THE INFLUENCE OF MULCHING ON SEVERAL VEGETABLE CROPS WITH SPECIAL REFERENCE TO BLACK POLYETHYLENE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Robert Paul Heslip

1959

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THE INFLUENCE OF MULCHING ON SEVERAL VEGETABLE CROPS

WITH SPECIAL REFERENCE TO BLACK POLYETHYLENE

By

ROBERT PAUL HESLIP

AN ABSTRACT

Submitted to the College of Agriculture, Michigan State University
of Agriculture and Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Horticulture

1959

Approved Robt. L. Carolus

(51)

ROBERT PAUL HESLIP ABSTRACT

Experiments were conducted to study the influence of black polyethylene, aluminum and straw mulches, hot tents, scraping, cultivation, and irrigation on the growth and yield of tomatoes, Seneca Prolific Hybrid summer squash, Burpee Hybrid slicing cucumbers, and muskmelons. Soil temperatures in mulched and cultivated plots were recorded and fresh petiole tissue extracts were analyzed for nitrate nitrogen, phosphate phosphorus, potassium and magnesium. Soil samples were analyzed once for nitrate nitrogen.

Cucurbits responded more to polyethylene (black plastic) mulching than tomatoes. Early yields of cucumbers, squash and muskmelons were increased by 126 percent, 182 percent and 247 percent, respectively, and the total yields by 28 percent, 58 percent and 81 percent, respectively, over cultivation. Black plastic mulched Spartan Rock muskmelons with an increase of 406 percent, and Harper Hybrid muskmelons with an increase of 333 percent over cultivation, responded most to mulching, while Honey Rock muskmelon with 166 percent responded least to cultivation. The response of the other melon varieties - Honey Dew, Delicious, Burpee Hybrid and Harvest Queen was intermediate with increases of from 236 percent to 268 percent over cultivation. Aluminum mulch and hot tents also increased yield and growth, but to a lesser extent than black plastic.

Fireball tomatoes did not respond markedly to black plastic unless they

were overhardened, in which case plastic greatly increased yields over normal cultivation. Early Hybrid and Moreton Hybrid tomatoes did not respond greatly to plastic mulching.

Tomatoes responded almost as well on plastic three feet in width as on four-foot plastic. However, with muskmelons there was a greater response on four-foot plastic. The cutting of slits in black plastic to allow moisture to enter the soil did not increase its effectiveness in this experiment.

Scraping the soil with a hoe to a depth of only one inch did not result in any increase in yield over cultivation. It is believed that the lack of response to scraping is due to the fact that the cultivation practiced was shallow and did not materially injure the roots in the surface soil.

Straw mulch was beneficial when used on Fireball tomatoes. When used on cucurbits, growth early in the season was depressed, resulting in lower early yields than with cultivation. Straw mulch also depressed the late yield of Honey Rock muskmelons.

Although Early Hybrid, Moreton Hybrid and Fireball tomatoes, in certain experiments, were benefitted, muskmelons did not respond favorably to irrigation.

Straw mulch did not depress the nitrate level in tomato plants but when used with cucurbits, the nitrate level was low. The use of ~~plastic or~~ aluminum mulch did not markedly alter the nutrient levels in any of the crops tested. Nitrate levels in the soil were highest in cultivated plots. Because of the size and rate of growth of plants grown with black plastic, nitrates did not accumulate in the soil but were utilized.

Soil temperature measurements indicated that black plastic increased the temperature, compared with cultivated soil, an average of 5° F at a two-inch depth, and 3° F at a four-inch depth. Aluminum mulch only slightly increased the soil temperature, and straw mulch slightly decreased the soil temperature. The increase in soil temperature from plastic mulching is undoubtedly one of the important reasons that yields of cucurbits, which are warm season crops, were increased.

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INTRODUCTION

Mulching is the application of a covering to the soil surface to prevent water loss and weed growth, to lessen temperature fluctuations, to alter soil temperature, or to promote soil productivity. Substances used for mulching range from natural materials, as straw, hay, leaves, wood chips, sawdust, corn cobs, manure, peat, and gravel to manufactured materials, such as asphalt or kraft paper, paper pulp, aluminum foil, cellophane, and polyethylene or other plastic films.

The economic applicability of a mulch is determined by the cost of the material and other expenses incurred, the savings made in weed control and labor, and increased returns due to earliness, higher yields, and improved quality. Mulching is most profitable on high value crops.

This study is concerned mainly with the use of black polyethylene film, a synthetic product which was first used in 1955. It is non-toxic to plant growth, resistant to decomposition by moisture, light and soil organisms, and is elastic and stretches rather than tears.

The effect of black polyethylene film on soil temperature, nutrient uptake, and upon plant maturity, growth and yield were investigated. Mulching with black polyethylene, aluminum foil, and straw were compared with cultivation.

REVIEW OF LITERATURE

The English word "mulch" has been used since the seventeenth century, and is probably derived from the German molsch, meaning soft, beginning to decay (Jacks et al. 1955). Since 1802 the practice of spreading mulch has been referred to as mulching. Rowe-Dutton (1957) mentions that the practice of mulching has been a subject of research for over half a century with several papers on the subject in the 1880's and 1890's. Considerable work was done in the late 1920's and early 1930's with the introduction of paper mulch.

Flint (1928 and 1929) mentioned that the use of asphalt paper mulch was originated in 1914 in the culture of sugarcane in the Hawaiian Islands by Eckart, and was later used for pineapple. Eckart as cited by Flint (1928) used paper mulch to control weed growth, and believed that the increase in soil temperature and moisture helped promote increased yields. By 1928, 90 percent of Hawaii's pineapple was grown with mulch. In 1924 the United States Department of Agriculture began work with paper mulches. It was found by Magruder (1930) that there was a detrimental effect due to soluble tar products in an asphalt building paper which retarded growth and distorted the leaves of vegetables. However, this effect persisted only a short time and on long season crops like cabbage and onions grown from plants, the plants recovered and produced larger crops than with cultivation. The use of a paper pulp was reported by Hamner and Rai (1954) in which waste paper is soaked and shredded and dries to a hardness of cardboard when it is applied around plants, providing adequate weed control with no harmful effects to the crops grown. Emmert (1957) reported on the use of black polyethylene and found that for mulching vegetables it gave excellent weed control. Carolus and Downes (1958) concluded that the best response to black plastic would be with a vine crop, such as muskmelon on sandy soils of poor structure during seasons of normal temperature and low rainfall where irrigation is practiced.

Jacks et al. (1955) reported that the early Roman writers appreciated the role of stones in conserving soil moisture, and Buck, cited by Jacks, found that the Chinese carry pebbles from stream beds to fields to use as a moisture conserving mulch. Harris and Yao (1923) showed that straw was more effective than manure, hay, grass, and wood shavings in conserving moisture as it absorbs or retains less moisture and forms little or no capillary system in itself. Smith (1931) in California found that soil under asphalt paper contained 14 percent moisture in the surface four inches after the dry season, as compared to 7 percent in cultivated soil. Moisture determinations were made June 20 after a potato crop had been harvested. Below four inches, moisture was low under the mulch. He observed that beads of moisture formed on the underside of the paper and that moisture

moisture

Not always

movement in the vapor phase accounted for the high moisture content at the surface in the mulched area. No irrigation was used during the study. Magruder (1930) found that at a depth of seven inches, soil under paper mulch contained more moisture than cultivated soil, although within 48 hours after a good rain, the cultivated areas had higher moisture contents. The rain did not enter the soil through the paper, but entered in the rows at the edge of the paper. Rowe-Dutton (1957) stated that mulches, by reducing evaporation, help conserve and maintain a more uniform supply of soil moisture.

Magruder (1930) and Smith (1927 and 1931) reported that dark papers gave higher daily mean soil temperatures. The maximum soil temperature occurred about two hours after the maximum air temperature; and the minimum soil temperature about one and three fourths hours after the minimum air temperature. Rowe-Dutton (1957) reported that organic mulches insulated against large soil temperature changes, with day temperature slightly lower and the night temperature slightly higher than bare soil. Dark mulches, such as asphalt paper, black plastic, and bituminous emulsion absorbed heat and increased the soil temperature, especially during sunny periods. Carolus and Downes (1958) stated that a mulch material that is darker than the soil will increase soil temperature and a mulch lighter in color than the soil will decrease soil temperature. Clarkson

(1959b) and Honma et al. (1959) reported that the maximum and minimum soil temperature was higher under a black plastic mulch.

Hartung, cited by Rowe-Dutton (1957), and Hamner and Rai (1954) reported that mulching resulted in adequate weed control, and Bushnell and Weaver (1930) stated that it took eight to ten inches of straw to obtain adequate weed control in potatoes. Rowe-Dutton (1957) reported that a primary concern in mulching may be weed control when labor is expensive and/or scarce. Carolus and Downes (1958) mentioned that an opaque material should be used to prevent light penetration and weed growth. Mulching can eliminate the harmful effects of cultivation in pruning and removing much of the surface root system of shallow laterally rooted crops. They stated that mulching reduces the amount of hand labor involved and reduces the loss due to careless cultivation and hand hoeing. The spread of disease by cultivation and from infected soil splashing on the crops can also be reduced by mulching.

The effect of mulching on soil structure was discussed by Jacks et al. (1955). Straw mulching increased the amount and size of soil aggregates, and made them more stable. Carolus and Downes (1958) stated that muskmelons may have been benefitted from mulching by protecting against temporarily hampered aeration caused by irrigation. The high oxygen requiring roots of melons are injured more than tomato roots by irrigation.

Flint (1928) reported that paper mulch increased soil temperature and moisture with increased nitrogen availability due to an increase in soil microorganism activity. Some mulches may have a detrimental effect on crops. Jacks et al. (1955) stated that mulches like straw with a high carbon-nitrogen ratio depressed nitrification. This was not caused by low ammonia supply as it was higher than in unmulched soil. If organic mulches are applied too early before the soil warms up, they may retard nitrification and reduce growth and yields. With black or white paper or acetyl-cellulose film, soil nitrification was greater than on cultivated plots. Clarkson (1959b) reported that in North Carolina black plastic mulch was effective in retaining nitrate nitrogen in the root area of soils by reducing the loss by leaching caused by rains or irrigation.

Edmond (1929) reported an increase in total yield and earliness of beans, cucumbers and sweet corn when using a paper mulch. Mulching of cabbage, tomato, and pepper resulted in an increase in total yield. Cucumbers gave the best response and sweet corn the poorest. Cucumbers on mulch seemed more resistant to certain diseases. He found no influence of mulching on the yield of lettuce, beets, or carrots. Paper mulch was found to be beneficial on warm season crops, especially during mid-summer droughts. Clarkson (1959a) states that where climatic conditions make it impossible to economically grow certain crops, it is doubtful that the use of black plastic mulches will have a marked effect on the growth of the crops. The results of Clarkson with bush beans indicated that mulching with black plastic produces a larger crop, but because of the low value of the crop it is doubtful if the increased yield would pay for the cost of mulching. However, Emmert (1957) in Kentucky, using pole beans, found that mulching gave an earlier crop and higher returns. With eggplant, the response found by Clarkson was sufficient to offset the cost of the mulch. With increased yields and decreased incidences of rot on lettuce, mulches may be economically feasible. Pickling cucumbers gave an increase in yield of 268 percent when mulched with black plastic and slicing cucumbers also gave larger early and total yields. Green peppers gave only slight yield increases, but Clarkson indicated that they may be benefitted more in cooler areas of production. Downes et al. (1959) reported that the use of black plastic mulch on green peppers resulted in increased total yields over cultivated plots.

Muskmelons

Cucurbits, according to Rowe-Dutton (1957), show more response to mulching than any other crop. This may be due partly to the shallow, lateral root system. A mulch keeps the fruit clean and helps prevent fruit and foliage diseases by preventing contact with damp soil. Emerson (1903) found that straw mulching gave earlier but smaller muskmelon fruits. Weaver and Bruner (1927) observed that the root system of muskmelon was very extensive and well-branched, spreading laterally throughout the surface four to eight inches of soil with few roots penetrating more than about twenty inches. Mulching protects and warms the surface layer of soil in which the roots grow. Carolus and Downes (1958) stated that black plastic mulch is beneficial to crops that are shallow rooted and/or have roots benefitted by higher temperatures, higher soil oxygen, or abundant moisture in the surface soil. The early and total yields at three locations in Michigan were significantly higher from plots mulched with black plastic than from cultivated plots. They found that cultivated plots did not respond to irrigation, but with black plastic and irrigation, there was a yield increase of 90 percent over cultivated plots. Clarkson (1959a) also found that muskmelon yields are readily increased by mulching with black plastic.

Tomatoes

Straw mulching, according to Emerson (1903), kept tomato fruit clean and benefitted the crop unless the mulch was applied before planting in which case early growth and yield was retarded. Soil moisture conditions are improved by mulching, tending to increase yields and reduce the amount of blossom end rot. Brunner and Weaver (1927) found that tomatoes had a deeper root system than muskmelons, and Carolus and Downes (1958) stated that possibly since the root system is not as shallow or extensive in the surface foot of soil as with muskmelons where the influence of black plastic is most pronounced. This may be an explanation for a lesser response than with melons. Rowe-Dutton (1957) reports that the results with tomatoes are variable, depending upon the location, climate, soil and type of mulch being used. Carolus and Downes (1958) reported a significant increase from black plastic mulch in total yields using Fireball tomatoes. The results with Moreton Hybrid were significant, but with a smaller increase in yields. They found that there was a difference between muskmelons and tomatoes in response to mulch with irrigation. Irrigation alone did not benefit either crop, but with mulch it increased the effect of mulching on melons but decreased the influence of mulch on tomatoes. Clarkson (1959a) reported an increase in yields and a decrease in the number of rotted and cracked tomatoes when using black plastic mulch.

MATERIALS AND METHODS

Mulching experiments were conducted in 1958 on the horticultural farm at East Lansing on a Hillsdale sandy loam soil. Before transplanting, 500 pounds of 5-20-20 per acre was broadcast and disced in the area. A starter solution of 4 pounds of 10-52-17 per 50 gallons of water was used at the rate of one-half pint per plant or hill at the time of transplanting through the plastic. The vegetables used in the experiments were tomatoes, muskmelons, cucumbers, and summer squash.

The polyethylene film (black plastic) used was either three or four feet wide, and 1.5 mils in thickness (.0015 inches). The film was pigmented with carbon to exclude light, which also increased its durability. Comparisons were made between plastic with and without slits. Four slits were cut two inches long radially ten to twelve inches from the base of the plant in order to determine whether they increased water infiltration enough to affect crop yield. Plants were also mulched with thirty inch widths of .7 mil aluminum foil on .7 mil clear polyethylene. Straw, applied three to four inches thick and four feet in width, was also used as a mulch material. Treatments of normal tractor cultivation, normal cultivation with hot tents used early in the season, and scraped rows (the surface one inch of soil scraped with a hoe to keep down weed growth) were also included in the experiments.

The black plastic was laid at the beginning of the season after the fertilizer had been broadcast, using a tractor mounted attachment designed for laying the mulch. The aluminum and straw mulches were laid by hand June 9 after all the crops had been planted.

The crops were harvested as often as was necessary to remove the fruits as they ripened. Records were made of the number and weight of both the marketable and the non-marketable fruit.

Squash (*Cucurbita pepo*)

Seneca Prolific Hybrid summer squash plants were grown in coldframes in veneer bands and planted in the field on June 5, 1958 in randomized blocks involving two replications. Plots consisted of seven hills of two plants each spaced at three-foot intervals in rows four feet apart. The complete area was irrigated when necessary during the season. The following treatments were compared.

1. Four-foot black plastic mulch
2. Thirty-inch aluminum mulch
3. Straw mulch
4. Cultivation
5. Scraping

The fruits were harvested from July 14 through August 18. The early yield was composed of the first four pickings (through July 22). On August 19, after the final harvest, the plants were removed and weighed.

Cucumbers (Cucumis sativus)

Banded Burpee Hybrid slicing cucumber plants were set in the field on June 4, 1958 in randomized blocks involving three replications. Plots consisted of twelve hills of two plants each, spaced at three-foot intervals in rows six feet apart. The entire area was irrigated when necessary during the season. The following treatments were compared:

1. Four-foot black plastic mulch
2. 30-inch aluminum mulch
3. Straw mulch
4. Cultivation
5. Scraping
6. Cultivated, plants covered with hot tents until June 21.

The fruits were harvested from July 18 through September 1, with the early yield composed of the first six harvests (through August 1). On September 1, after the final harvest, the plants were removed and weighed.

Tomatoes (Lycopersicon esculentum)

The plants were started in the greenhouse and transplanted to the coldframe in veneer bands prior to setting in the field. A split plot design was used in which irrigation versus no irrigation were the main plots and mulching treatments and varieties were the sub-plots. Ten plants of Fireball or Early Hybrid spaced two feet apart within the row, or eight plants of Moreton Hybrid spaced two and one-half feet apart within the row were placed in 20 foot rows, six feet apart. Irrigation was used on half of each area five times during the season.

The fruits were harvested from July 18 for Fireball through September 12 (in the Fireball test) or September 18 (in the variety test). Moreton Hybrid and Early Hybrid were picked from July 24 through September 25. The early yield comprised the first seven harvests (through August 19) for Fireball, and the first seven harvests (through August 28) for Moreton Hybrid and Early Hybrid. At several harvests, the fruits in both experiments were examined for "greywall" and yield records made using two categories--the first being considered as marketable fruit, the second as unmarketable. After the final harvest the plants were pulled and were weighed after the green fruits were removed.

Fireball Test:

Fireball plants were set in the field May 22, 1958 in three replications with the following treatments being compared:

1. Four-foot black plastic mulch
2. 30-inch aluminum mulch
3. Straw mulch
4. Cultivation

5. Scraping

6. Cultivated, plants covered with hot tents until June 21.

Variety Test:

Tomato plants of three varieties, Fireball, Moreton Hybrid and Early Hybrid, were planted in the field May 29, 1958 in two replications with the following treatments being compared:

1. Four-foot black plastic with starter solution
2. Four-foot black plastic with starter solution and slits
3. Four-foot black plastic with slits
4. Three-foot black plastic with slits and starter solution
5. Cultivation, with starter solution.

Muskmelons (*Cucumis melo*)

Banded muskmelon plants were set in the field June 6, 1958. A split plot design was used with irrigation versus no irrigation being the main plots and mulching treatments and varieties being the sub-plots. Six hills of two plants each were planted in 32 1/2 foot rows six feet apart. Irrigation was used on half the area five times during the season.

Honey Rock:

Three replications were used in this experiment in which the following treatments were compared:

1. Four-foot black mulch
2. 30-inch aluminum mulch
3. Straw mulch
4. Cultivation
5. Scraping
6. Cultivated, plants covered with hot tents until June 21.

The fruits were harvested from August 22 through September 22 with the early yield being made up of the first four harvests (through August 29).

Variety Test A:

Two replications were used in this experiment with the following varieties:

1. Burpee Hybrid
2. Delicious
3. Harper Hybrid
4. Harvest Queen
5. Honey Dew
6. Spartan Rock

Four-foot plastic mulch was compared with normal cultivations. The fruits were harvested from August 18 through September 22. The early yield for Burpee Hybrid, Delicious, Harper Hybrid, and Spartan Rock was through August 27, the early yield for Harvest Queen was through September 5, and for Honey Dew, September 1.

Variety Test B:

Two replications, involving three varieties, Burpee Hybrid, Delicious and Honey Rock were used in this experiment in which the following treatments were compared:

1. Four-foot black plastic mulch
2. Four-foot black plastic mulch with slits
3. Three-foot black plastic mulch with slits
4. Cultivation

The fruits were harvested from August 18 for Burpee Hybrid and Delicious, with the early yield through August 27, while with Honey Rock, harvesting began August 22 with the early yield through August 29. Harvesting ended September 22 for all three varieties.

Nutrient Studies

Analyses for nitrate nitrogen, phosphate phosphorus, potassium and magnesium were made three times during the season from fresh petiole tissue extracts. The samples were analyzed according to the methods described by Carolus (1938) and Danielson (1953).

Squash samples were taken on July 17 and August 6. A petiole from approximately half way up the stem was removed from each plant. Duplicate samples, each composed of fourteen petioles from a row of plants were taken to be tested.

Cucumber samples were taken on July 17, August 6 and August 26. A petiole from the center part of the main stem of each plant was taken. Duplicate samples each composed of twenty-four petioles from a row of plants were taken to be tested.

Tomato samples were taken from the Fireball test on all three dates mentioned above. A leaf petiole from below a fruit cluster which had not yet started to ripen was taken from each plant, using duplicate samples of petioles from ten plants from a row.

Muskmelon samples from the Honey Rock test were taken on all three dates. A leaf petiole from the center part of the main stem of each plant was taken, with duplicate samples of twelve petioles from a row analyzed.

On July 22, soil samples were taken from both the Fireball and the Honey Rock tests and analyzed for nitrate nitrogen according to the method described by Jackson (1958). Two samples taken from each row were made using a sample of the top six inches of soil as obtained with a soil sampling tube.

Temperature Measurements

Throughout the season, temperatures were recorded from a two- and a four-inch depth under the various mulches and in bare soil, using Weston dial thermometers. Twenty-four hour temperature records were made on August 21 to 22 and September 4 to 5, using ten thermocouples to measure the temperature at depths of three and six inches under the various mulches and in bare soil, and three inches above the bare ground in the shade and in the sun. The temperatures were recorded at two-hour intervals from 8:00 a. m. until 12:00 p. m., and at four-hour intervals from 12:00 p. m. until 8:00 a. m.

Climatic Conditions

The total rainfall for 1958 in East Lansing was 21. 97 inches, 9. 23 inches below the mean. During the months of May, June, July, August, and September, the rainfall was 0. 15, 3. 73, 4. 42, 2. 58 and 1. 80 inches for a total of 12. 68 inches, as compared to a mean of 3. 72, 3. 36, 2. 72, 2. 85 and 2. 90 inches for a total of 15. 55 inches.

The average temperatures in 1958 for May, June, July, August and September were 55. 5, 61. 0, 69. 0, 69. 5 and 61. 0°F, respectively, as compared to a mean of 56. 5, 66. 1, 71. 0, 69. 9 and 61. 9°F.

RESULTS

Squash

The comparative effects of mulching and cultivation on summer squash are shown in Table I. Black plastic gave the highest yields of squash - 530 bushels per acre at mid-season and 1067 bushels at the end of the harvest period, both of which were significantly higher than normal cultivation, which gave early and total yields of 188 and 675 bushels, respectively. Aluminum mulch was second to black plastic with early and total yields of 398 and 907 bushels, the early yield being significantly higher than from cultivation. Straw mulch and scraping did not significantly affect the yields of squash, as compared to cultivation.

Figure 1 shows that the magnitude of difference between the yield of squash grown with black plastic and cultivation became greater as the season progressed, while the yield obtained using straw mulch remained only slightly lower than that from cultivation. Black plastic resulted in an increased yield of 182 percent for early yield and 58 percent for total yield over normal cultivation.

The average weight per fruit from the use of black plastic, aluminum, or straw mulch was .739, .736 and .727 pounds, respectively, while cultivation and scraping gave fruits of .672 and .719 pounds, respectively. Since at harvest time all fruits were picked down to the same size, it would appear

TABLE I

Effects of Mulching Practices on the Yield and Growth of Seneca Prolific Hybrid Summer Squash*
(Marketable Yield in 45 Pound Bushels per Acre)

Harvest Period	Plastic	Aluminum	Straw	Cultivated	Scraped
Early (July 14 to 22)	530	398	154	188	243
Late (July 25 to August 18)	537	509	484	487	510
Total	1,067	907	638	675	753
Average weight/fruit (lbs)	0.74	0.74	0.73	0.67	0.72
Vine weight**	14.8	13.7	13.5	11.1	11.3

	Early yield	Total yield	Vine weight
L.S.D. .05	173 bu.	240 bu.	2.55 tons
L.S.D. .01	286 bu.	397 bu.	N.S.

*Two replicates
**Weighed August 18 (in tons per acre)

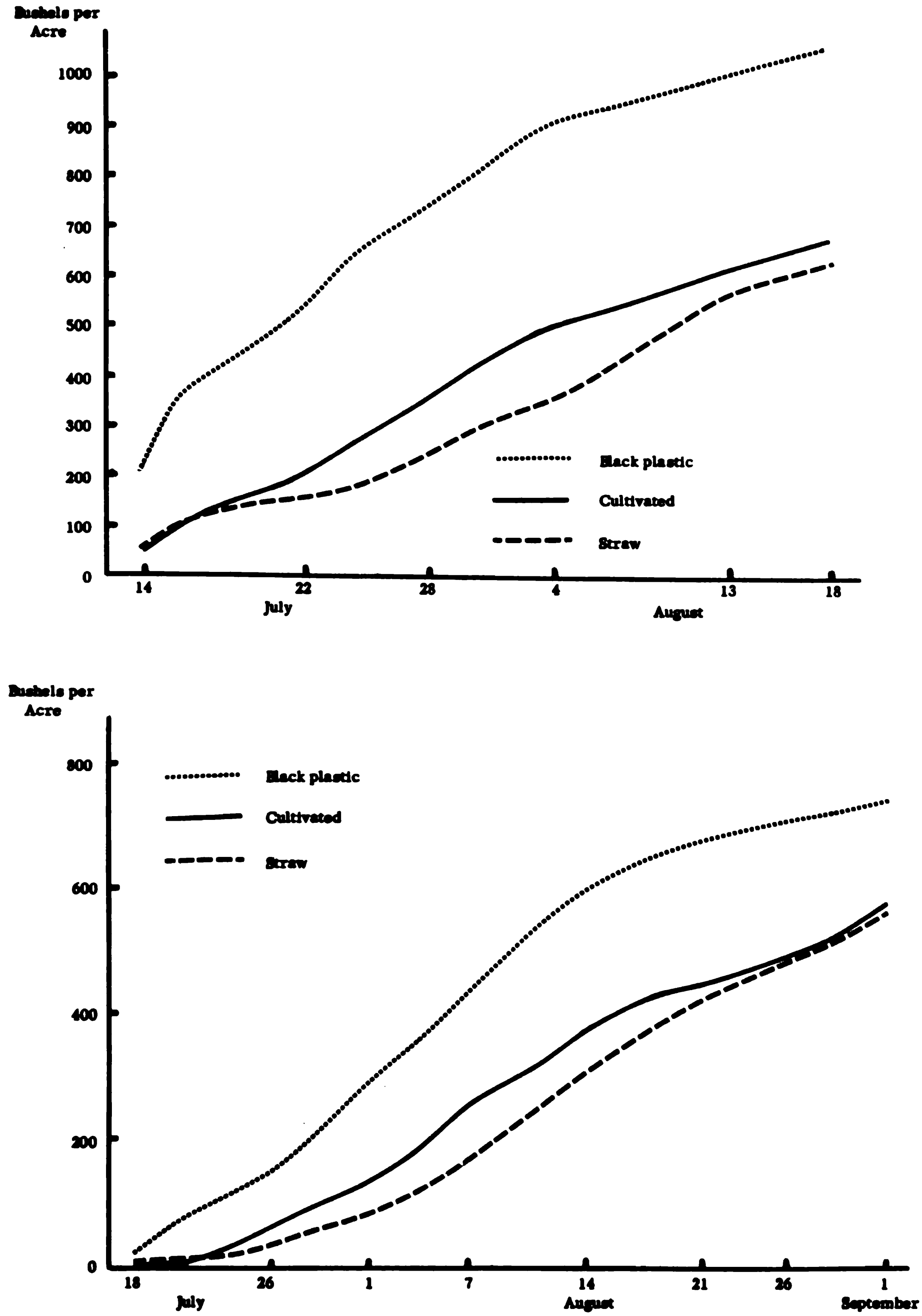

Figure 1. The effect of mulching practices on the cumulative yield. (Upper) Seneca Prolific Hybrid summer squash. (Lower) Burpee Hybrid slicing cucumbers.

that mulching increased the rate of growth of the fruits.

Leaf measurements, made of the width of the third true leaf of each plant after they had been in the field 21 days, indicated that with mulching, the plants grew larger. The average width of leaves was 15.4, 13.3 and 12.9 centimeters, respectively, from black plastic, aluminum and straw, as compared to 10.8 and 11.9 centimeters for cultivated and scraped plots. Figure 2 shows that plants grew larger and yielded more when black plastic and aluminum mulches were compared to cultivation, scraping and straw. The fresh vine weight of plants grown with black plastic was significantly larger (14.8 tons per acre) than plants grown with normal cultivation (11.1 tons per acre) as shown in Table I. Plants grown with aluminum and straw mulch also had larger fresh vine weights than with cultivation (13.7 and 13.5 tons per acre, respectively).

Cucumbers

Slicing cucumbers responded favorably to mulching, especially in early yield. Black plastic, aluminum, and hot tents, with early yields of 289, 233 and 168 bushels per acre, gave significantly higher yields than cultivation, with 128 bushels, while straw with 79 bushels was significantly lower than from cultivated plots, Table II. No significant treatment differences were obtained in the total yield of cucumbers. Figure 1 shows that the magnitude of the difference between the yield of cucumbers grown with black plastic

Figure 2. The effect of mulching practices on vine growth and yield (first two harvests) of squash. (Upper) - P, Black plastic; C, Cultivated; St, Straw. (Lower) A, Aluminum; S, Scraped.
(Photographed July 18)

TABLE II

Effect of Mulching Practices on the Yield and Growth of Burpee Hybrid Cucumber*
(Marketable Yield in 48 Pound Bushels per Acre)

Harvest Period	Plastic	Aluminum	Straw	Cultivation	Scraped	Hot Tents
Early (July 18 to Aug. 1)	289	233	79	128	104	168
Late (Aug. 4 to Sept. 1)	451	471	485	450	468	535
Total	740	704	563	578	572	703
Average weight/fruit (lbs)	0.65	0.62	0.64	0.62	0.61	0.64
Vine weight**	1.38	1.39	1.19	1.30	1.43	1.48

	Early yield	Total yield	Vine weight
L. S. D. .05	37 bu.	191 bu.	.34 tons
L. S. D. .01	52 bu.	N. S.	N. S.

*Three replicates
**Weighed September 2 (in tons per acre)

and cultivation became greater as the season progressed, although the percent increase declined; and the total yield from straw mulch was not greatly different from that obtained with normal cultivation. The percent increase in yield from black plastic was 126 for early yield and 28 for total yield, showing that the mulch had its greatest effect in increasing early yield.

Measurements of the width of the second true leaf of the plants, made when the plants had been in the field 21 days, indicated that hot tents, black plastic and straw resulted in increased size of leaves over leaves from plants grown with normal cultivation. Figure 3 shows that plants grew larger when black plastic and aluminum mulches were used as compared to cultivation, scraping, and hot tents. Plants growing with straw mulch were smaller than those in cultivated plots. As shown in Table II, there was no significant difference in fresh vine weight of plants between mulching and cultivation treatments, but straw mulching resulted in the lowest weight (1.19 tons per acre) and hot tents gave the highest weight (1.48 tons per acre).

Tomatoes

The 1958 season was very satisfactory for growing tomatoes. In experiments with tomatoes, the yields were high. Irrigated Moreton Hybrid grown on four-foot black plastic with starter solution and slits at a spacing of six by two feet had a total yield of 71 tons per acre of which 62 tons were

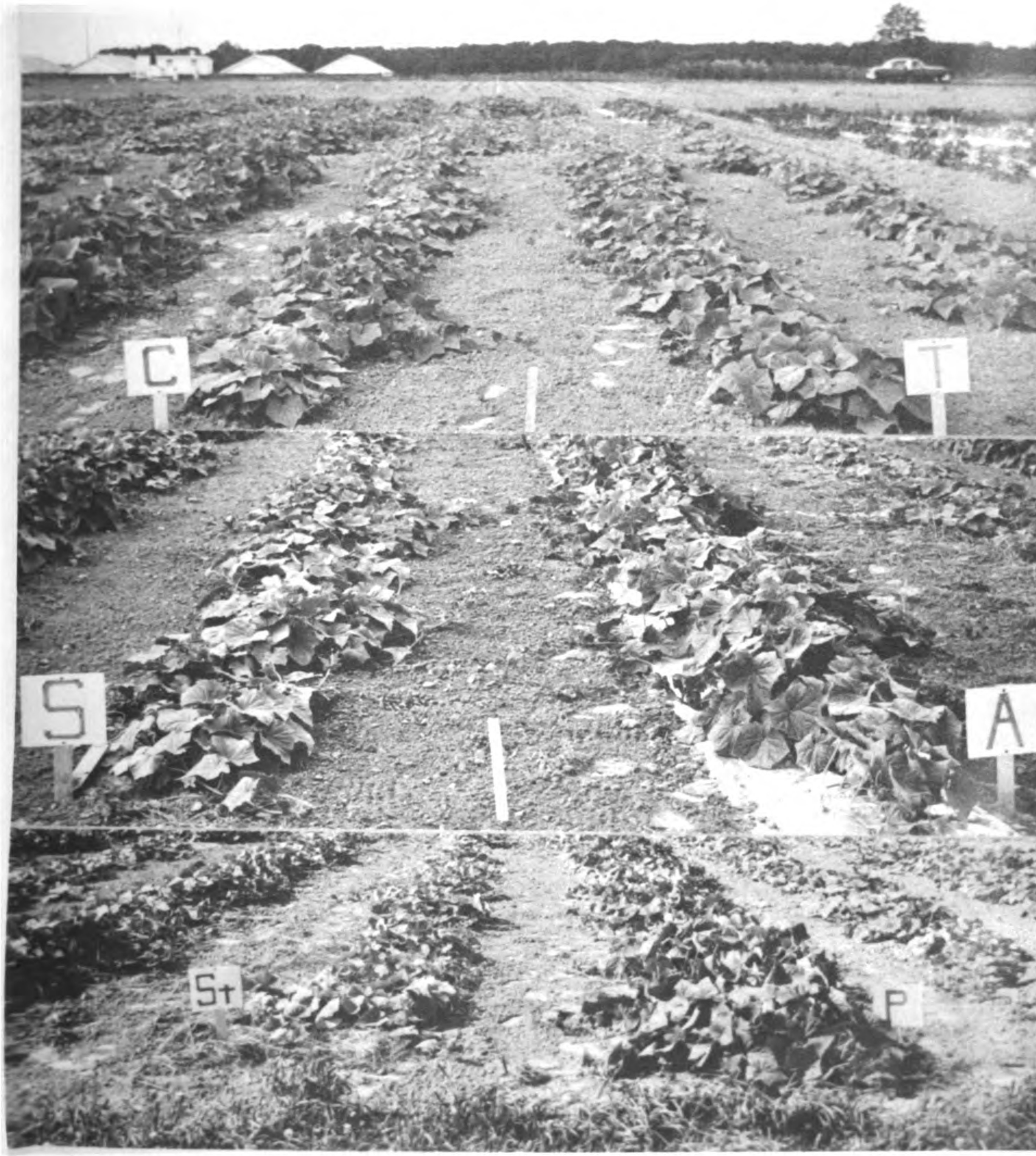

Figure 3. The effect of mulching practices on vine growth of slicing cucumbers. (Upper) - C, Cultivated; T, Hot Tents. (Center) - S, Scraped; A, Aluminum. (Lower) - St, Straw; P, Black Plastic.

(Photographed July 18)

marketable. The total yield in cultivated plots of irrigated Moreton Hybrid was 59 tons per acre of which 54 tons were marketable.

There was also a very high incidence of "greywall", a disorder that affects the tomato fruits by causing a necrotic breakdown of parenchyma cells under the epidermis of the fruits. "Greywall" affected approximately 30 percent of the fruits harvested, but there was no difference in the incidence between treatments.

Fireball Test:

As shown in Table III, black plastic, aluminum, straw and hot tents resulted in significantly higher yields over cultivation, although with irrigation, black plastic did not increase the yield. Straw and hot tents resulted in the largest early yields - 746 and 740 bushels per acre, respectively, as compared to 623 bushels for cultivation. The early yield response to black plastic and straw was significantly greater without irrigation, while with hot tents, the response was better with irrigation.

Black plastic as compared to cultivation, increased the early yield by 14 percent and the total yield by 28 percent. Black plastic and straw without irrigation resulted in significantly higher total yields - 1, 374 and 1, 408 bushels per acre, respectively, as compared to 1, 082 (irrigated) and 1, 132 bushels (non-irrigated) for cultivated plots.

Straw mulching resulted in slightly larger fruits than cultivation and hot tents resulted in smaller fruits. There was little measurable difference

TABLE III

Effect of Mulching Practices and Irrigation on the Yield and Growth of Fireball Tomato*
(Marketable Yield in 56 Pound Bushels per Acre)

Harvest Period	Plastic	Aluminum	Straw	Cultivation	Scraped	Hot Tents	Average
Irrigated							
Early (July 18 to Aug. 19)	633	670	698	629	565	766	660
Total (July 18 to Sept. 12)	1452	1116	1317	1082	995	1240	1200
Non-irrigated							
Early	702	681	789	617	567	713	678
Total	1374	1271	1408	1132	1180	1216	1264
Average							
Early	667	676	746	623	566	740	669
Late	1415	1194	1363	1107	1087	1228	1232
Weight/fruit (lbs)	0.28	0.27	0.29	0.28	0.27	0.26	0.28
Plant weight**	5.49	4.26	4.28	3.51	3.82	3.94	4.22

	Irrigation x Treatment		Treatment Averages		Plant Weight
	Early	Total	Early	Total	
L.S.D. .05	33 bu.	267 bu.	24 bu.	189 bu.	1.15 tons
L.S.D. .01	45 bu.	363 bu.	32 bu.	257 bu.	1.57 tons

*Three replicates
**Weighed September 15 (in tons per acre)

in the size of fruit from plastic mulched plots and cultivated plots, while scraping and aluminum resulted in slightly smaller fruits than did cultivation.

Measurements of plant diameter and height made one month after field planting indicated that the plants grew largest when hot tents were used, followed by black plastic, straw, aluminum, cultivation, and scraping in that order. There was little measurable difference in the size of plants growing with aluminum, cultivation, or scraping treatments. Figure 4 shows that there was little difference in the size of plants on July 18 when the first harvest was made. Black plastic resulted in significantly larger fresh plant weights than obtained with cultivation at the end of the harvest season, as shown in Table III. The use of aluminum and straw mulches resulted in only slightly larger plants than cultivation.

Variety Test:

In this test, the Fireball tomato plants used were one week older than those in the previous test when planted in the field. As shown in Table IV, A four-foot black plastic with starter solution; with slits; and with starter solution plus slits resulted in early yields of 532, 470 and 529 bushels per acre respectively, all of which were significantly higher than cultivation with 362 bushels. The yield on three-foot plastic with slits, 433 bushels per acre, was not significantly higher than cultivation. The percent increase of four-foot plastic over cultivation was 47 for early yield, and 133 for total yield.

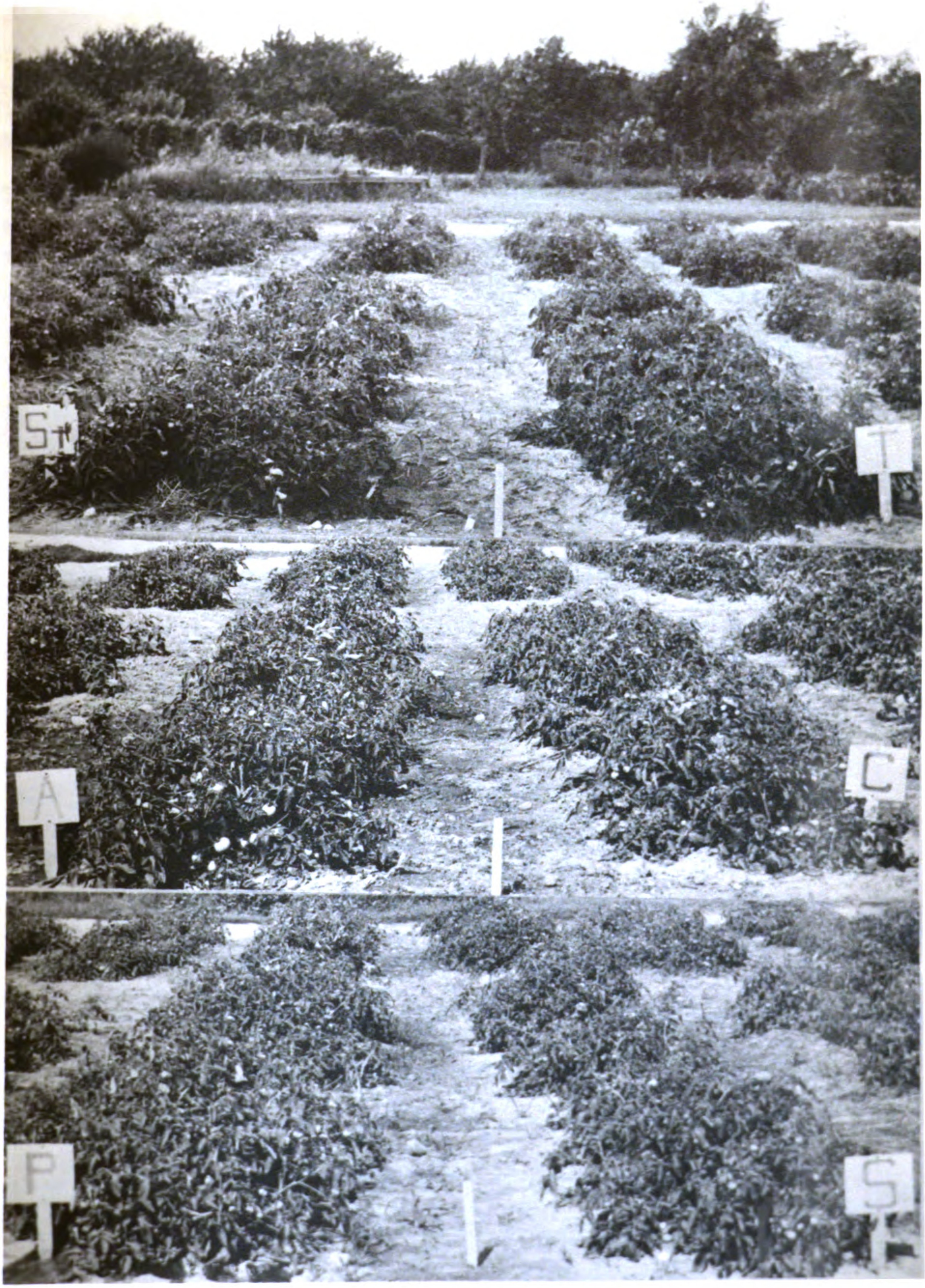

Figure 4. The effect of mulching practices on plant growth of Fireball tomatoes. (Upper) - St, Straw; T, Hot Tents. (Center) - A, Aluminum; C, Cultivated. (Lower) - P, Black Plastic; S, Scraped.

(Photographed July 18)

Four-foot plastic with starter solution; with slits; and with starter solution plus slits, resulted in total yields of 1, 176, 1, 053 and 1, 092 bushels per acre, which were significantly higher than cultivation with 506 bushels. Three-foot plastic with slits (890 bushels) was also significantly higher than cultivation. In this experiment, irrigation proved to be beneficial for Fireball. Four-foot plastic resulted in a significantly higher increase in plant weight at the end of the harvest season, while three-foot plastic resulted in a smaller increase over cultivation.

There was a significant increase in early yield over cultivation with the use of black plastic mulch on Early Hybrid tomatoes as shown in Table IV-B. Four-foot black plastic resulted in an increase of 51 percent for early yield and 28 percent for total yield. Both three- and four-foot widths of black plastic resulted in significantly higher total yields. Irrigation significantly increased the total yield of Early Hybrid. Both widths of black plastic resulted in highly significant increases over cultivation in the plant weight at the end of the harvest season.

As shown in Table IV-C, black plastic did not significantly increase the yield, either early or total, of Moreton Hybrid tomatoes. Four-foot black plastic resulted in an increase of 24 percent over cultivation in the early yield and only 11 percent in the total yield. Irrigation significantly increased the total yield over non-irrigated tomatoes. Both the three- and four-foot widths of black plastic significantly increased the plant weight at the end of the harvest season over cultivation.

TABLE IV

Effect of Mulching Practices and Irrigation on the Growth and Yield of Three Varieties of Tomato*
(Marketable Yields in 56 Pound Bushels per Acre)

Harvest Period	4 ft. Plastic + Starter Solution	4 ft. Plastic + Slits + Starter Solution	4 ft. Plastic + Slits	3 ft. Plastic + Slits + Starter Solution	Cultivated + Starter Solution	Average
			A: Fireball			
Irrigated						
Early (July 18 to Aug. 19)	566	595	563	421	393	508
Total (July 18 to Sept. 18)	1252	1211	1300	895	528	1037
Non-irrigated						
Early	498	464	377	446	331	423
Total	1101	974	806	885	484	850
Average						
Early	532	529	470	433	362	465
Total	1176	1029	1053	890	506	943
Average weight/fruit (lbs)	0.27	0.29	0.27	0.27	0.27	0.27
Plant weight**	2.18	1.98	1.62	1.31	0.56	1.53

	Irrigation x Treatment Early	Irrigation x Treatment Total	Treatment Averages Early	Treatment Averages Total	Plant Weight
L.S.D. .05	190 bu.	337 bu.	134 bu.	238 bu.	0.85 tons
L.S.D. .01	N.S.	484 bu.	N.S.	342 bu.	1.22 tons

*Two replicates
**Weighed September 26 (in tons per acre)

TABLE IV CONT'D

Harvest Period	4 ft. Plastic + Starter Solution	4 ft. Plastic + Slits + Starter Solution	4 ft. Plastic + Slits	3 ft. Plastic + Slits + Starter Solution	Cultivated + Starter Solution	Average
		B: Early Hybrid				
Irrigated						
Early (July 24 to Aug. 28)	977	862	1017	927	615	880
Total (July 24 to Sept. 25)	1931	1818	1911	1784	1454	1780
Non-irrigated						
Early	803	898	821	881	641	809
Total	1427	1578	1495	1526	1201	1445
Average						
Early	890	880	919	904	628	844
Total	1679	1698	1703	1655	1327	1612
Average weight/fruit (lbs)	0.29	0.28	0.28	0.28	0.27	0.28
Plant weight*	8.12	8.31	7.79	7.36	4.55	7.19

	Irrigation x Treatment		Treatment Averages		Plant Weight
	Early	Total	Early	Total	
L.S.D. .05	369 bu.	440 bu	261 bu.	311 bu.	1.42 tons
L.S.D. .01	N.S.	N.S.	N.S.	N.S.	2.05 tons

*Weighed September 26 (in tons per acre)

TABLE IV CONT'D

Harvest Period	4 ft. Plastic + Starter Solution	4 ft. Plastic + Slits + Starter Solution	4 ft. Plastic + Slits	3 ft. Plastic + Slits + Starter Solution	Cultivated + Starter Solution	Average
		C: Morton Hybrid				
Irrigated						
Early (July 24 to Aug. 28)	810	606	814	745	642	723
Total (July 24 to Sept. 25)	2109	2226	1790	1983	1924	2006
Non-irrigated						
Early	782	846	855	693	627	761
Total	1866	1694	1770	1612	1509	1690
Average						
Early	796	726	834	719	635	742
Total	1988	1960	1780	1797	1717	1844
Average weight/fruit (lbs)	0.38	0.39	0.38	0.38	0.40	0.39
Plant weight*	7.88	7.68	7.48	6.75	5.06	6.97

	Irrigation x Treatment		Treatment Averages		Plant Weight
	Early	Total	Early	Total	
L.S.D. .05	N.S.	N.S.	213	N.S.	1.16 tons
L.S.D. .01	N.S.	N.S.	N.S.	N.S.	1.67 tons

*Weighed September 26 (in tons per acre)

Muskmelons

The 1958 season was a poor year for muskmelons. The average temperatures during June and July were below normal, especially during June when the temperature averaged 5.1°F below normal. Infestations of powdery mildew and cucumber mosaic were heavy at the horticultural farm, resulting in premature death of the plants and reduced yields.

Honey Rock Test:

As shown in Table V, black plastic and aluminum mulches, with early yields of 230 and 116 bushels per acre, respectively, were significantly higher than cultivation with 80 bushels per acre. Straw mulch retarded the growth of muskmelons and resulted in no early yield. Hot tents did not increase the early yield enough to be significant.

Black plastic and aluminum mulches significantly increased the total yields of marketable melons, with 419 and 304 bushels per acre, respectively, as compared to 193 bushels for cultivation. Straw mulch, with 109 bushels, significantly decreased the total yield under that of cultivated and also decreased the average size of the fruit produced.

There was no difference in yield from irrigation. Yields on black plastic and with hot tents were greater with irrigation, while yields were greater with aluminum and straw without irrigation.

Figure 5 shows that plants on black plastic developed more rapidly than

TABLE V

Effect of Mulching Practices and Irrigation on Yield of Honey Rock Muskmelon*
(Marketable Yields in 50 Pound Bushels per Acre)

Harvest Period	Plastic	Aluminum	Straw	Cultivated	Scraped	Hot Tents	Average
Irrigated							
Early (Aug. 22 to Aug. 29)	233	104	0	79	63	109	98
Total (Aug. 22 to Sept. 22)	448	255	98	199	193	257	242
Non-irrigated							
Early	228	128	0	80	62	86	97
Total	390	349	119	186	193	225	244
Average							
Early	230	116	0	80	63	98	98
Total	419	304	109	193	193	241	243
Average weight/fruit (lbs)	2.28	2.22	1.90	2.21	2.30	2.28	2.20

	Irrigation x Treatment		Treatment Averages	
	Early	Total	Early	Total
L.S.D. .05	46 bu.	71 bu.	33 bu.	50 bu.
L.S.D. .01	63 bu.	96 bu.	45 bu.	68 bu.

*Three replicates

Figure 5. The effect of mulching practices on plant growth of Honey Rock musk-melons. (Upper) - A, Aluminum; P, Black Plastic. (Center) - C, Cultivated; S, Scraped. (Lower) - St, Straw; T, Hot Tents.

(Photographed July 18)

those grown with normal cultivation. Hot tents and aluminum mulch also resulted in larger plants, while the growth of plants on straw was retarded.

Variety Test A:

Table VI shows that all six varieties of muskmelons used in this test produced significantly higher early and total yields on black plastic than with cultivation. Irrigation did not increase yields, but in some cases, depressed yields. Burpee Hybrid, Delicious, Harper Hybrid, Honey Dew and Spartan Rock all had higher yields without irrigation, while Harvest Queen on black plastic resulted in higher yields with irrigation.

There was little difference in the size of fruit between mulching and cultivation. The largest difference was with Spartan Rock in which fruit on black plastic averaged 1.59 pounds, and those in cultivated plots averaged 1.38 pounds.

Figure 6 shows the growth response of Honey Dew, Burpee Hybrid, and Delicious to mulching. Burpee Hybrid and Honey Dew responded more to mulching than did Delicious, although there was a noticeable difference in size of plants in all varieties with and without black plastic mulch.

Variety Test B:

Table VII-A shows that the early and total yield of Delicious melons on four-foot black plastic was significantly higher than on cultivated plots. The early, but not the total yield, on three-foot black plastic was significantly higher than with cultivation. Irrigation did not increase yields - with four-

TABLE VI

Effect of Plastic Mulch and Irrigation on Yield of Melon Varieties*
(Marketable Yields in 50 Pound Bushels per Acre)

Variety and Harvest Period	Irrigated		Non-Irrigated		Average Yield		Average Weight per Fruit (lbs)	
	Plastic	Cultivated	Plastic	Cultivated	Plastic	Cultivated	Plastic	Cultivated
Burpee Hybrid								
Early (Aug. 18 to Aug. 27)	319	23	314	152	316	87		
Total (Aug. 18 to Sept. 22)	433	180	448	295	441	238	2.70	2.61
Delicious								
Early (Aug. 18 to Aug. 27)	398	139	427	159	412	150		
Total (Aug. 18 to Sept. 22)	491	297	512	273	502	285	2.48	2.38
Harper Hybrid								
Early (Aug. 18 to Aug. 27)	165	45	311	64	238	55		
Total (Aug. 18 to Sept. 22)	499	322	523	276	511	299	2.57	2.59
Harvest Queen								
Early (Aug. 29 to Sept. 5)	252	93	246	56	249	74		
Total (Aug. 29 to Sept. 22)	446	217	373	335	410	276	2.73	2.83
Honey Dew								
Early (Sept. 1 to Sept. 8)	167	49	106	24	136	37		
Total (Sept. 1 to Sept. 22)	344	178	358	199	353	189	2.70	2.66
Spartan Rock								
Early (Aug. 18 to Aug. 27)	219	22	266	75	243	48		
Total (Aug. 18 to Sept. 22)	298	70	333	138	315	104	1.59	1.38
Average of Varieties								
Early	253	62	278	88	266	75		
Total	419	211	425	253	422	232	2.46	2.41

	Irrigation x Treatment Averages		Irrigation x Treatment within Variety		Treatment within Varieties	
	Early	Total	Early	Total	Early	Total
L. S. D. .05	41 bu.	65 bu.	101 bu.	160 bu.	72 bu.	112 bu.
L. S. D. .01	56 bu.	89 bu.	138 bu.	217 bu.	97 bu.	152 bu.

*Two replicates

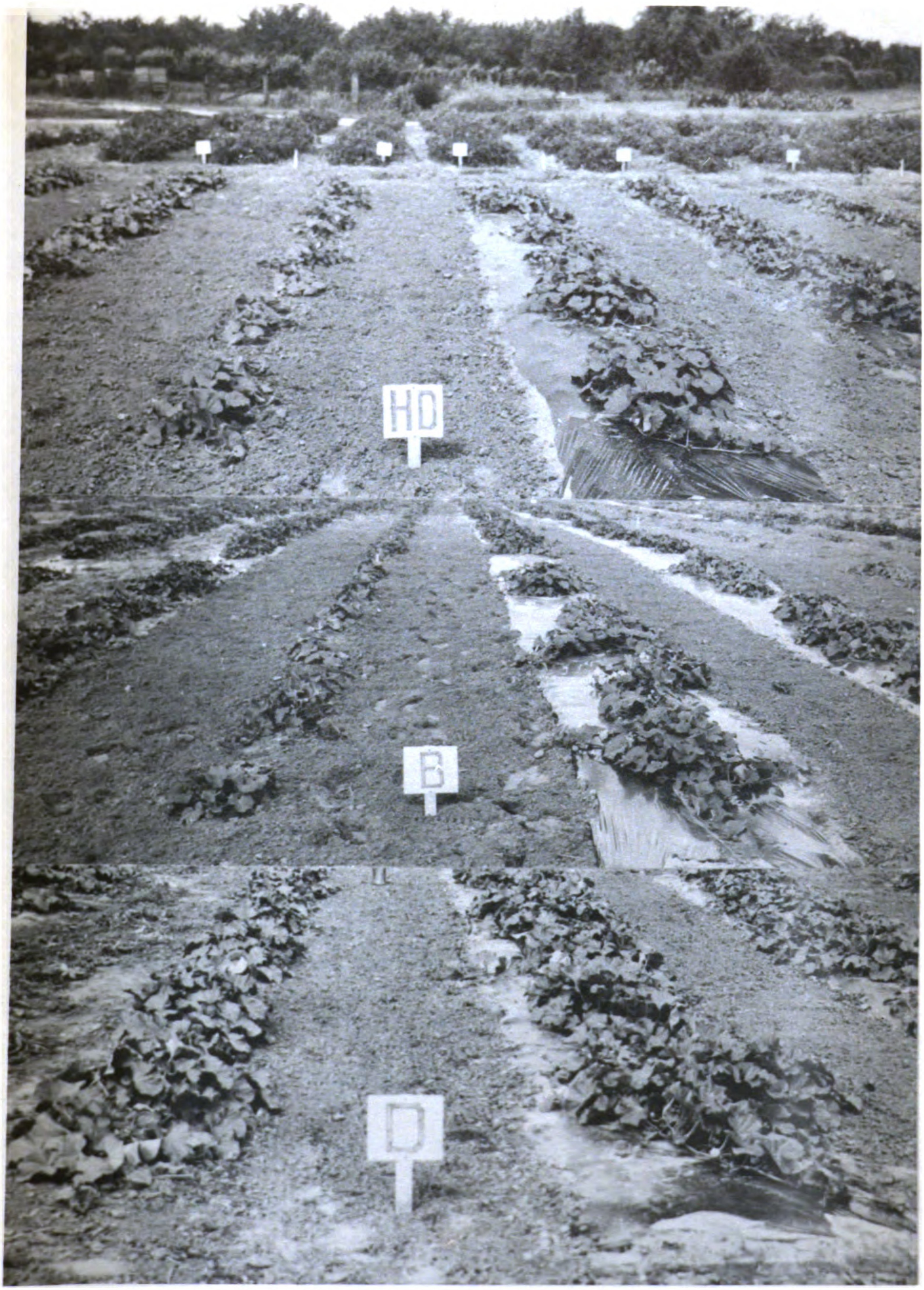

Figure 6. The effect of plastic mulch on plant growth of melon varieties.
(Upper) - H. D., Honey Dew. Left, cultivated; right, plastic mulch.
(Center) - B, Burpee Hybrid. Left, cultivated; right, plastic mulch.
(Lower) - D, Delicious. Left, cultivated; right, plastic mulch.
(Photographed July 18)

foot plastic and no slits, the yield was slightly higher without irrigation, while with three- and four-foot plastic with slits and cultivation, the yield was slightly higher with irrigation. Melons from cultivated plots were slightly larger than from mulched plots, with the melons from three-foot plastic being the smallest.

Burpee Hybrid muskmelons, as shown in Table VII-B produced yields on black plastic that were significantly higher than with cultivation. Both early and total yields were increased by the use of the mulch. Irrigation reduced the yields slightly with three- and four-foot plastic and cultivation, but slightly increased the yield on four-foot plastic with slits. There was little difference in the size of fruit, except with four-foot plastic with slits where the size was slightly reduced.

The early yield of Honey Rock with four-foot plastic was significantly higher than normal cultivation, although there was no significant difference with the use of three-foot plastic (Table VII-C). Both three- and four-foot plastic significantly increased the yield over cultivation. Four-foot plastic and cultivation resulted in slightly smaller melons.

Nutrient Studies

Table VIII shows the effect of mulching on the nutrient level in squash leaf petioles. On July 17, the nitrate nitrogen level in plants grown on straw was much lower than from any of the other plots, while the phosphate phosphorus level was very high. On August 7, the nitrate level of plants on straw plots

TABLE VII

Effect of Plastic Mulching and Irrigation on Yields of Three Varieties of Muskmelon*
(Marketable Yields in 50 Pound Bushels per Acre)

Harvest Period	4 ft. Plastic	4 ft. Plastic + Slits	3 ft. Plastic + Slits	Cultivated	Average
		A: Delicious			
Irrigated					
Early (Aug. 18 to Aug. 27)	399	455	190	70	279
Total (Aug. 18 to Sept. 22)	479	532	367	356	434
Non-irrigated					
Early	394	408	207	111	280
Total	498	474	360	303	409
Average Yield					
Early	397	431	198	90	279
Total	488	503	363	329	421
Average weight/fruit (lbs.)	2.51	2.62	2.43	2.72	2.57

	Irrigation x Treatment Early	Irrigation x Treatment Total	Average Treatment Early	Average Treatment Total
L.S.D. .05	80 bu.	86 bu.	56 bu.	61 bu.
L.S.D. .01	117 bu.	127 bu.	83 bu.	90 bu.

*Two replicates

TABLE VII CONT'D

Harvest Period	4 ft. Plastic	4 ft. Plastic + Slits	3 ft. Plastic + Slits	Cultivated	Average
		B: Burpee Hybrid			
Irrigated					
Early (Aug. 18 to Aug. 27)	277	273	224	71	211
Total (Aug. 18 to Sept. 22)	457	448	372	207	371
Non-irrigated					
Early	394	334	252	125	276
Total	510	432	382	267	398
Average Yield					
Early	336	304	238	98	244
Total	484	440	377	237	385
Average weight/fruit (lbs.)	2.87	2.46	2.78	2.89	2.75

	Irrigation x Treatment Early	Irrigation x Treatment Total	Average Treatment Early	Average Treatment Total
L. S. D. .05	112 bu.	88 bu.	79 bu.	62 bu.
L. S. D. .01	166 bu.	130 bu.	117 bu.	92 bu.

*Two replicates

TABLE VII CONT'D

Harvest Period	4 ft. Plastic	4 ft. Plastic + Slits	3 ft. Plastic + Slits	Cultivated	Average
		C: Honey Rock			
Irrigated					
Early (Aug. 22 to Aug. 29)	172	138	107	60	119
Total (Aug. 22 to Sept. 12)	376	360	268	254	318
Non-irrigated					
Early	214	189	117	86	152
Total	402	323	326	175	307
Average Yield					
Early	195	163	112	73	136
Total	389	342	297	214	311
Average weight/fruit (lbs.)	2.72	2.63	2.57	2.54	2.62

	Irrigation x Treatment		Average Treatment	
	Early	Total	Early	Total
L.S.D. .05	97 bu.	113 bu.	69 bu.	80 bu.
L.S.D. .01	144 bu.	166 bu.	101 bu.	117 bu.

*Two replicates

had increased and the phosphate level had decreased to approximately the same level as in plants from the other plots.

The potassium level was high in plants from straw and cultivated plots and low in black plastic and aluminum plots on July 17. On August 7, the potassium level in plants on black plastic was lowest, but had decreased in straw and cultivated plots to approximately the same level as aluminum.

The magnesium level in plants on black plastic and aluminum was higher than straw and cultivated plots on July 17, but on August 7, the magnesium values had become approximately the same.

As shown in Table IX, the nitrate nitrogen level in cucumber leaf petioles was lower in plants grown on straw than other treatments - black plastic, aluminum and cultivation. The phosphate phosphorus level was very high in plants grown on straw mulch when tested July 17 but by August 7, had dropped considerably, but was still higher than in plants from the other treatments. On August 26, there was very little difference in the phosphate level of the plants from any of the treatments.

The potassium level was lower in plans from the black plastic and aluminum mulched plots than from straw mulch with the potassium level in plants from cultivated plots being the highest. On August 7, the potassium content was highest in straw plots, followed by cultivated and black plastic with aluminum plots having the lowest potassium content in the plants. Black plastic plots had the highest potassium content in plants on August 26,

TABLE VIII

Influence of Mulching Practices on Nutrient Level in Summer Squash Leaf Petioles (Expressed in parts per million Fresh Weight)

	Plastic	Aluminum	Straw	Cultivated
Nitrate - N				
July 17	443	533	288	623
Aug. 7	391	652	433	490
Phosphate - P				
July 17	77	80	203	80
Aug. 7	89	93	85	77
Potassium				
July 17	2075	3050	4575	4550
Aug. 7	2100	2700	3350	2750
Magnesium				
July 17	2350	2050	1100	1550
Aug. 7	1400	1550	1200	1350

TABLE IX

Influence of Mulching Practices on Nutrient Level in Cucumber Leaf Petioles (Expressed in parts per million Fresh Weight)

	Plastic	Aluminum	Straw	Cultivated
Nitrate - N				
July 17	890	838	235	883
Aug. 7	618	708	556	804
Aug. 26	569	358	300	513
Phosphate - P				
July 17	84	64	294	64
Aug. 7	31	33	80	32
Aug. 26	53	48	44	54
Potassium				
July 17	3300	3275	4550	5250
Aug. 7	4600	4150	5100	4650
Aug. 26	5238	3938	4750	4825
Magnesium				
July 7	1800	2250	2250	2250
Aug. 7	1350	1500	1550	1450
Aug. 26	2050	2250	2150	2100

followed by cultivated, straw, and aluminum mulch plots in that order.

The magnesium level in the plants was highest on aluminum mulch, straw mulch, and cultivated, with black plastic mulched cucumber plants having the lowest magnesium content in plants from the different treatments on August 7 and 26.

Table X shows that the nitrate nitrogen level in Fireball tomato leaf petioles decreased after July 17 with all treatments used. On July 17, the nitrogen level was highest in plants grown on black plastic with straw mulched plots being intermediate and cultivated and aluminum mulched plots being lowest. On August 7, plants on aluminum mulch had the lowest nitrogen level on August 26 with cultivated plots having the highest.

The phosphate level was highest in plastic mulched plots and lowest in cultivated plots on July 17 while on August 7 the phosphorus level was lowest in plastic mulched plots and highest in straw plots. On August 26, black plastic mulched and cultivated plots had the lowest phosphorus level, followed by straw plots with aluminum mulched plots having the highest phosphorus level.

On July 17 the potassium level in the tomato plants was highest in cultivated plots, followed by aluminum mulch, plastic mulch, and straw. On August 7 cultivated plots were still highest, with straw, aluminum, and plastic mulch following in that order, while on August 26, black plastic mulched plants had the lowest potassium content, with no difference between the other treatments.

There was little difference in the magnesium content of plants as measured on July 17 and August 26, but on August 7 the content was lowest in black plastic plots with no difference between the other treatments.

Table XI shows that the nitrate nitrogen content of muskmelon leaf petioles was highest in plastic mulched plots on July 17, followed in order by cultivated and aluminum mulched plots with straw mulched plots having the lowest concentration of nitrogen in the plants. Because of the low nitrate level in the plants mulched with straw, half of each straw plot was side-dressed with ammonium nitrate at the rate of 200 pounds per acre on July 29 and separate tissue tests run from both the side-dressed and the non-side-dressed parts of the straw mulched plots. On August 7 cultivated plots had the highest nitrogen level, followed by straw with side-dressing, aluminum mulch, plastic mulch and straw with no side-dressing. Straw plots with side-dressing had the highest nitrate level on August 26, followed by cultivated, aluminum mulch, plastic mulch and straw mulch without side-dressing.

Plants grown with straw mulch without side-dressing had the highest phosphate phosphorus level throughout the summer, with aluminum mulched plots having the lowest level. On August 7, side-dressed straw plots had a higher phosphate level than plastic and aluminum mulched or cultivated plots while on August 26, the phosphate level in side-dressed straw plots was approximately the same as cultivated plots.

Plants grown on black plastic mulch had the lowest potassium level on

TABLE X

Influence of Mulching Practices on Nutrient Level in Fireball Tomato Leaf Petioles
(Expressed in parts per million Fresh Weight)

	Plastic	Aluminum	Straw	Cultivated
Nitrate - N				
July 17	875	603	708	628
Aug. 7	488	299	549	579
Aug. 26	270	300	195	418
Phosphate - P				
July 17	395	310	295	157
Aug. 7	60	102	115	84
Aug. 26	39	58	47	41
Potassium				
July 17	2200	2700	1875	3200
Aug. 7	2000	2475	2800	3675
Aug. 26	2138	3000	3000	2950
Magnesium				
July 17	3100	2900	2900	3100
Aug. 7	1450	1700	1650	1750
Aug. 26	2450	2500	2500	2500

TABLE XI

Influence of Mulching Practices on Nutrient Level in Leaf Petioles of Honey Rock Muskmelon
(Expressed in parts per million Fresh Weight)

	Plastic	Aluminum	Straw		Cultivated
			No added nitrogen	Side dressed* 200 lbs. NH_4NO_3	
Nitrate - N					
July 17	1135	933	113	-	970
Aug. 7	507	618	162	723	855
Aug. 26	335	373	278	1008	598
Phosphate - P					
July 17	65	53	178	-	73
Aug. 7	30	15	96	55	28
Aug. 26	38	31	62	36	35
Potassium					
July 17	4950	5500	5775	-	5400
Aug. 7	5225	5000	7600	7300	5650
Aug. 26	4775	4550	6563	5538	4300
Magnesium					
July 17	900	1050	900	-	1200
Aug. 7	1700	1550	1250	1400	1350
Aug. 26	2200	2050	2050	2100	2050

*Side dressed July 29, 1958

July 17. On August 7 and 26, there was little difference in the potassium level of black plastic, aluminum, or cultivated plots while on both dates, straw mulched plots had the highest potassium level.

The magnesium level was low in black plastic plots on July 17, and high on August 7 and 26, while cultivated plots had high magnesium levels on July 17 and low on August 7 and 26. The magnesium level in plants grown on aluminum and straw mulch had intermediate levels, except on July 17 when straw plots had low magnesium levels.

Table XII shows the nitrate nitrogen level in the soil on July 28. In the Fireball tomato test, the nitrate level was high in cultivated plots with little difference in black plastic, aluminum, straw, hot tents and scraped plots. Non-irrigated plots had higher nitrate levels for all treatments except scraping where there was little difference between irrigated and non-irrigated.

In Honey Rock melon tests, the nitrate level was higher in the non-irrigated rows, except for straw plots where there was no difference in the nitrate level between irrigated and non-irrigated. Straw plots had very low nitrate levels as did the irrigated rows where hot tents were used. Black plastic and aluminum mulched and scraped plots had high nitrate levels in the irrigated rows while aluminum and black plastic mulched and hot tents resulted in high nitrate levels in the non-irrigated rows.

TABLE XII

The Influence of Mulching and Irrigation Practices with Tomatoes and Muskmelons on the Nitrate Nitrogen Level in the Soil*
(Expressed in parts per million of Moist Soil)

Treatment	Irrigated (ppm)	Non-irrigated (ppm)	Average (ppm)
	A: Fireball Tomatoes		
Black plastic	1.25	2.50	1.88
Aluminum	1.00	2.50	1.75
Straw	1.00	3.50	2.25
Cultivation	4.50	7.50	6.00
Hot tents	0.75	1.50	1.13
Scraped	3.25	3.00	3.13
	B: Honey Rock Muskmelons		
Black plastic	5.40	8.75	7.08
Aluminum	4.75	11.25	8.00
Straw	1.75	1.75	1.75
Cultivation	3.25	6.00	4.63
Hot tents	1.50	8.00	4.75
Scraped	5.25	6.90	6.08

*Surface six inches of soil, July 28, 1958

Soil Temperature Measurements

Table XIII shows the averages of temperature measurements made during July and August at depths of two and four inches in soil exposed to the sun and not covered by foliage. The temperature was higher at the two inch depth than the four inch depth in all treatments except at 4:00 p. m. under straw mulch where the temperature at the lower depth averaged 1.3°F higher. The temperature under black plastic mulch was higher than in soil in all other plots except at 4:00 p. m., when it was the same as under aluminum mulch. The temperature averaged from two degrees higher at 9:00 a. m. to seven degrees higher at 12:00 to 1:00 p. m. under black plastic than in normally cultivated soil at the two inch depth. At the four inch depth the temperature difference was approximately the same, ranging from three-tenths degrees higher at 12:00 to 1:00 p. m. to seven degrees higher at 4:00 p. m. At 12:00 to 1:00 p. m. the temperature under black plastic mulch at two inches averaged ten degrees higher than at four inches deep. The soil under aluminum mulch warmed up approximately as much as did cultivated soil, but the temperature stayed higher longer. Temperatures of soil under straw mulch averaged one to three degrees lower than the temperature of cultivated soil.

As shown in Table XIV, the soil temperatures as recorded by thermocouples warmed up more slowly than did the air, but also cooled more

TABLE XIII

The Effect of Mulching and Cultivation on Soil Temperatures (Average of Readings made in July and August with Dial Thermometer in Degrees F)

Time	Black Plastic		Aluminum		Straw		Cultivated	
	2 inch	4 inch	2 inch	4 inch	2 inch	4 inch	2 inch	4 inch
9:00 a. m. (7)*	68.4	67.5	66.7	66.0	65.1	64.6	66.4	65.4
10:00 a. m. (6)	73.8	69.0	68.1	66.3	66.9	64.8	69.4	66.0
11:00 a. m. (4)	77.7	70.8	72.0	68.2	69.3	66.3	73.0	68.4
12 - 1:00 p. m. (2)	79.0	69.0	71.5	67.7	72.0	66.3	72.0	68.7
2:00 p. m. (5)	78.7	76.0	73.7	71.6	70.5	68.2	74.7	71.6
3:00 p. m. (4)	80.6	73.3	75.8	71.3	72.4	67.0	74.4	69.7
4:00 p. m. (3)	76.7	77.0	74.7	72.3	70.7	72.0	70.7	70.0
Average	76.4	71.8	71.8	69.1	69.6	67.0	71.5	68.5

*Number of readings averaged

TABLE XIV

Effects of Mulching and Cultivation on Soil Temperatures*

Time	Black Plastic		Aluminum		Straw		Cultivation		Air Temperature - 3 ins.	
	3 ins.	6 ins.	3 ins.	6 ins.	3 ins.	6 ins.	3 ins.	6 ins.	in sun	in shade
August 21-22										
10:00 p. m.	66	67	67	68	63	65	62	66	55	56
12:00 p. m.	62	65	63	67	62	63	59	67	49	50
4:00 a. m.	58	61	59	61	59	61	54	58	42	43
8:00 a. m.	81	82	77	79	78	78	72	75	87	79
10:00 a. m.	82	82	73	67	76	75	76	72	92	88
12:00 m.	87	80	80	74	78	77	86	77	95	84
2:00 p. m.	79	74	79	75	69	69	80	75	90	80
4:00 p. m.	73	67	71	66	63	63	70	67	74	69
6:00 p. m.	74	69	71	68	65	64	68	67	66	65
8:00 p. m.	69	68	69	69	65	64	67	68	59	59
10:00 p. m.	69	70	69	70	63	67	67	69	60	61
Average	72.7	71.4	70.7	69.5	67.4	67.8	69.2	69.2	69.9	66.7
September 4-5										
8:00 p. m.	75	73	76	75	72	72	72	73	71	69
10:00 p. m.	71	71	71	71	68	68	69	69	61	65
12:00 p. m.	66	67	67	68	65	64	62	66	58	59
4:00 a. m.	66	67	66	64	65	64	62	65	58	58
8:00 a. m.	66	68	66	66	66	67	63	66	63	63
10:00 a. m.	76	77	75	73	74	72	74	70	81	81
12:00 m.	72	70	71	72	70	71	74	71	76	75
2:00 p. m.	70	69	69	70	67	67	71	68	71	71
4:00 p. m.	72	69	70	70	67	66	70	67	74	75
6:00 p. m.	69	66	68	68	65	65	68	66	69	68
Average	71.3	69.7	69.9	69.7	67.9	66.6	68.5	68.1	68.2	68.4

*Temperatures recorded with thermocouples and potentiometer.

slowly and did not become as low as did the air temperature. Temperatures under black plastic and aluminum mulches did not go as low as did cultivated soil, while soil under straw mulch became as cool or cooler than did cultivated soil.

DISCUSION

The results of the mulching experiments with various crops and varieties in 1958 indicated that black plastic mulch increased the total yields of cucumbers, tomatoes, squash and muskmelons 28 percent, 31 percent, 58 percent and 81 percent, respectively over cultivated plots (Figure 7). In this study, as well as in work reported by Rowe-Dutton (1957), cucurbits responded most to mulching. The increase in yield was undoubtedly due to increased soil temperature and protection of the soil from drying and the roots from being pruned by cultivation. Improved aeration under the plastic because of less packing by tractors and implements, rains and irrigation and the fact that no cultivation was needed meant that the shallow roots of the plants could grow undisturbed in the surface layer of soil.

Tomatoes (Figure 8) did not respond as well to plastic mulching as did muskmelons (Figure 9), with squash and cucumbers intermediate in their response (Figure 7). Carolus and Downes (1958) also found that melons responded more to plastic than did tomatoes.

The early yields of tomatoes, cucumbers, squash and muskmelons grown on plastic, as shown in Figure 7, were 29 percent, 126 percent, 182 percent and 247 percent more, respectively, than on cultivated plots. It is probable that the cultivated soil temperature was more nearly at its

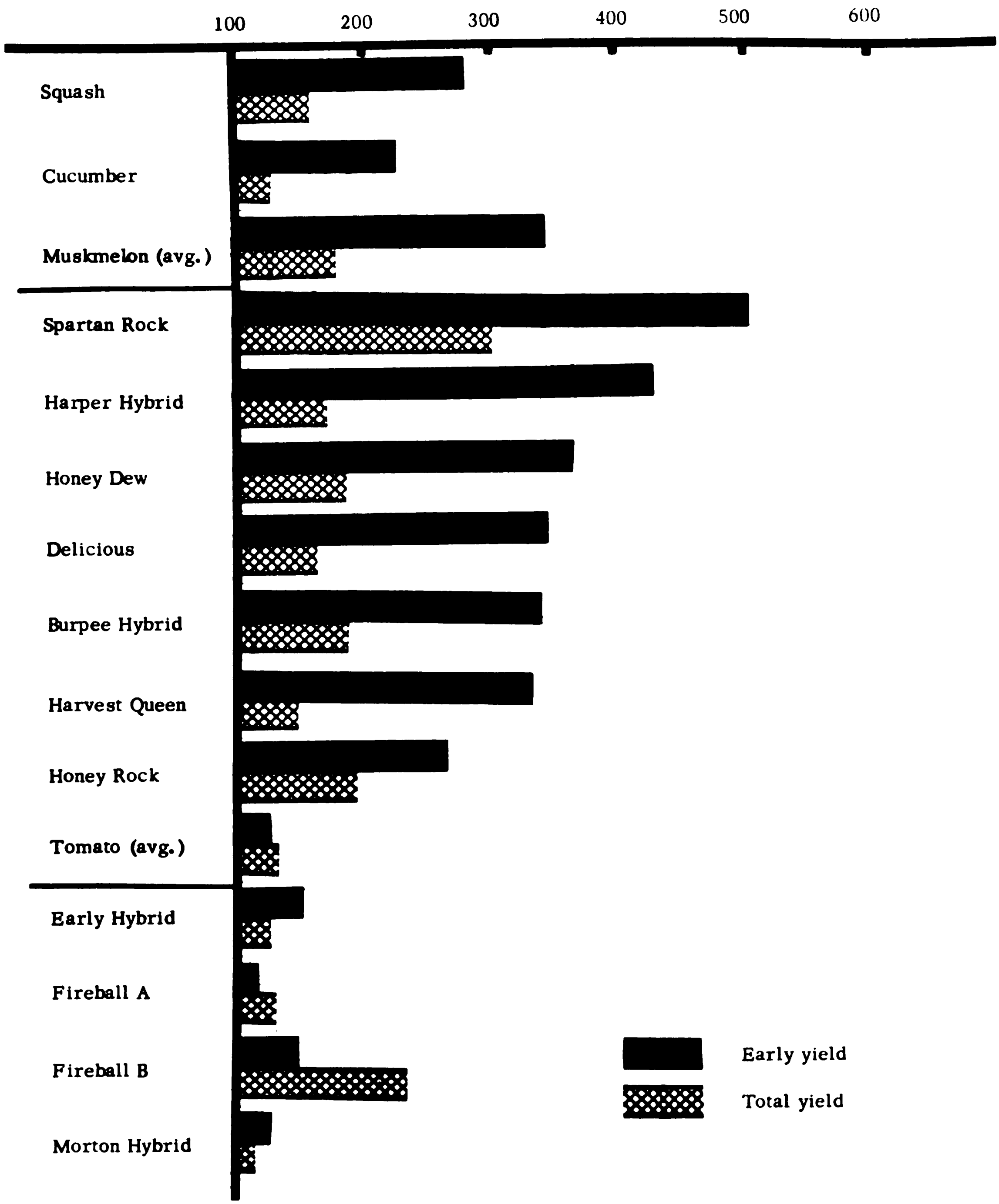

Figure 7. Comparative increases in yield of various crops and varieties from plastic mulch. (Cultivated yields equal 100)

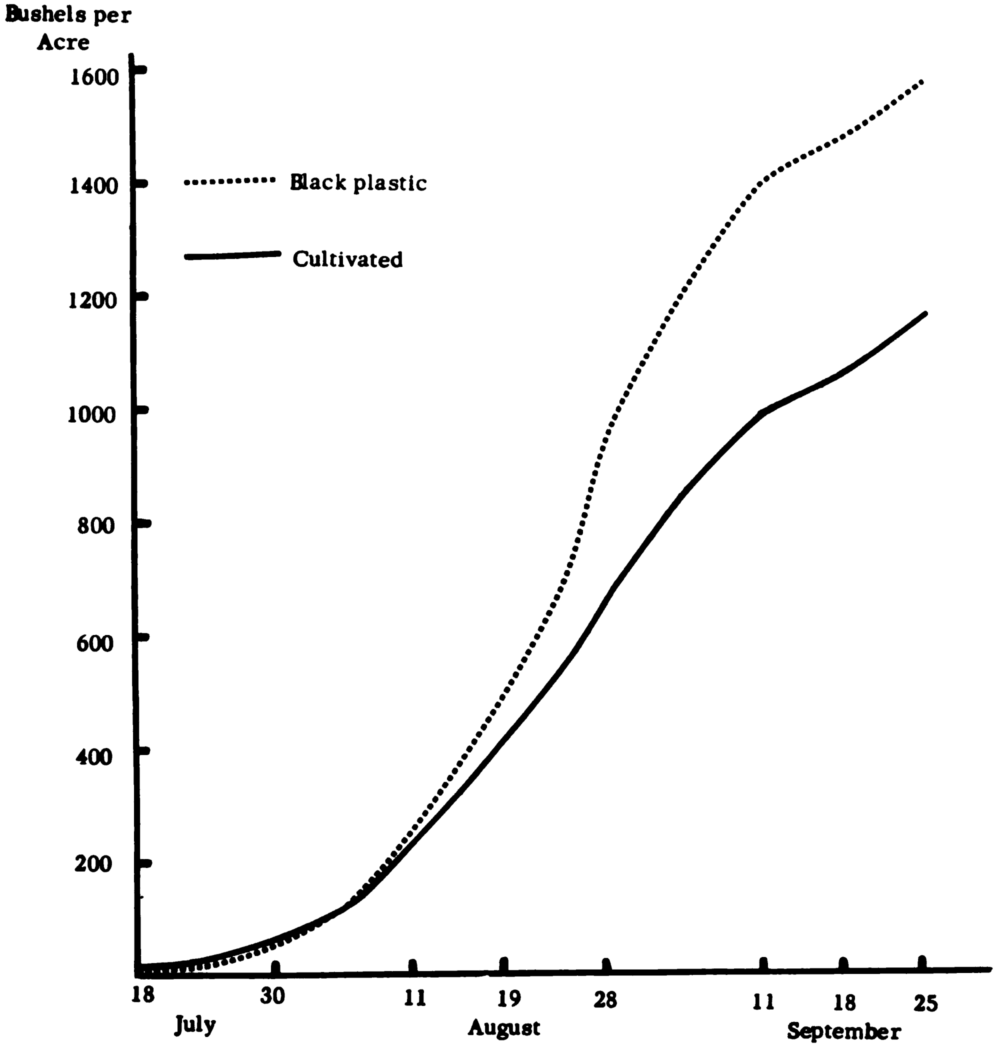

Figure 8. The comparative effect of black plastic mulching and cultivation on the cumulative yield of tomatoes. (Average of all varieties)

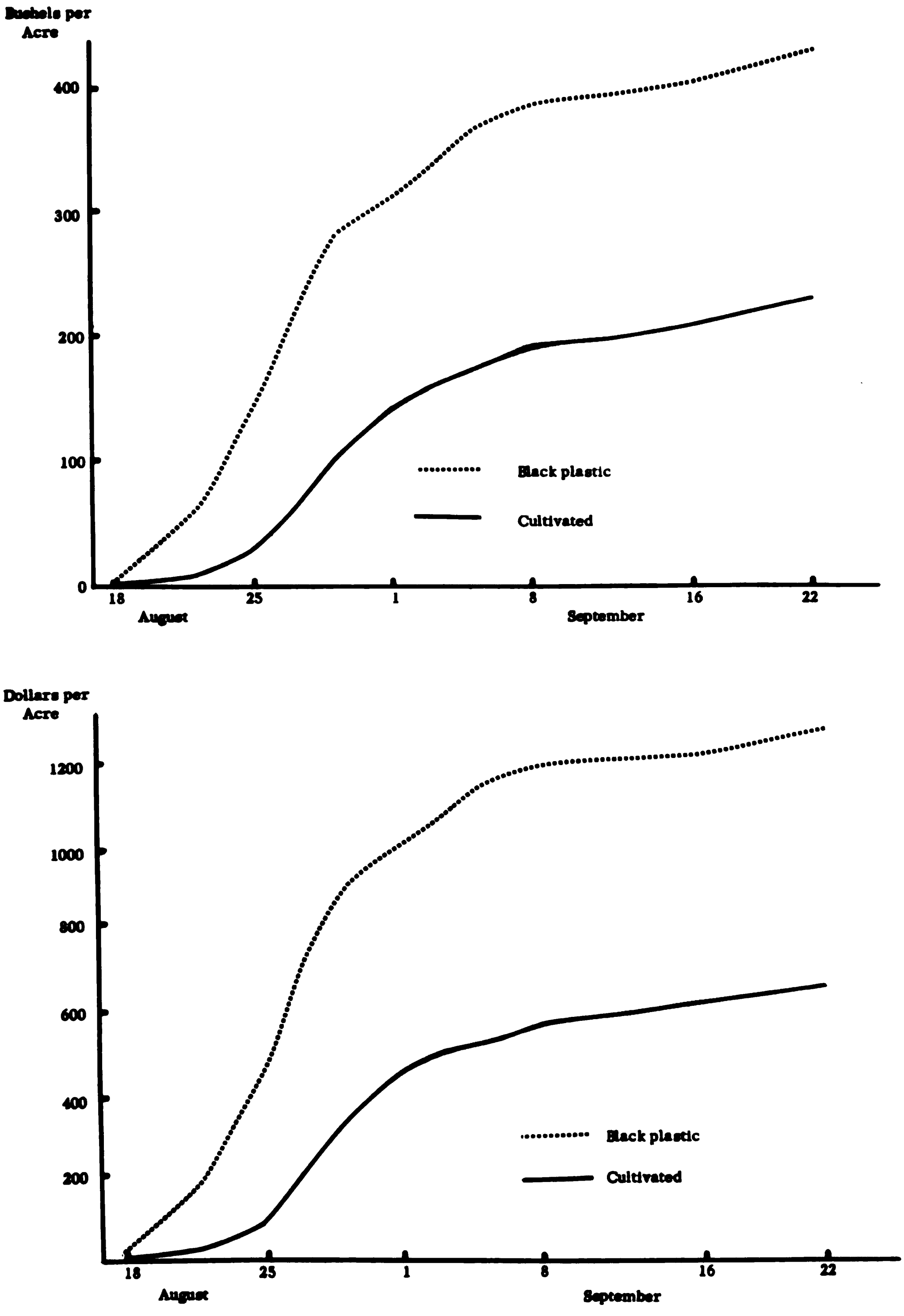

Figure 9. The comparative effect of black plastic mulching and cultivation on the cumulative yield (upper figure) and dollar value (lower figure) of muskmelons. (Average of all varieties)

optimum for tomato growth than for cucurbit growth, thus the increase in soil temperature brought about by mulching with black plastic during June and July when temperatures were below normal had more influence on cucurbits than on tomatoes. This is a possible explanation why plastic mulching increased the total yield of tomatoes, which was the reverse of the manner in which black plastic affected the cucurbits. Aluminum mulch was not as effective in increasing the early yield of cucurbits as black plastic although tomatoes showed no difference in early yield from either aluminum or plastic mulched plots. Since the aluminum mulch did not have much effect on soil temperature, it is probably the difference in soil temperature under the two mulches that caused cucurbits to show less response than tomatoes to aluminum mulch.

There was a difference in the response of varieties to plastic mulching in this experiment (Figure 7). Among the melon varieties, all of which had significantly higher yields with plastic mulch, Spartan Rock responded most favorably while Honey Rock showed the least response to black plastic. This response may be due in part to the difference in time at which the melons matured or in the optimum temperature required by each variety. Those varieties which responded most favorably to plastic mulching may be the ones which require a higher temperature for optimum growth than those varieties that did not show as much response to plastic mulching. With tomato varieties in the variety-mulching test, Fireball responded more to plastic mulching than did Early Hybrid while Moreton Hybrid responded the least.

In the Fireball mulching test, there was no significant increase in total yield from irrigation, while Fireball, Moreton Hybrid and Early Hybrid in the variety-mulching test produced higher yields in irrigated plots. The difference in response to irrigation may have resulted from a difference in location; the Fireball mulching experiment was located in a slightly lower area where the moisture content of the soil may not have fallen below that necessary for adequate plant uptake.

Muskmelons did not respond as favorably to irrigation as did the tomatoes in the variety-mulching test. This does not agree with the results of Carolus and Downes (1958) in 1957 when muskmelons on plastic were benefitted by irrigation. This possibly resulted from a difference in the amount and distribution of rainfall through the two seasons. The melon varieties also responded differentially to irrigation, with Spartan Rock and Burpee Hybrid in cultivated plots without irrigation yielding twice as much as with irrigation. Burpee Hybrid on plastic produced slightly higher yields without irrigation and the early yield of Harper Hybrid was almost twice the yield as with irrigation. Harvest Queen, with a higher yield on plastic with irrigation, was the only variety that responded favorably to irrigation, although cultivated plots produced slightly higher yields without irrigation.

It is possible that there would have been a larger increase in yield of plastic mulched crops over cultivation if the cultivation had been on a field scale, cultivating as deeply as most growers do. Scraping, which was done to eliminate the pruning of shallow roots which happens under normal cultivation, did not produce any increase in yield over cultivation, indicating that the cultivating was not materially injuring the roots in the surface soil.

Straw Mulching

Under the conditions of the experiment, straw mulching was not harmful to Fireball tomatoes, whereas the yield and plant size of squash, cucumbers, and muskmelons were reduced. Emerson (1903) and Rowe-Dutton (1957) reported that straw mulch increased tomato yields unless applied before the plants were well established in the field. Rowe-Dutton also mentions that straw did not reduce yields in some areas where moisture was very limiting, but in cool areas lower temperatures under straw had a greater effect on growth than did increased soil moisture, thus resulting in lower yields.

It was found in this experiment that the nitrate level in the soil and in tomato leaf petioles from straw mulched plots was not lower than with plastic mulching. However, with cucurbits, the nitrate level was markedly reduced both in the soil and in the plants, which may have been responsible for the low early yields. Jacks et al. (1955) had reported that straw depressed nitrification without reducing ammonia supply. Tomatoes, if they utilize ammonia nitrogen readily, would not be affected as much from a low nitrate supply as cucurbits, which may not utilize ammonia nitrogen readily.

A possible explanation for the difference in response of tomatoes and cucurbits to straw mulching may be in the root system. Tomatoes have a deeper root system than cucurbits (Weaver and Bruner, 1927) and may have been able to obtain nitrogen from areas in the soil where nitrogen was not tied up in decomposing the straw.

The Effect of Hardening on Fireball Tomatoes

When Fireball plants, all started in the greenhouse at the same time, were set out in plantings one week apart, it was observed that the later planted ones did not develop or yield as well as the earlier planted ones. The plants used in the Fireball mulching test (Fireball A) were set out May 22 and protected from frost and cool weather for one week with hot tents, while the plants used in the variety-mulching test (Fireball B) were set out May 29 during slightly warmer weather and were not protected with hot tents. Those set out early were not as hardened and did not suffer the setback in growth that the later planted, more hardened plants did. Since plants in four-inch bands were used, root injury during planting would not have accounted for the difference in Fireball A and B. Moreton Hybrid and Early Hybrid plants, which were the same age as the Fireball plants and were set out May 29 and 30, did not appear to be as hardened and did not suffer the set back that Fireball B plants did. This may have been due to a varietal difference in response to hardening and the fact that the Moreton Hybrid and Early Hybrid did not have flower primordia and buds as well developed as Fireball B plants did at the time of planting.

The later planted Fireball B never obtained the plant size and yield, especially in cultivated plots, as those set out one week earlier, with late growth and yield being reduced more than early growth and yield. The later planted Fireball did respond favorably to plastic mulching. This response may have been from an increased soil temperature which, in turn, may have increased nitrification under the mulch as reported by Flint (1928) and Jacks et al. (1955). The tomato plants in the Fireball mulching test probably had some accumulation of carbohydrates with a moderate nitrogen supply which helped to promote fruiting and vegetative growth, while the Fireball B plants, being more hardened had a higher carbohydrate supply in cultivated plots than in plastic mulched plots. As discussed by Kraus and Kraybill (1918) an improper balance of carbohydrates and nitrogen, as in cultivated plants in Fireball B would result in less fruit set and vegetative growth while plants with a balance of carbohydrates and nitrogen would be fruitful and fairly vegetative.

Economic Factors Related to Mulching

Plastic three feet wide may have been sufficient for tomatoes, as shown by the fact that four-foot plastic was not significantly better. Thus, three-foot plastic could be used with approximately the same results as with four-foot plastic, but at a lesser cost per acre. It appears though that musk-melons would respond more to four-foot plastic as shown by the difference in yields obtained between the two widths of plastic.

It does not appear that the systematic placing of slits in plastic is worth while for melons or tomatoes, as there was no difference in the yield between plots with or without slits. The placement of slits only where water accumulates in depressed areas of the plastic would save time and effort and undoubtedly give equally satisfactory results.

Although hot tents did significantly increase the early yield of cucumbers and Fireball tomatoes, and the total yield of muskmelons in comparison with cultivation, plastic mulching gave much larger early yields for cucumbers and muskmelons and total yields for muskmelons. Thus, it would be more profitable to use the plastic mulch than hot tents on cucurbits. With tomatoes there was not any great difference in early or total yields between the use of hot tents and plastic mulch. Thus, under the conditions of the experiment, it appears that hot tents would have resulted in as high yields as plastic. However, the cost of hot tents and labor required in applying them may be equal to or greater than the cost of plastic mulching. It may be possible to combine the use of black plastic and hot tents to obtain even greater increases in yield of cucurbits, especially early yield.

With both squash and cucumbers, the large increase in early yield would more than pay for the additional costs incurred by mulching with plastic, as both crops bring high prices on the early market. The cumulative value of muskmelons (Figure 9), which was obtained by using the price per bushel of Number 1 melons at the time of harvest at the Detroit Farmers' Market and subtracting 50 cents per bushel for the cost of harvesting, containers, and marketing was approximately $1, 270 for plastic mulched plots as compared to $650 for cultivated plots. If the cost of mulching an acre of melons were less than $200, then the use of plastic mulch would have more than paid for itself.

An important factor to consider in the use of black plastic is that the crop it is used on should be one of high value, possibly with a premium on the early crop. The additional value of the crop should more than offset the cost of mulching. A fertile soil which has been carefully prepared to give a smooth bed should be used.

There are many problems yet to be solved in the use of black plastic mulch. When using plastic on a commercial basis, one should use a tractor-mounted applicator to lay the mulch. The development of a transplanter for bare root plants, such as tomatoes, would reduce the cost and time necessary for planting through the plastic. It may be possible to use a weed control spray on the soil between the rows of plastic so that no weeding is necessary during the growing season. In the fall, the plastic would have to be taken up again, or possibly if in satisfactory condition, used another year with a different crop. However, the application of fertilizer through the plastic the second year may present a problem unless liquid fertilizers are used. Black plastic may also become popular with home gardeners as a way to save labor in weeding their crops.

SUMMARY AND CONCLUSIONS

The growth and yield of summer squash, slicing cucumbers, muskmelons and tomatoes, as influenced by plastic, aluminum and straw mulch, hot tents, scraping, cultivation and irrigation, were observed and recorded during the season of 1958.

Cucurbits were found to respond more to plastic mulching than tomatoes. Rate of growth and both early and total yields were increased by the use of plastic mulch. Aluminum mulch and hot tents also increased yield and growth, but to a lesser extent than black plastic.

Fireball tomatoes did not respond markedly to black plastic unless they were over hardened, in which case, it greatly increased yield over normal cultivation. Early Hybrid and Moreton Hybrid did not respond greatly to plastic mulching.

Tomatoes responded almost as well to three-foot plastic as to four-foot plastic. However, with muskmelons, there was a greater response to four-foot plastic. The cutting of slits in black plastic did not increase its efficiency in this experiment.

Scraping the soil did not result in any increase in yield over cultivation. It is believed that the lack of response to scraping is due to the fact that the cultivation practices were shallow and did not materially injure the surface soil roots.

Straw mulch was beneficial when used on tomatoes. When used on cucurbits, growth early in the season was depressed, resulting in lower early yields than with cultivation.

Tomatoes in the variety-mulching experiment were benefitted by irrigation although the earlier planted Fireball showed no response to irrigation nor did muskmelons respond favorably to irrigation.

Straw mulch did not depress the nitrate level in tomato plants, but when used with cucurbits the nitrate level was low. Plastic or aluminum mulch did not markedly alter the nutrient levels in any of the crops tested. Nitrate levels in the soil were highest in cultivated plots. Because of the size and rate of growth of plants grown with black plastic, nitrates did not accumulate in the soil.

Measurements of soil temperature showed that black plastic increased the temperature over cultivated soil an average of 5° F at a two-inch and 3° F at a four-inch depth. Aluminum mulch only slightly increased and straw mulch slightly decreased the soil temperature.

The following conclusions appear to be justified on the basis of these experiments:

1. Black plastic benefitted cucurbits more than it did tomatoes and can be recommended for use with muskmelons and early crops of other cucurbits.

2. A higher soil temperature is one of the principal ways in which black plastic benefits crops, especially warm season crops.

3. The use of black plastic results in a higher day and night temperature in the soil.

4. Black plastic is more beneficial to over-hardened tomato plants than to properly hardened plants.

5. Three-foot black plastic may be used with tomatoes in place of four-foot plastic, but with cucurbits, four-foot plastic appears to be more beneficial.

6. The systematic cutting of slits in plastic mulch is not recommended, but placing slits in depressed areas in the plastic is recommended to allow rain and irrigation water to enter the soil.

7. Straw mulch, if applied properly, is beneficial to tomatoes, but has detrimental effects on cucurbits, especially muskmelons.

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