again the soil was plowed after tarping and before planting; consequently the tarped area probably was contaminated to some extent with untreated soil which was moved laterally in the plowing operation. This probable mixing of untreated soil with treated soil would result in the treatment appearing to be less effective based on disease incidence in subsequent crops grown in the plots than in the pot experiments performed in the greenhouse. Soil plowing does distrub the tarping area as is clear from samples collected and assessed during the growing season .

Plastic tarping is particularly effective because plant pathogens do tend to be concentrated in the upper 10 cm of soil. Pathogens to this depth were consistently killed by

tarping with clear or old plastic for four weeks or longer. The cultural practice of using a black plastic mulch causes the roots to be concentrated in the upper layers of the soil (32) and thus to be at a depth most effectively treated by solar energy. Under these conditions the propagules present at depths below 10 cm constitute much less of a source of inoculum to the crop . There is little infection and that which occurs, occurs late; thus there is little or no disease, little or no loss, and no significant buildup of inoculum in the surface layers.

Many advantages result from tarping with old plastic that has been used for one season in plastic tunnels. It gives results equal to those obtained with clear plastic and obviously cuts the cost of the tarping material .

In tarping it is recommended to cover the entire soil surface within a house so that all soil will be treated. This eliminates the possibility of lateral mixing of untreated soils from the aisles with treated soil; it reduces weed growth in the aisles; it should also reduce moisture loss at the edges and thus greatly improve the efficiency of the treatment.

The cooperating farmer in Kraineh tarped three houses for his own use with clear plastic in strips (thus covering 50% of the house) for the maximum period (eight weeks) . He obtained better results than did we in our experimental houses in which we had controls (no treatment) , different colored traps and varying time periods .By extending the width of the treated area , the accumulative effects will be greater;

soil temperatures will be higher at the surface and penetrate deeper and more evenly than in case of strip tarping .

There was no significant difference between old and clear plastic tarping in reduction of the pathogens .

Black plastic tarps have the advantage that with proper advance soil preparation , there need be no removal of tarps at planting time and thus soil disturbance could be minimized . As stated previously black plastic concentrates root development in the upper soil layers and continues to provide effective weed control during the growing season . Yellow plastic was better than black as a tarp in reducing the pathogen levels during two to four weeks periods ; but subsequent disintegration limited the total period of treatment possible with this color .

The soil should be prepared before tarping so as to be ready for planting immediatly after removing the tarps with a minimum of subsequent soil disturbance .

Tarping with either clear or old plastic is less expensive than other methods of treating soils to control pathogens . The cost of materials to treat 1 sqm with methyl bromide amounts to 70 fils (700 fils /lb / 10 sqm), while one Kg of plastic tarp (0.03 mm thick) has a surface of 40 sqm and costs 400 fils or only 10 fils per sqm . Also plastic is hazardous neither to the applicator nor to the crop to

Even at lwer depths (20 - 25 cm) where the soil temperature was around 37°C, significant reductions in pathogen levels were observed. Sub lethal temperatures in miost soil may weaken the resting structures of plant pathogens sufficiently to render them vulnerable to attack by antagonistic components of the soil microflora(28).

The pathogens consistently isolated from soil samples prior to treatment were: Fusarium solani, which causes root rot of tomato and cucumber plants; F. oxysporum which is present in lower density in the soil, is responsible for cucumber and tomato wilts; Pythium sp, and Rhizoctonia solani which were present in some plots in very low concentrations prior to treatment; neither exceed 500 propagules/g of oven dry soil. F. solani had a concentration of 1799 - 5837 propagules/g of oven dry soil at Kraimeh ; F. oxysporum, a density of 171 - 604 propagules/g of oven dry soil; and R.solani a concentration of 100 - 461 propagules/g of oven dry soil, all in the upper 10 cm of soil prior to treatment. The same pattern was present at the other locations. The concentration of F. solani was consistantly highest followed by F. oxysporum. R. solani and Pythium sp. were present in small concentrations, not exceeding 178 propagules/g of oven dry soil for R. solani in the upper 20 cm at Kawar Farm and 583 propagules/g of oven dry soil for Pythium sp. In Jameel Farm the density for

Pythium sp. was 295 propagules/g of oven dry soil in the upper 20 cm of soil prior to treatment.

In our experiments there were no significant differences correlated with the tarping which was initiated at the different locations .

VI. Conclusion:

Clear plastic (0.03 mm) and old plastic(0.08 mm) were equally effective when used as plastic tarps in reducing harmful microorganisms present in soils in the Jordan Valley. These tarps were much more effective than either yellow or black tarps. The thicker tarp did not transmit as much solar energy as the clear plastic, but was equally efficient due to lower heat loss at night. The thinner clear plastic transmitted more solar energy, but had a higher heat loss during the night.

There were significant differences between tarping for 2, 4, 6 and 8 week periods; eight weeks was most effective. The tarps should be in place for at least 8 weeks during the hottest part of the year (July and August) in Jordan Valley area. Indeed we recommend that careful and thorough soil preparation be performed at least by the end of June, that tarps be emplaced immediately thereafter , and left in place until planting time. The longer the period of tarping and the closer the soil moisture level can be held to saturation, the more complete is propagule reduction, especially at lower depths .

Tarping whole plastic houses with the drip system previously installed under the tarps and avoidance of plowing after tarping minimizes both lateral and vertical soil disturbance. Also continued complete tarping minimizes the amount of wind blown inoculum introduced from surrounding areas into the area to be planted. Irrigation should be by trickle or drip system to avoid soil erosion which may result from surface irrigation methods. Careful disking, if feasible, results in a smooth, even surface for the planting bed, across which the tarp can be pulled snugly giving close contact with the soil surface. If the entire area within a plastic house is tarped no more water should be needed to maintain desired soil water content than that required for saturating one meter planting strips and not covering the intervening pathways. With this program to minimize propagule survival obviously every effort should be made to not reintroduce inoculum at planting time. Transplanting of healthy seedlings or better yet direct seeding with seed coated with fungicides is recommended. If seedlings are to be transplanted into tarped area, obviously the seedlings should have been grown under as sterile conditions as possible .

If some weeds have developed, the use of a contact herbicide before black mulching and planting and of other selective herbicides after planting should be considered. Temperatures resulting from tarping are lethal to most weed seeds.

At planting time we recommend removal of the clear wide plastic and use of black mulch strips for planting. The black mulch has served advantages:

1. it continues to provide weed control.
2. conserves water
3. results in shallow root systems, i.e in root systems being concentrated where the solar energy treatment is most effective in reducing inoculum of pathogens.

At present tarping as performed in the experiments is considered effective for only one season. As with fumigation with methyl bromide, it must be repeated every summer to maintain minimal levels of pathogen propagules.

However if tarping covers the complete area within a plastic house, and precautions are taken against reintroduction of soil-borne pathogens, tarping less frequently than every year might be feasible.

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Appendix Table 1.(A). Effect of tarping on population of common soil infesting pathogens. 1)

Population at different soil depths.

Type of plastic	Duration of tarping (wks)	Fusarium solani			F. oxysporum			Rhizoctonia solani		
		0-5	5-10 2)	10-20	0-5	5-10 2)	10-20	0-5	5-10 2)	10-20
Clear	2	0/2336	719/4232	1466/3576	0/700	0/395	8/204	0/184	0/320	38/190
	4	0/2286	665/4162	943/3496	0/302	0/464	0/250	0/131	0/238	33/224
	6	0/1866	288/2062	709/3379	0/556	0/495	0/304	0/200	0/400	20/160
	8	0/2209	290/3223	703/3516	0/361	0/604	0/237	0/131	0/236	12/200
Old	2	54/1816	499/4162	1779/3558	0/416	0/604	0/237	0/289	0/461	37/171
	4	0/2209	173/2166	808/3516	0/361	0/604	0/237	0/200	0/301	24/120
	6	0/2265	131/1875	638/2902	0/400	0/309	0/270	0/290	0/409	31/210
	8	0/1990	103/2052	613/3611	0/188	0/395	0/204	0/135	0/184	8/150
Yellow	2	457/2286	1331/4162	1947/3358	0/416	21/352	426/561	0/160	318/350	186/190
	4	294/2266	375/1975	1654/2902	0/356	18/313	218/304	0/271	496/550	200/209
	6	0/2218	702/4683	2058/3742	0/302	0/464	358/505	0/131	214/238	212/224
	8	0/2298	649/4332	1573/3496	0/435	0/352	392/561	0/131	211/238	180/190

continued to Appendix Table 1. (A) .

Black	2	1678/2209	3830/5177	2883/3516	145/428	235/604	383/505	123/131	228/238	217/224
	4	1466/2157	3840/5487	2765/3788	6/302	18/464	174/300	121/131	226/238	215/224
	6	1035/1816	3910/5837	2321/3414	0/340	8/271	150/289	246/271	437/461	274/289
	8	909/2218	2341/4683	1817/3496	0/302	9/464	222/505	117/131	314/338	210/224
No cover	2	2200/2200	4612/4683	3440/3496	353/361	597/604	501/505	129/131	238/238	224/224
	4	1775/1799	2018/2062	3314/3379	462/471	388/395	202/204	198/200	300/300	170/170
	6	2043/2109	5002/5179	3409/3479	427/435	117/120	109/110	188/190	380/380	130/130
	8	2232/2278	4082/4162	3558/3558	413/416	604/604	237/237	169/171	461/461	189/189

1) Soil samples assessed by direct plating .

2) All figures are the averages of three replications . The numerator is the number of propagules / gm oven dried soil found at the end of the tarping period, the denominator is the initial density of indicated propagules/gm of oven dry soil prior to treatment .

Appendix Table. 2. Air temperatures in the Jordan Valley (Deir Alla) for the period 1975 - 1978.

Year	Month	Maximal (avg)	Minimal (avg)	Monthly (avg)	No. of days $\geq 40^{\circ}C$ (max)	Monthly (max)
1975						
	June	36.0	21.5	28.8	0	39.8
	July	38.5	23.5	31.0	5	41.5
	August	37.3	23.9	30.6	1	40.7
	September	36.1	22.8	29.5	2	41.4
1976						
	June	36.5	21.0	28.8	2	41.4
	July	37.4	23.4	30.4	1	40.4
	August	37.0	23.2	30.1	0	39.5
	September	35.7	22.9	29.1	0	39.5
1977						
	June	37.3	21.8	29.6	5	43.3
	July	39.2	24.3	31.8	10	44.5
	August	39.7	24.9	32.3	11	46.0
	September	36.0	23.2	29.6	1	40.2
1978						
	June	37.1	21.2	29.2	7	42.5
	July	40.5	25.0	32.7	20	47
	August	37.4	23.3	30.3	3	40.4
	September	35.6	22.5	29.1	2	41.6

Appendix Table 3. Average number of sunshine hours of June through September 1977 - 1978 . Deir Alla

Year	June			July			August			September		
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31	1 - 10	11-20	21-30
1977	11.5	12.2	12.7	12.5	12.4	12.6	12.3	11.4	11.5	10.6	9.3	10.0
1978	11.7	13.0	12.7	12.9	12.6	12.4	12.4	11.9	11.8	11.3	10.8	9.8