

EFFECTS OF MULCHING, PINCHING, AND VINE SPREADING
ON PRODUCTION OF FRESH MARKET TOMATOES

by

Randolph Gilbert Gardner

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APPROVED:

J. A. Barden, Chairman

J. M. Johnson

C. R. O'Dell

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INTRODUCTION

Production of fresh market tomatoes by trellising requires a tremendous input of labor over the entire growing season. Many growers, lacking the labor required for trellis production, have become interested in other methods of producing tomatoes.

Cage production of tomatoes, currently being tested as a low labor alternative to trellising, has been shown to give good yields of high quality fruit. A big drawback to caging, however, is the high initial investment (approximately \$1500 per acre) required for wire to build cages.

Growers are also going to ground culture of early varieties to lengthen the harvest season over that now possible with trellis-grown main season varieties. Methods of increasing yield, fruit quality, and ease of harvest for ground-grown tomatoes would be of value to the grower.

Mulching with black plastic, plastic coated paper, or straw has generally been recommended in Virginia as a way of improving yield and quality of ground-grown tomatoes. However, little experimental work has been conducted in Virginia looking critically at fruit quality or yield as influenced by mulching.

General observations by the author over a number of years have shown that ground-grown tomato vines seldom fall naturally so that foliage is spread uniformly over the soil surface. Winds accompanying summer storms often topple plants to one side so that by harvest time heavily bunched foliage exists over part of the soil surface with

little or no growth over other areas. Previous experience has shown that a more uniform distribution of foliage over the soil surface can be achieved by hand separating and spreading laterally the main branches of mature tomato vines. The heavy fruit load was found to keep branches in place after spreading.

Vine spreading was viewed as a possible way of improving ease of harvest and also as being of possible benefit to the fruit by increasing light penetration, air circulation, and coverage by spray materials within the plant canopy.

Pinching away the apex of young tomato plants stops growth of the main stem and forces early growth of lateral branches. Pinching was viewed as being of possible use in giving a better natural distribution of growth over the soil surface or in facilitating hand spreading of vines.

The objectives of this study were to test the effects of mulching, pinching, and vine spreading on yield, quality, and ease of harvest of ground-grown tomatoes for fresh market.

REVIEW OF LITERATURE

Mulching-straw and other. Work has been carried out at various locations over the years to test the effects of straw and other organic materials as mulches for tomatoes. Rowe-Dutton, who reviewed the results of many of these experiments, concluded that organic materials were very effective in conserving soil moisture and were generally beneficial to tomatoes in hot, dry areas or during drought (19).

Early experiments in Nebraska (7, 23) revealed increases in yield of tomatoes for straw mulch versus clean cultivation. Rosa's work in Missouri with straw mulch showed an average yield increase of 13.5 percent over 4 years for mulching. Yield was decreased in one wet year by mulching (18). In Ohio (2) substantial increases in yield resulted from mulching with grass clippings in a very dry year; however, the average results over 3 years showed little difference in yield between mulched and bare soil control plots. Isenberg and Odland (11) compared sawdust, leaves, corn fodder, grass clippings, and manure as mulches for tomatoes and reported an increase in yield over clean cultivated tomatoes for all of these mulches. None of the mulches, however, was found to be any better than another for increasing yield.

In Montana (1) clean cultivation gave better tomato yields than straw mulch, presumably because of lower soil temperature under mulch. Straw mulch was found to maintain soil temperature as much as 10° F cooler during the warmer part of the day. In addition, other tests

(7, 11, 23) showed that applying organic mulches before plants were well established could retard early growth and yield by lowering soil temperatures.

Little experimental evidence indicating effects of straw mulch on tomato fruit quality is available. Werner had fewer small, rotting, or rough fruits with straw mulched than with clean cultivated plants (23). Also, Emerson made a general statement to the effect that straw mulch kept fruit cleaner and less subject to rot (7).

Mulching-paper and black plastic. Paper as a mulch was first tested for tomatoes in the 1920's. Thompson and Platenius showed a 17 percent average increase in tomato yields over 3 years from the use of black asphalt impregnated paper mulch compared to clean cultivation (22). Yield in the first two weeks was increased 30 percent by mulching. Edmond reported an almost 3-fold increase in yield of tomatoes on paper mulch as compared to clean cultivation (6). However, other workers who have compared tomatoes grown on black asphalt paper with clean cultivation found yield results to be variable depending on cultivar and season (10, 15, 23).

Effects of paper mulch on fruit quality have also been variable. Magruder (15) found no difference in percent number one fruit from paper mulched and clean cultivated tomatoes. In Werner's tests paper mulch gave a higher percentage of prime fruit than clean cultivation on irrigated plots but not on unirrigated plots (23).

Work with black plastic as a mulch for tomatoes was begun in the early 1950's. Experiments in Michigan, Kentucky, Oregon and Florida

(3, 4, 8, 9) showed increases in total and marketable yields of ground-grown tomatoes for black plastic mulched compared to clean cultivated tomatoes. Carolus and Downes (3) and Emmert (8) also reported increases in early yields on plastic mulch.

Nickeson in South Dakota did not find an increase in yield of tomatoes on black plastic (17). Schales and Reynolds in a test comparing black plastic, smoke gray plastic, and plastic coated paper with clean cultivation reported no differences in yield of tomatoes among any of the treatments (20). Other work comparing paper and black plastic mulches on vegetable crops has shown similar growth and yield responses with paper and black plastic mulches (5).

Work in Oregon by Clarkson and Frazier (4) showed that plastic mulch decreased the percent of small, cracked, and rotted fruit. In Florida ground rot was decreased from 50 percent of marketable sized fruit on bare soil to 27 percent on black plastic (9). Also, most of the fruit lost in plastic mulched plots was due to fruit lying on bare soil beyond the plastic. Lockhart and Chipman found black plastic mulch to be effective in reducing storage rots of tomatoes when used in 8 ft. widths but not when used in 3 ft. widths (14).

Transplant clipping. Recent work has been conducted with the clipping of southern-grown tomato transplants prior to transplant harvest to increase uniformity for mechanical harvest and to regulate harvest schedules. Jaworski et al. (13) compared yields of clipped and non-clipped transplants of 5 determinate vined processing cultivars at two locations and found no differences in usable fruit yield for

clipped and non-clipped plants. Plants for these experiments were clipped prior to transplant harvest by a rotary mower, removing the terminal bud together with the first inflorescence. Jaworski and Webb in earlier tests with the determinate cultivar H-1350 at three locations also reported no differences in fruit yield of clipped and non-clipped transplants (12). Clipping in these tests, however, did delay blossoming and fruit ripening. Also, clipping plants 2-7 days prior to transplanting delayed blossoming more than clipping 9-15 days prior to transplanting.

MATERIALS AND METHODS

Field experiments were conducted in 1971 and 1972 at the VPI&SU Horticulture Research Farm, Blacksburg, Virginia, using the tomato cultivar Manapal.

The soil type for both field plots was Lodi Silt Loam. Soil test results in 1971 showed the soil to be high in available phosphate, potash, and calcium; pH was 6.5. Soil test results in 1972 showed the soil to be high in available phosphate and calcium and medium in potash; pH was 6.6. Broadcast applications of 5-10-10 and 10-10-10 fertilizers at the rate of 1000 lb. per acre were plowed down in April of 1971 and 1972, respectively. A heavy rye cover crop was plowed down both years.

Plants were hand set using a long-handled bulb transplanter to make holes. One-half pint of starter solution, made by dissolving 3 lbs. of 10-52-17 fertilizer in 100 gal. of water, was applied around each plant. Plants were set 3 ft. apart in 5 ft. rows.

The plots were sprayed at weekly intervals, beginning one week after setting plants, for insect and disease control. Endosulfan (Thiodan) was the insecticide used both years. Folcid (Difolatan) fungicide was used in 1971; daconil (Bravo) was used in 1972.

Roto-tilling and hand hoeing were used both years for weed control on bare soil areas. Weeds which grew through the straw mulch were hand pulled. In addition, trifluralin (Treflan) herbicide was applied as a broadcast treatment over the entire plot in May for the 1972 experiment.

1971 Experiment. Seed were sown April 15 in a flat containing a 1:1 mix of vermiculite and peat moss. On May 3, the seedlings were transplanted into flats of a steam sterilized mix of 1/2 topsoil and 1/2 peat moss. Three applications of 10-40-10 fertilizer solution were made to the plants during the growing period in the greenhouse. Plants were moved directly to the field on May 25 for transplanting.

A split plot design with 5 replications was used in the 1971 experiment. Each replicate contained 14 rows of 10 plants each. The two outside rows and the end plants of each row were used as guard plants.

Mulching was tested against bare soil culture in the main plots. Mulch used in 1971 was a 4 ft. wide kraft paper with a thin bonded layer of black polyethylene. This mulch was laid on 5 ft. centers by a tractor drawn mulch laying machine one week prior to field setting of plants.

The following 6 treatments were assigned to sub-plots within each main plot:

1. non-pinched, non-spread check plants;
2. non-pinched plants with main branches spread moderately;
3. non-pinched plants with main branches spread the maximum amount possible;
4. pinched, non-spread plants;
5. pinched plants with moderate spreading of branches;
6. pinched plants with maximum spreading of branches.

Plants were hand-pinched on June 10, removing the apex of the plant immediately above the leaf subtending the first inflorescence. At the time of pinching, the buds of the first inflorescence were barely visible.

Spreading of vines was carried out on August 4, one day before harvest of the first fruit. Spreading was accomplished by separating the main branches of the plants by hand and moving the branches laterally to the desired position. In the case of maximum spreading, branches were moved as far apart as possible to give maximum exposure of foliage and fruit to light and air circulation. In the case of moderate spreading, branches were moved apart enough to approximate a condition half way between non-spread and maximum spread plants.

Fruit was harvested when it reached the pink stage of ripening. In 1971, harvesting began on August 5 and continued through September 29. Total weight and number of fruit were tabulated for each treatment row at each harvest. Fruit was graded according to U.S.D.A. standards for fresh market tomatoes. U.S. No. 1 and U.S. No. 2 fruit were classified as marketable, and all other fruit was classified as cull. The weight of each grade was recorded.

1972 Experiment. Seed were sown April 17 in a flat of Cornell peat-lite mix (21). The seedlings were transplanted May 1 into flats of Cornell peat-lite mix. Plants were field set on May 30.

A split plot design with 4 replications was used (Fig. 1). Each replicate contained 15 rows of 10 plants each. End plants of rows were used as guards. Guard rows were also included on each side of treatment rows, resulting in each replicate containing 6 treatment rows of 8 record plants each.

Non-mulch, mulch, and double mulch treatments were assigned to main plots. Black polyethylene, 1.5 mils thick and 4 ft. wide, was laid on 5 ft. centers by hand 5 days prior to setting of plants.



Fig. 1. Field plot in mid-June for the 1972 experiment.

The double mulch treatment consisted of rye straw laid over the bare soil area between rows mulched with black plastic. The straw was laid on June 6 approximately 4 inches deep over the bare soil and extending about 6 inches over the edges of the plastic mulch.

Two treatments consisting of non-spread check plants and plants with main branches spread the maximum amount possible were assigned to the sub-plots of each main plot (Fig. 2, 3). Spreading was carried out on August 4; time required for spreading was recorded. In addition to spreading treatment rows, foliage of adjacent guard rows was also spread.

Daytime soil temperatures were recorded in July at a depth of 3 inches under bare soil, straw, and black plastic. Internal temperatures of fruit exposed to direct sunlight, moderate shade, and heavy shade were also recorded during the harvest season. These temperature readings were taken by inserting temperature sensitive shafts of dial-type soil thermometers into the soil or fruit and reading after approximately 10 minutes.

Fruit harvest in 1972 began on August 8 and continued through September 26. Fruit from each treatment row was graded as marketable, including U.S. No. 1 and U.S. No. 2, and cull. Weight and number of fruit in each grade were recorded for each harvest. In addition, fruits culled because of ground scars and rot were counted, weighed and recorded separately from other culls. Data were subjected to an analysis of variance and Duncan's Multiple Range Test.

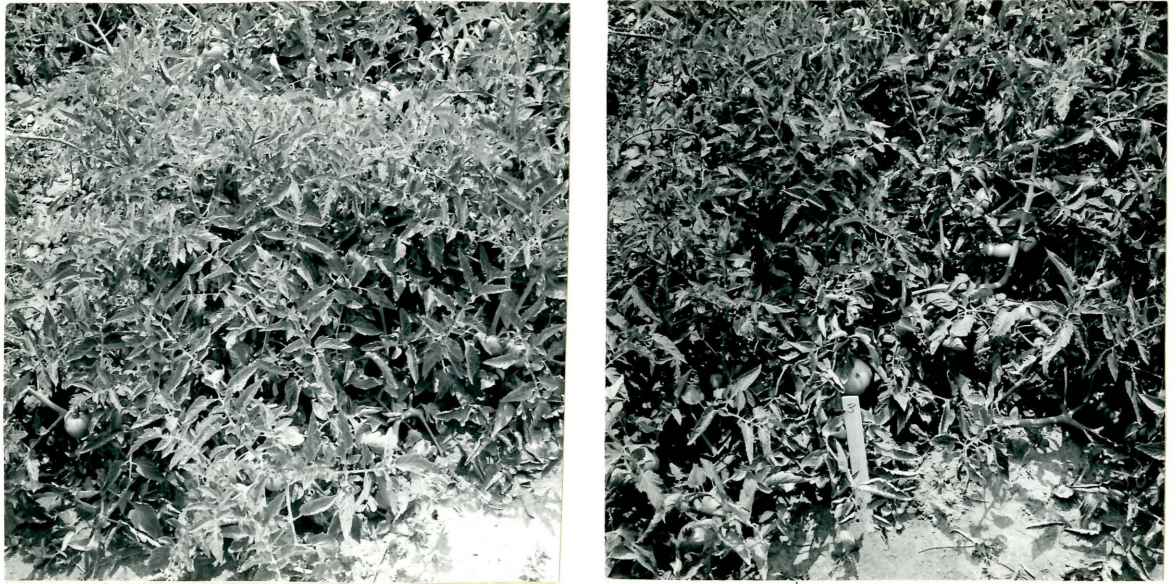


Fig. 2. View of non-spread plant (left) and same plant after spreading (right) in August of 1972. Note increased exposure of fruit after spreading.



Fig. 3. View of a spread tomato vine 2 weeks after spreading.

RESULTS

Both 1971 and 1972 were extremely wet growing seasons (Table 1). In 1971 heavy rainfall in May, June, and early July kept soil practically saturated from the time plants were set until the latter part of July. In 1972 heavy rainfall in June and July kept soil wet until after the first week in August. The harvest seasons in both years were relatively dry until after the middle of September. Temperatures were much below normal in June and the first week of July in 1972.

Greenhouse plant production for the 1971 experiment was complicated by a toxic effect on plant growth arising from the soil mix. Because of this toxicity, plants at the time of field setting were not as uniform or vigorous as desirable. Plant establishment and early growth in the field were further hindered by high soil moisture.

Observations made one month after field setting in 1971 showed the flowers of the first inflorescence to be open on all non-pinched plants and small pea-sized fruit set on some. The second inflorescence was beginning to open on some non-pinched plants. Side branches of non-pinched plants appeared uneven in size and stage of flower bud development. Pinched plants had no open flowers on the first inflorescences of the lateral branches and appeared to be about 5 days from anthesis. Side branches of pinched plants were fairly uniform in size and all appeared at about the same stage of flower bud development. Extreme variability in size of plants was evident throughout the plot at this time; however, mulched plants were in general more uniform in size and much ahead of unmulched plants in amount of vegetative growth.

Table 1. Monthly rainfall and mean air temperatures^z for the 1971 and 1972 growing seasons, VPI&SU Horticulture Research Farm, Blacksburg, Virginia.

Year	Month				
	May	June	July	Aug.	Sept.
	Mean temp. (°F)				
1971	58	72	68	68	66
1972	59	63	66	68	67
1941-70 Mean ^y	61	68	72	70	64
	Rainfall (inches)				
1971	8.3	5.8	4.0	2.6	4.2
1972	4.5	6.7	7.1	2.5	6.5
1941-70 Mean	3.5	3.8	4.0	3.5	3.2

^zData for 1971 and 1972 were from weather records kept at the Horticulture Research Farm, Blacksburg, Virginia.

^yTemperature and rainfall means for the period 1941-70 were from climatological summary data furnished by C. W. Crockett, NOAA Climatologist for Virginia, Blacksburg, Virginia.

During the 1971 season, vines on mulch remained visibly larger than unmulched plants until the middle of July, when unmulched plants made a heavy flush of growth and surpassed mulched plants in vine size for the season. Pinched plants, both on and off mulch, had much greater growth in length of main stems than non-pinched plants.

Weed control by a practical amount of tilling and hand hoeing was ineffective during the 1971 season because of a high weed seed population in the soil and because high soil moisture allowed weeds to re-establish themselves after cultivation. Weed control in the area between strips of mulch was particularly difficult since cultivation could not be performed along the edges of the mulch. This failure to control weeds between mulched rows, together with less vine growth to shade out weeds on mulched rows, resulted in much greater weed growth between mulched rows than between unmulched rows.

Plants at time of setting in 1972 were very uniform in size. A late season frost on June 11, however, damaged plants on straw mulch, destroying the first inflorescence on most of the plants. About 40 percent of double mulched plants were damaged so badly that they had to be replanted. These replants were observed to be delayed in growth and fruit ripening. Early growth of plants in 1972 again was more uniform and vigorous on mulch than on bare soil (Fig. 4, 5). The increased growth of mulched plants continued throughout the season so that by harvest time vine growth on mulch greatly exceeded that on bare soil.

Soil temperature readings at a 3-inch depth under black plastic, straw, and in bare soil showed plastic to increase soil temperature over bare soil whereas straw maintained a lower soil temperature (Table 2).



Fig. 4. Tomato plants on bare soil (left) and plastic mulch (right) in late June, 1972, showing difference in amount and uniformity of growth.



Fig. 5. Tomato plants on bare soil (foreground) and plastic mulch (background), showing difference in amount of growth in mid-July, 1972.

Table 2. Soil temperatures at 3 inch depth on July 9, 1972, VPI&SU Horticulture Research Farm, Blacksburg, Virginia.

<u>Soil temperatures (°F) under following treatments</u>				
<u>Time</u>	<u>Air temp.</u>	<u>Bare soil</u>	<u>Black plastic</u>	<u>Straw</u>
10:30 a.m.	74	74	78	69
2:30 p.m.	84	81	86	72
4:30 p.m.	79	81	86	74

The combination of herbicide and tillage on bare soil areas in 1972 gave excellent weed control. The straw mulch was also effective in controlling weed growth. The few weeds which grew through the straw were easily pulled by hand.

The pinched plants in the 1971 experiment showed no natural tendency to give a more desirable distribution of plant growth over the soil surface than non-pinched plants. In addition, pinched plants were more difficult to spread because of increased stem length. Vine growth on bare soil in some areas of the 1971 plot and vine growth on mulch in some areas of the 1972 plot was so extensive that spreading vines the maximum amount possible left some foliage heavily bunched. Some breakage of stems was unavoidable both years during spreading in areas of excessive vine growth, but no harmful effects to the vines or fruit were noted either year following vine spreading. Time required for spreading 300 vines in the 1972 season was 2-1/2 hours. Although no time records were kept for harvesting fruit from spread and non-spread plants, harvest appeared to be easier on spread plants.

Internal temperature readings of fruit approximately 3 inches in diameter taken on the afternoon of August 26 showed the average temperature of fruit in direct sunlight to be 94°F, fruit in moderate shade was 86°F, and that under heavy shade was 79°F. Air temperature was 88°F.

Because of poor growth and extreme variability among plants in two of the replicates, harvest of fruit in 1971 was confined to 3 replicates. The summary of harvest data for the 1971 season given in Table 3 shows that pinching as performed in this experiment delayed

Table 3. Effects of pinching and spreading treatments on mean fruit weight, yield, and percent marketable tomato fruit, 1971.

Treatment	Cumulative harvest periods								
	Aug. 5 - Aug. 16			Aug. 5 - Aug. 31			Aug. 5 - Sept. 29		
	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit
Non-pinch non-spread	.39a ^z	1.6a	81.7a	.37a	7.5a	64.3b	.32a	26.4a	59.4a
Non-pinch mod. spread	.44a	2.8b	70.1a	.39a	11.1b	59.7b	.33a	29.4a	58.8a
Non-pinch max. spread	.42a	2.4ab	71.2a	.40a	11.5b	64.1b	.34a	30.5a	59.5a
Pinch non-spread	--	--	--	.41a	6.2a	48.1a	.34a	27.8a	53.1a
Pinch mod. spread	--	--	--	.40a	6.3a	53.7ab	.33a	26.4a	54.2a
Pinch max. spread	--	--	--	.37a	5.2a	57.5ab	.31a	24.4a	53.7a

^z Means within a column not followed by a letter in common differ significantly at the 5% level.

fruit harvest. The first harvest on pinched plants was made on August 19. Moderate spreading of non-pinched plants gave an increase in fruit yield over non-pinched, non-spread check plants for the cumulative yield through August 16. Both moderate and maximum spreading of non-pinched plants gave an increase in fruit yield over other treatments for the cumulative harvest through August 31. For the total harvest season no differences in yield resulted from any of the treatments. Average fruit weight was unaffected by treatments used in 1971. No differences were noted in percent marketable fruit for any treatments for the cumulative harvest through August 16 or for the total harvest season. The pinch, non-spread treatment gave a decrease in percent marketable fruit compared to non-pinched treatments for the cumulative harvest through August 31.

Mulching in the 1971 experiment resulted in no differences in fruit yield or average fruit weight at any time during the harvest season (Table 4). For the cumulative yield through August 16 and for the total season yield no difference in percent marketable fruit was found for mulching. Mulching did, however, give an increase in percent marketable fruit for the cumulative harvest through August 31.

Spreading of vines in the 1972 experiment increased yield of fruit for both the early season (Aug. 8 - Aug. 28) and total harvest season without affecting average fruit weight, percentage marketable fruit, or percentage of ground scarred and rotted fruit (Table 5). Total yield was suppressed in 1972 by an attack of verticillium wilt which first became apparent in mid-August. Failure of fruit to size normally as a result of the wilt disease is apparent from a comparison of mean fruit weights in the 1971 and 1972 experiments (Tables 4, 6).

Table 4. Effect of mulch on mean fruit weight, yield, and percent marketable tomato fruit, 1971.

Treatment	Cumulative harvest periods								
	Aug. 5 - Aug. 16			Aug. 5 - Aug. 31			Aug. 5 - Sept. 29		
	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit
Non mulch	.42a ^z	2.3a	64.3a	.38a	7.3a	51.3a	.32a	28.0a	54.9a
Mulch	.42a	2.2a	84.5a	.39a	8.7a	64.5b	.34a	27.5a	58.0a

^zMeans within a column not followed by the same letter differ significantly at the 5% level.

Table 5. Effect of vine spreading on mean fruit weight, yield, percent marketable fruit, and percent ground scar and rot of tomatoes, 1972.

Treatment	Cumulative harvest periods							
	Aug. 8 - Aug. 28				Aug. 8 - Sept. 26			
	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	% Ground scar & rot	Ave. fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	% Ground scar & rot
Non-spread	.34a ^z	3.0a	62.2a	13.8a	.28a	22.0a	61.3a	3.0a
Spread	.34a	3.7b	62.4a	11.4a	.29a	25.3b	62.2a	2.6a

^zMeans within a column not followed by the same letter differ significantly at the 1% level.

Table 6. Effect of mulches on mean fruit weight, yield, percent marketable fruit, and percent ground scar and rot of tomatoes, 1972.

	Cumulative harvest periods							
	Aug. 8 - Aug. 28				Aug. 8 - Sept. 26			
	Fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	% Ground scar & rot	Fruit wt. (lb.)	Yield (T/A)	% Mkt. fruit	% Ground scar & rot
Non-mulch	.35a ^z	3.8a	67.8a	16.2a	.30a	27.8a	64.9a	3.8a
Mulch	.33a	4.0a	57.6a	14.6a	.28a	23.9ab	59.3a	3.3ab
Double mulch	.33a	2.2b	61.6a	7.0a	.27a	19.2b	61.2a	1.3b

^zMeans within a column not followed by a letter in common differ significantly at the 5% level.

The double mulch treatment used in 1972 resulted in a lower early yield (Aug. 8 - Aug. 28) compared to non-mulch and single mulch treatments (Table 6). For the total harvest season double mulching gave a lower yield than the non-mulch treatment. No differences in average fruit weight or percent marketable fruit resulted from mulch treatments for either the early season or total harvest season in 1972. Double mulching, however, did decrease the percentage of scarred and rotted fruit over the non-mulch treatment for the total harvest.

DISCUSSION

Pinching: The delay in fruit harvest as a result of pinching was not surprising since removal of the first inflorescence through pinching delayed fruit set for about two weeks. These results agree with experimental work on clipping of transplants in which the first inflorescence was removed (12, 13). The failure of pinching to influence fruit quality and yield for the total harvest season also agrees with previous work on transplant clipping. The greater stem length of pinched plants apparently resulted from the lack of early fruit to help slow vegetative growth on pinched plants. Earlier workers with clipping did not mention this influence on plant growth. However, the experiments on transplant clipping were performed with determinate vined processing varieties which probably would not respond as the vigorous indeterminate vined 'Manapal'. Also, clipping was performed before transplanting, which would probably influence growth differently from pinching as performed in this experiment.

Since limiting rather than increasing vine growth is often desirable with tomatoes for ground culture and since delay of fruit harvest for fresh market is usually not desirable, pinching as performed in this experiment would not appear to have application to commercial production. Also, the failure of pinching to give a more desirable distribution of growth over the soil surface or to facilitate spreading would rule out its use in conjunction with spreading.

Spreading: The effects of spreading on increasing early yield both seasons and total yield for the 1972 season are not easily

explainable. Since no differences in fruit weight resulted from spreading in either year, spreading apparently influenced yield through the number of fruit harvested. Since spreading was carried out when the plants had already set most of their fruit, spreading evidently hastened the ripening of fruit present at time of spreading.

Temperature rather than light is the major factor influencing color development in tomato fruits (16). Therefore, greater exposure of tomato fruit to sunlight by spreading branches would have its effect on ripening through modifying the temperature of fruit rather than through a direct influence of light. Perhaps spreading of branches exposed fruit to sunlight so that temperature was closer to the optimum for color development.

Internal fruit temperatures in direct sunlight, moderate shade, and heavy shade taken in the 1972 experiment show that the temperature of fruit varied with the amount of light striking the fruit. Coloring of fruit is most rapid in the temperature range of 70 to 80° F. (16). Fruit in moderate shade would probably be in this range more of the time than fruit in direct sunlight or that in heavy shade. Since spreading as carried out in these experiments probably placed more fruit in the moderate shade position, ripening could have been hastened by temperature changes of fruit brought about by spreading.

Moving of branches apart also gave better exposure of foliage to light and air circulation. Greater photosynthesis and an increased food supply for fruit development may have resulted from the spreading of vines.

The ability of vine spreading to increase early yield and possibly total yield could be of considerable value to the grower of ground tomatoes. Spreading would have increased gross returns for the cumulative harvest through August 31 in 1971 by about \$600 per acre. In 1972, spreading would have increased gross returns for the total harvest season by about \$800 (Appendix, Table 7). Labor required for spreading one acre of tomatoes, based on the 2-1/2 hour requirement for spreading 300 vines in the 1972 experiment, would be approximately 25 hours. However, the apparently easier harvest of fruit on spread plants might offset labor required for spreading. Vine spreading, therefore, appears worthy of further testing to evaluate its worth in the production of ground-grown, fresh market tomatoes.

Mulching: Results of these two experiments with mulching agree with other work showing that paper and plastic mulches increase early plant growth over clean cultivation (5, 10). The heavier plant growth at time of maturity on plastic mulched plants in 1972 agrees also with the findings of other workers (3, 4, 8, 9). This more vigorous plant growth on paper and plastic mulch has been attributed by other workers to the following reasons: increased soil temperature (3, 5, 8), more uniform soil temperature (5), soil moisture conservation (3, 4, 8, 9), weed control (3, 4, 5), elimination of root pruning by close cultivation (3, 5), maintenance of good soil physical condition (3, 5, 8), increased soil nitrogen (3), prevention of nutrient leaching (9), and increased CO₂ in the micro-climate surrounding plants (5).

Early plant growth stimulation in the present experiments probably resulted from a combination of most of these factors. However, increased soil temperature appears to have been of major importance in 1972 because of the much cooler than normal temperatures in June. Soil moisture conservation appears to have been of little benefit either year since soil moisture was high both years from time of setting plants through July. In 1971, mulch probably had its greatest influence in early season by maintaining soil structure and keeping soil drier around plants.

The greater plant growth at maturity on bare soil than on mulch in 1971 does not agree with the findings of other experiments on use of paper or plastic mulch. The only apparent explanation is that soil texture and fertility differences within the plot may have worked in favor of bare soil plants during the latter part of the growing season.

Failure of paper and plastic mulches to increase total yield of tomatoes agrees with the findings of Schales and Reynolds (20) and Nickeson (17). This result, however, disagrees with other experiments (3, 4, 8, 9), which showed increases in total and marketable yields for mulching with black plastic.

Plant spacing used in the present experiments as compared to other studies may be responsible for the failure to show a yield increase. Plants in the two present experiments were grown at a spacing giving 15 sq. ft. per plant. Clarkson & Frazier (4) grew their plants at a spacing with 24 sq. ft. per plant. Carolus and Downes (3) used 14 sq. ft. for the small determinate vined Fireball cultivar and 21 sq. ft. for the indeterminate 'Moreton Hybrid'. Geraldson (9)

used 9 sq. ft. for the determinate cultivar Step 410. The wider spacings used by Clarkson and Frazier and Carolus and Downes would certainly have favored yield on their larger growing mulched plants, since photographs of their plots showed bare soil between rows of both unmulched and mulched plants. Considering plant size, Geraldson's spacing was closer to the spacing in the present experiments. However, he was working with a sandy soil on which he attributed his yield increase for mulching to the prevention of nutrient leaching.

A wider spacing of plants in the 1972 experiment would probably have favored yield on plastic mulch because of the larger vine growth on mulch. However, growing more plants per acre at the decreased spacing required on bare soil because of less vine growth would also increase yield. Because of the different space requirements of mulched and unmulched tomatoes, comparison of yields of both grown at the same spacing is likely to favor one or the other depending on the spacing used.

The high soil moisture level throughout both growing seasons would prevent mulch, by its moisture conserving ability, to aid in increasing yield in either of these experiments. This agrees somewhat with Carolus and Downes's work in which yields of 'Moreton Hybrid' tomato were increased 47 percent by black plastic on unirrigated plots and only 31 percent on irrigated plots (3). Also, straw mulching experiments have shown more benefits on yield in dry years than in wet years (2, 18) and have even been detrimental to yield in excessively wet years (18).

The lower early yield of tomatoes on the double mulch treatment resulted from frost killing plants, which necessitated replanting, and by the first inflorescence being destroyed on other plants. The lower yield for the entire harvest season of double mulched compared to unmulched plants probably resulted from verticillium wilt affecting double mulch yield more because of its lateness.

It was observed during harvesting that a fruit on bare soil, plastic, or straw which had the weight of the vine or other fruit pressing it against the surface often showed rot or scarring severe enough to make it unmarketable. This was particularly true of early set fruit which ended up under the vine as a result of the vine falling to one side. Later set fruit which was observed to lie entirely free of surface contact or to lie with only its own weight holding it against the soil or mulch surface showed little scarring. As harvest progressed toward the ends of the vines, less and less fruit had enough surface contact to give scarring. This is evident from the percentages of ground scar and rot for early and total seasons in Table 6. Rotted fruit in both seasons was negligible compared to other reasons for cullage.

The failure of mulching to increase quality of fruit in early season (August 5 - August 16 in 1971 and August 8 - August 28 in 1972) or for the total harvest season appears to have resulted from 3 reasons: 1) fruit was held off the ground and did not benefit from mulching; 2) the weight of the vine on the fruit caused it to rot or scar severely enough to be unmarketable whether on mulch or bare soil; 3) fruit rested on soil or mulch lightly enough that no appreciable

difference in scarring or rotting occurred. The increase in percent marketable fruit for mulch for the cumulative harvest through August 31 in 1971 apparently resulted from a decrease in ground scar and rot brought about by the mulch.

In 1971, much of the fruit harvested from mulched rows after August 31 was located on the bare soil area between the mulch. Also, heavy weed growth between mulch adversely affected fruit size and quality. The increase in quality of fruit from unmulched plants over mulched plants in the latter part of the season of 1971 resulted from greater vine growth and less weed competition on unmulched plants.

The ability of straw mulch to decrease the percent of ground scarred and rotted fruit over clean cultivation for the total harvest season agrees with the findings of Werner (23). However, the percentage levels of scarred and rotted fruit in the 1972 experiment were so small that the difference was not reflected in percent marketable fruit.

Relatively dry weather during most of both harvest seasons probably favored fruit quality on bare soil over that which would be expected in a wet harvest season. However, the months of August and September are usually relatively dry in southwest Virginia (Table 1), which would make the 1971 and 1972 harvest seasons fairly typical. The thorough spray program used in both years was probably also responsible for minimizing the amount of fruit lost to rot.

Because of the failure of paper and plastic mulches or the combination of plastic and straw mulch to increase total season yield or percent marketable fruit, mulching systems as tested in this study

would appear to be of little value during similar wet seasons in the production of late season, ground-grown tomatoes.

With early season, determinate vined cultivars mulching with black plastic might increase earliness because of increased early plant growth and fruit development resulting from higher soil temperatures as measured in the 1972 experiment. For growers lacking irrigation, mulching would probably be of considerable value in dry seasons because of soil moisture conservation.

The cost of black plastic for mulching one acre as applied in these tests is approximately \$125. Additional costs of mulching resulting from machine and labor costs in laying the mulch, extra labor required in hand-setting plants through mulch, and labor required for removing mulch following harvest would probably amount to about \$75 per acre. With a high value crop such as fresh market tomatoes, small increases in early yield, total yield, or fruit quality could return enough extra income to pay the additional costs of mulching.

LITERATURE CITED

1. Anonymous. 1915. Mont. Agr. Exp. Sta. Ann. Rpt. for 1913-14: 396.
2. _____. 1922. Mulching vs. clean cultivation for vegetables. Ohio Agr. Exp. Sta. Ann. Rpt. for 1921-22. Bul. 362: xxvi-xxvii.
3. Carolus, R. L., and J. D. Downes. 1958. Studies of muskmelon and tomato responses to polyethylene mulching. Mich. Agr. Exp. Sta. Quart. Bul. 40(4): 770-785.
4. Clarkson, V. A., and W. A. Frazier. 1957. Plastic mulches for horticultural crops. Oregon Agr. Exp. Sta. Bul. 562.
5. Courter, J. W., and N. F. Oebker. 1964. Comparisons of paper and polyethylene mulching on yields of certain vegetable crops. Proc. Amer. Soc. Hort. Sci. 85: 526-531.
6. Edmond, J. B. 1929. Mulch paper for vegetable crops is tested. Mich. Agr. Exp. Sta. Quart. Bul. 11(3): 115-117.
7. Emerson, R. A. 1903. Experiments in mulching garden vegetables. Neb. Agr. Exp. Sta. Bul. 80.
8. Emmert, E. M. 1957. Black polyethylene for mulching vegetables. Proc. Amer. Soc. Hort. Sci. 69: 464-469.
9. Geraldson, C. M. 1962. Growing tomatoes and cucumbers with high analysis fertilizers and plastic mulch. Proc. Fla. State Hort. Soc. 75: 253-260.
10. Hutchins, A. E. 1933. Mulch paper in vegetable production. Minn. Agr. Exp. Sta. Bul. 298.
11. Isenberg, F. M., and M. L. Odland. 1950. Comparative effects of various organic mulches and clean cultivation on yields of certain vegetable crops. Pa. Agr. Exp. Sta. Progr. Rpt. 35.
12. Jaworski, C. A., and R. E. Webb. 1966. Preliminary tests on the performance of clipped tomato transplants. Proc. Amer. Soc. Hort. Sci. 91: 550-555.
13. _____, G. E. Wilcox, and S. A. Garrison. 1969. Performance of tomato cultivars after various types of transplant clipping. Proc. Amer. Soc. Hort. Sci. 94: 614-616.
14. Lockhart, C. L., and E. W. Chipman. 1963. Chemical and cultural treatments for the control of storage rots of tomatoes. Can. J. Plant Sci. 43: 503-507.

15. Magruder, R. 1928. Paper mulch for the garden. Ohio bi-monthly Bul. 133. XIII (4): 144-147.
16. Minges, P. A., 1962. Fruit ripening and defoliation. Amer. Veg. Grower 10(9): 12.
17. Nickeson, R. 1960. Mulch protection for vegetables. S. Dak. Farm and Home Res. 11 (3): 18-22 (Orig. not seen).
18. Rosa, J. T. 1923. Controlling soil moisture for vegetable crops in Missouri. Mo. Agr. Exp. Sta. Bul. 204.
19. Rowe-Dutton, Patricia. 1957. The mulching of vegetables. Commonwealth Bur. Hort. and Plant Crops Tech. Commun. 24.
20. Schales, F. D., and H. S. Reynolds. 1966. Vegetable mulching in Virginia--developments during 1965. The Veg. Growers News 20 (9): 3-4.
21. Sheldrake, R., Jr., and J. W. Boodley. 1965. Commercial production of vegetable and flower plants. Cornell Univ. Ext. Bul. 1056: 18.
22. Thompson, H. C., and H. Platenius. 1931. Results of paper mulch experiments with vegetable crops. Proc. Amer. Soc. Hort. Sci. 28: 305-308.
23. Werner, H. O. 1933. Soil management experiments with vegetables. Neb. Agr. Exp. Sta. Bul. 278.

A P P E N D I X

Table 7. Estimated market values of fruit harvested from non-spread and spread treatments in 1971 and 1972.

Treatment	Time period	Mkt. fruit (T/A)	Price/ton ^z	Gross mkt. value
		1971 ^y		
Non-spread	Aug. 5 - Aug. 16	1.31	x \$375	= \$491.25
	Aug. 17 - Aug. 31	3.51	252	884.52
	Sept. 1 - Sept. 28	10.86	297	3255.42
Med. spread	Aug. 5 - Aug. 16	1.96	375	735.00
	Aug. 17 - Aug. 31	4.66	252	1174.32
	Sept. 1 - Sept. 28	10.67	297	3168.99
Max. spread	Aug. 5 - Aug. 16	1.71	375	641.25
	Aug. 17 - Aug. 31	5.66	252	1426.32
	Sept. 1 - Sept. 28	10.77	297	3198.69
		1972		
Non-spread	Aug. 8 - Aug. 28	1.87	418	781.66
	Aug. 29 - Sept. 25	11.62	340	3950.80
Spread	Aug. 8 - Aug. 28	2.31	418	965.58
	Aug. 29 - Sept. 25	13.43	340	4566.20

^zPrices based on marketing information furnished by Southwest Virginia Growers Co-op, Nickelsville, Virginia.

^yData from non-pinch treatments only.

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EFFECTS OF MULCHING, PINCHING, AND VINE SPREADING
ON PRODUCTION OF FRESH MARKET TOMATOES

by

Randolph Gilbert Gardner

(ABSTRACT)

Field experiments were conducted with the tomato cultivar Manapal during the 1971 and 1972 growing seasons to test the effects of mulching, pinching, and vine spreading on production of ground-grown, fresh market tomatoes.

Pinching out the apex of tomato plants 7 days after field setting in 1971 delayed fruit harvest but did not affect total yield or fruit quality. Pinching gave no better natural distribution of foliage over the soil surface than non-pinching and made spreading more difficult by stimulating vegetative growth.

Hand spreading the main branches of mature tomato vines prior to the first fruit harvest increased early season yield both years and increased total season yield in 1972 without affecting average fruit weight, percent marketable fruit, or percent ground scar and rot.

Mulching with polyethylene coated kraft paper in 1971 did not influence average fruit weight or yield for either the early or total harvest season. Mulching increased the percent marketable fruit for the cumulative harvest through August but did not affect quality for the total harvest season. Mulching with black plastic in 1972 did not affect average fruit weight, yield, percent marketable fruit, or

percent ground scar and rot for either the early or total harvest season. Mulching with a combination of plastic and straw decreased the percent of ground scar and rot compared to non-mulching for the total harvest season without influencing average fruit weight or percent marketable fruit.