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Fertilizer-Plant Population Studies for Once-Over Tomato Harvest[1]

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Abstract. Growth rate of several tomato cultivars, indexed by stem diameter measurements, was not influenced by broadcasting 50–100–100 lb./A fertilizer, by sidedressing 60 to 80 lb N, or by increasing the plant population from 5,800 to 23,200 plants/A in either single or dual rows at 2 locations.

Broadcasting 5–10–10 fertilizer prior to planting increased total yields, but the earliest maximum yield of marketable fruit was delayed. Sidedressing N also delayed the earliest maximum yield.

Fertilizer application did not influence fruit size, but size was reduced at high plant populations and at later harvests. The once-over maximum yield was increased at a high plant population when spacing between dual rows was 18 or 24 inches.

Mechanical harvest of tomatoes for processing is continuing to get attention in eastern United States. In the Mid-west, the date of occurrence of the earliest once-over maximum yield of red, ripe fruit on determinate plants was predicted approximately 50 days prior to harvest if plants are spaced 16 to 18 inches in the row, (2). In general, high plant population per acre is recommended for tomatoes grown for machine harvest to maximize early yield and profit (5).

The literature is replete with reports of the general fertility requirements and spacing of field-grown tomato plants (3, 5, 6, 7, 8, 9, 10). Experiments have shown that at close plant spacings high fertility levels are required to increase the total yield and number of fruit per plant.

This investigation was initiated to determine the influence of fertilizer and plant spacing on growth, date of the earliest maximum yield, and the total yield of tomatoes grown for machine harvest.

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Materials and Methods

Studies were conducted over a 4-year period at 2 locations. In 1966, Georgia-grown tomato plants of 'Heinz 1350' were transplanted into 20-ft rows in a factorial experiment utilizing the split-plot design at Blacksburg, Virginia. There were 3 replications, 3 levels of fertility, 3 plant spacings in the row, and 3 harvest dates. Guard plants were used in the borders between fertilizer treatment plots of each replicate and at each end of every row.

The soil was a Groseclose silt loam, with a pH of 6.1, high to very high in available P and K, and medium to high for Ca and Mg.

The fertilizer treatments used were 50, 100, and 150 lb./A N and 100, 200, and 300 lb./A of both P and K.

In December about 1/3 of the 5–10–10 fertilizer was broadcast over a rye cover crop. The second increment, approximately 1/3, was broadcast just before plowing in May. Each plant was treated with 1/2 pint of 10–52–17 starter solution (3 lb./50 gal. water). The final 1/3 of the fertilizer was sideplaced at the last cultivation in June.

Three rows, 5 feet apart, were planted in each spacing plot, permitting 3 harvests. Plant populations at spacings of 18, 9, or 4.5 inches in a row were 5,800, 11,600, and 23,200 plants/A. After the majority of fruits were set, guard plants at the end of each row were removed.

Similar plantings were made in 1967, 1968, and 1969 using Georgia-grown cultivars 'ES 24' in 1967, 'Campbell 16' in 1968, and 'Campbell 17' in 1969. Each year, cultivars were transplanted into 20 ft rows in a factorial experiment utilizing the right-angle split-plot design. There were 4 replications, 4 levels of fertility, 4 plant spacings, and 3 once-over harvests. Guard plants were planted in the outside rows of each replicate and at each end of record rows. These experiments were located at both Blacksburg and Painter, Virginia in 1967 and at Painter, only, in 1968 and 1969. In both areas, the soils were heavily fertilized for vegetable crops in the past.

The soil at Painter is a Sassafras fine sandy loam. Fertilizer was applied at the following rates (in lb. per acre): 1967—none, 50–100–100 broadcasted 13 days prior to planting, 5–100–100 broadcasted + 40–0–0 as NH_4NO_3 after second cluster set, and 50–100–100 broadcasted + 80–0–0 as NH_4NO_3 after second cluster set; 1968—none, 50–100–100 broadcasted 6 days prior to planting, the broadcast treatment with ureaform and NH_4NO_3 each sidedressed 21 and 42 days, respectively, after planting to give 60 lb./A N; 1969—none, 50–100–100 broadcasted 13 days prior to planting, the broadcast treatment with ureaform and NH_4NO_3 each sidedressed 43 days after planting to give 60 lb./A N.

In each of the 3 years, single and dual rows were compared in each of 2 populations, 5,800 and 1,600 plants/A. Spacing in single rows on 5-ft centers had 9 and 18 inches between plants. Dual row plants consisted of rows 14 inches apart in 1967 and 1968 and 24 inches apart in 1969 on 5-ft centers with 18 and 36 inches between plants.

In each of the 4 years, diameter measurements were made of the main stem, within one inch of ground level. In each year except 1969, stems were marked with a felt pen to insure measurement at the same location. Three randomly selected plants in each fertilizer-spacing treatment were measured every 7 days for the first 6 weeks after transplanting and then every 3 or 4 days until their stems stopped enlarging. The date that stem enlargement ceased was determined by the method described by Austin and Ries (2). In 1969, mylar bands were used as described by Alls and Austin (1) to approximate the date that the stem stopped enlarging.

An additional spacing experiment with 'Campbell 16' was conducted in Blacksburg in 1969. Greenhouse seedlings were pricked out 2 weeks after April 4 seeding and transplanted in the field 4 weeks later. The treatments were arranged in a split-plot factorial design with 4 replications. The treatments consisted of single rows on 5-ft centers, 9 inches between plants, dual rows 12, 18, and 24 inches apart, each on 5-ft centers with 18 inches between plants. Stem diameter measurements were used to determine the harvest dates, and 3 harvests were made at 7-day intervals beginning 44 days after stem enlargement ceased.

In 1966, the date of the occurrence of the earliest once-over maximum yield of ripe fruit of 'Heinz 1350' was predicted to be 54 days after the stem stopped enlarging. Once-over destructive harvests were made 10 days prior to the predicted date, on the predicted date, and 10 days after the predicted date. Weights of red ripe, green, and deteriorated fruit were obtained at each once-over harvest. The first harvest of 'ES 24' in 1967 was made 30 and 42 days after stem enlargement ceased at Painter and Blacksburg, respectively. In 1968 and 1969, the earliest harvest date was 35 days after the stems stopped enlarging. In each of the 3 years, 3 harvests were made on each treatment at 7-day intervals. Weights of red ripe, near-ripe (red inside, but not fully red on the outside), green, and deteriorated fruits were obtained at each once-over harvest. Counts were made of the red ripe fruit in 1968 and 1969 in order to estimate fruit size.

Results and Discussion

Fertilizer and spacing treatments had no significant effect on the number of days before the stems stopped enlarging in any of the experiments. This lack of response to treatments may have been due to several factors such as: "hardened" transplants in some of the experiments, relatively large variation in plant size in each replicate, and a failure of tomato stems to respond to additional fertilizer when soil levels were high in mineral nutrients.

A once-over maximum yield of ripe fruit was obtained at each predicted harvest in 1966 (Table 1). Varying plant spacing in the row did not influence the percent or yield of ripe fruit. The average once-over maximum yield for the 3 fertilizer levels and 3 plant spacings was about 17 T/A.

The highest percent of ripe fruit was obtained from those plots which were fertilized with 50–100–100 lb./A. This constituted only 60% of all the fruit harvested and was similar to the results in Michigan in 1962 and 1963 with yields between 55 and 60% of ripe fruit (2). There were no differences in the total weight of fruit among the fertilizer or spacing treatments.

In Blacksburg in 1967, the maximum yield for a once-over destructive harvest was obtained at the 3rd harvest, 60 days after the stem stopped enlarging and 118 days after transplanting. Varying fertility rate and plant spacing did not influence the tons per acre or the percentage of marketable fruit. The average once-over maximum

Table 1. The effect of different rates of 5–10–10 fertilizers and plant spacing on the predicted harvest dates and yield of 'Heinz 1350' in 1966.

Fertilizer lb.	Spacing inches	Harvests 1	2[x]	3	Average[y]
		Percent ripe fruit			
1000	18 × 60	44	54	45	
	9 × 60	46	61	46	
	4.5 × 60	46	65	45	
					50a
2000	18 × 60	46	61	41	
	9 × 60	28	57	45	
	4.5 × 60	33	49	47	
					45b
3000	18 × 60	46	50	48	
	9 × 60	44	55	48	
	4.5 × 60	39	52	45	
					47b
Average[y]		41a	56c	45b	

[x]Predicted harvest time.
[y]Means followed by different letters are significantly different at the 5% level.

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yield of ripe and marketable fruit was about 13 and 18T, or 46 and 64%, respectively. These data indicate that the sequence of harvesting was begun too soon to be sure that 18T of marketable fruit was the earliest maximum yield. Also, there might have been more ripe and less near-ripe fruit with a later harvest. These results are similar to those obtained in 1966 at Blacksburg, using the 'H-1350'.

At Painter, significant interactions were noted between fertilizer rate and harvest date and between plant spacing and harvest date (Table 2). With no fertilizer, the earliest maximum yield of about 7T was obtained 35 days after stem enlargement ceased or 85 days from transplanting, and this maximum yield did not change for at least 15 days. Although green fruit were reduced from 10 to 1T during the same period. Broadcasting 50–100–100 lb./A did not influence the time when the earliest maximum yield occurred. Although the yield was increased to 9.3T of marketable fruit and remained unchanged for 14 days (Table 2). The percentage of marketable fruit changed from 33 to 67% and green fruit decreased from 15 to 1T during this period.

Sidedressing with N delayed the time of the earliest maximum yield by 2 weeks (Table 2). Ten and 11T of marketable fruit were obtained by additions of 40 and 80 lbs. of N, respectively, about 48 days after the stem ceased to enlarge or 100 days after transplanting. These data show that a higher once-over tomato yield may be obtained on a fertile sandy loam by further application of a complete fertilizer. Sidedressing additional N caused a slight increase in yield, but delayed the occurrence of the maximum yield.

At 5,800 plants/A, the earliest maximum yield of marketable fruit from plants spaced 36 inches apart in dual rows was 8 days earlier than from plants spaced 18 inches in single rows. However, there was no difference in the yield of marketable fruit (Table 3). The earliest maximum yield, constituting 69% of the total fruit harvested and 2T green fruit, was obtained from the single row. The marketable yield from dual rows constituted 46% of the total fruit and 5½T green. The maximum yield from dual rows, however, did not change for 7 days, and there was 65% of fruit marketable and only 2T green fruit from the later harvest.

Table 2. Effect of fertilizer rates on once-over harvest yield of marketable fruit of 'ES 24' at Painter, Virginia, 1967.

Fertilizer lb.	Harvest	Marketable fruit Tons	Marketable fruit Percent	Green fruit tons
None	1	7.4a[w]	35	9.8
	2	6.6a	41	4.1
	3	7.2a	63	0.9
1000[x]	1	9.3b	33	14.9
	2	11.0b	52	4.9
	3	10.9b	67	1.0
1000[y] +40	1	6.8a	27	13.6
	2	8.2a	43	4.7
	3	10.4b	61	1.7
1000[z] +80	1	6.3a	23	15.7
	2	10.2b	48	5.9
	3	11.3c	64	3.3

[w]Means not followed by the same letter are significantly different at the 1% level.
[x]1000 lb/A 5–10–10.
[y]1000 lb/A 5–10–10 + 40 lb N using ammonium nitrate.
[z]1000 lb/A 5–10–10 + 80 lb N using ammonium nitrate.

Table 3. Effect of plant spacing on once-over harvest yield of marketable fruit of 'ES 24' at Painter, Virginia, 1967.

Spacing inches	Harvest	Marketable fruit Tons	Marketable fruit Percent	Green fruit tons
18 × 60 5800 plants	1	7.0a[x]	27	14.3
	2	9.7a	50	4.2
	3	11.8b	69	2.0
36 × 14 × 60 5800 plants	1	6.5a	24	15.4
	2	10.2b	46	5.4
	3	10.2b	65	1.9
18 × 14 × 60 11,600 plants	1	7.6a	31	12.0
	2	8.9a	45	5.2
	3	9.0a	64	1.4
9 × 60 11,600 plants	1	8.7a	36	11.3
	2	7.3a	42	4.6
	3	8.8a	62	1.7

[x]Means not followed by the same letter are significantly different at the 1% level.

The earliest maximum yield of marketable fruit was obtained at least 5 days earlier by growing plants at 11,600 plants/A rather than at 5,800 plants/A, but the yields were not as high. When comparing dual and single rows at 11,600 plants/A, no differences in the time of the earliest maximum harvest or yield in the tonnage of fruit were observed. The maximum yield occurred about 35 days after the stem stopped enlarging or 85 days after transplanting and did not change for about 15 days. At the first harvest, over 11T of fruit were green and only about 34% were marketable; 15 days later, only about 1½T were green and 63% were marketable. These data show that the occurrence of the earliest maximum yield will vary and that it is important to know when it will occur so that harvesting can be scheduled accordingly.

The average yield of marketable fruit obtained from the plant population treatments in Blacksburg was about 7T higher than that obtained at Painter. While a trend toward increased yield was noted at the higher plant population at Blacksburg, the difference was not statistically significant, just the opposite from that obtained at Painter.

The time period from when the stem stopped enlarging to the earliest maximum yield differed at Blacksburg and Painter. This, as well as the observed differences in yield, may have resulted from differences in soil type, moisture, and temperature between locations. For example, there was about a 4°F difference between the average minimum temperatures (Fig. 1). Similar temperature differences were observed in 1968. Austin and Ries (2) reported that the once-over maximum yield was obtained within 6 days or less of the predicted date, using the index when the stem stopped enlarging, in 13 out of 14 plantings. The plantings consisted of several cultivars located in East Lansing, Michigan; Leipsic and Napoleon, Ohio; Frankfort, Indiana; and Morris, Marengo, and Waterman, Illinois.

There were significant interactions between fertilizer application and harvest time in 1968 (Table 4). With no fertilizer, the earliest maximum yield of approximately 14T of ripe and near-ripe fruit was obtained at the first harvest and did not change for at least 14 days. However, about 7½T of fruit were green and only 59% of the

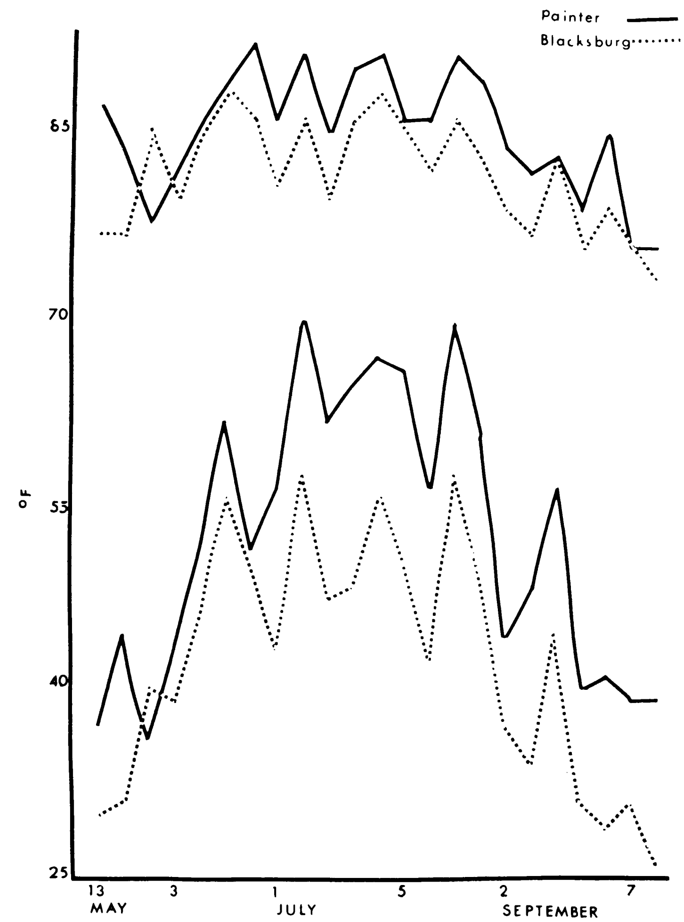

Fig. 1. Average maximum and minimum temperatures at Blacksburg and Painter, Virginia during the 1967 growing season.

fruit were marketable. At the third harvest, only 1T of fruit was green, but the percentage of marketable fruit decreased, due to a large amount of deteriorated fruit. Except for the deterioration, these results are similar to those obtained in 1967, when no fertilizer was used.

Fertilizer, 50–100–100 lb./A delayed the time when the earliest maximum yield occurred by one week (Table 4).

Table 4. Effect of fertilizer on once-over harvest yield of 'Campbell 16' in 1968 and 'Campbell 17' in 1969 at Painter, Virginia.

Fertilizer lb.	Harvest	Ripe and near-ripe fruit[w]			
		1968		1969	
		Tons	Percent	Tons	Percent
None	1	14.3b	59b	12.1a	58a
	2	13.8b	62b	6.6b	52a
	3	7.9a	43a	3.0c	37c
1000[x]	1	13.8b	44a	14.6a	57a
	2	20.6c	69c	7.0b	54a
	3	14.7b	59b	3.4c	38c
1000[y] +60 N	1	15.4b	47a	15.5a	60b
	2	20.8c	67c	7.5b	60b
	3	15.7b	58b	3.6c	44c
1000[z] +60 N	1	15.1b	49a	14.9a	61b
	2	18.9c	63b	8.6b	62b
	3	14.7b	52b	5.0c	45c

[w]Means not followed by the same letter are significantly different at the 1% level.
[x]1000 lb/A 5–10–10 broadcasted prior to planting.
[y]1000 lb/A 5–10–10 + 60 lb N sidedressed (ureaform).
[z]1000 lb/A 5–10–10 + 60 lb N sidedressed (ammonium nitrate).

About 20½T of ripe and near-ripe fruit were obtained about 42 days after the stem ceased to enlarge, or 86 days from transplanting. The highest percentage of marketable fruit was obtained at the second harvest. Additional N did not influence the time when the earliest maximum yield occurred, or the tonnage. Ammonium nitrate did not increase the percentage of marketable fruit in the second harvest beyond that of no fertilizer applied.

The highest yield of marketable fruit was obtained at the first harvest in 1969 (Table 4). Before the third harvest, during the week of August 16–22, 3.6 in. of rain fell and even with a vigorous spray program, many of the fruits deteriorated and failed to provide any useful data. There was a slight increase in marketable fruit when additional fertilizer was used. Sidedressing with additional N increased the percentage of marketable fruit.

Doubling the plant population increased the yield of marketable fruit (ripe and near-ripe) from about 14 to 17T in 1968, but did not influence the yield in 1969.

Size of fruit was influenced by plant population and harvest date, but not by fertilizer treatment. The higher plant population produced smaller fruit. Fruit size decreased with successive harvests. This is probably due to the deterioration of the earlier fruit and ripening of later formed fruit, which are typically smaller.

The effects of varying spacing of the same plant population per acre (11,600) are shown in Table 5. Spacing between dual rows at 18 or 24 inches increased the yields of marketable fruit when plant populations were 11,600/A. The yield of marketable fruit did not exceed 67%, which was the amount obtained at the first harvest. However, dual rows 18 and 24 inches apart had about 15% deteriorated fruit at the first harvest. When plants were spaced closer together, deteriorated fruit increased to 23%. The yield of marketable fruit decreased in successive harvests. These data indicate that once-over harvests began relatively late to ensure the earliest maximum yield. The rapid breakdown of the fruit was attributed to 3.73 inches of rain during the harvest period.

Conclusions

The influences of soil fertility and plant spacing on growth and fruiting behavior of several tomato cultivars at 2 locations were studied. Stem diameter measurements indicated that the growth rate was not influenced by broadcasting 50–100–100 lb./A fertilizer or by sidedressing with up to 80 lb. N. Also, increasing the plant

Table 5. Effect of plant spacing on once-over harvest yield of 'Campbell 16' at Blacksburg, Virginia, 1969.

Harvest	Spacing inches	Ripe		Marketable	
		Tons	Percent	Tons	Percent
1	9 × 60	11.3a[x]	48	14.6a[x]	59
	12 × 18 × 60	13.2a	44	16.8ab	56
	18 × 18 × 60	16.2b	52	19.6b	63
	24 × 18 × 60	18.0b	56	21.5c	67
2	9 × 60	7.8a	44	9.4a	54
	12 × 18 × 60	6.9a	38	8.6a	48
	18 × 18 × 60	12.6b	44	15.9b	56
	24 × 18 × 60	10.9b	43	12.8c	50
3	9 × 60	6.1a	46	6.6a	50
	12 × 18 × 60	5.9a	42	6.5a	46
	18 × 18 × 60	7.2a	44	8.1a	50
	24 × 18 × 60	6.4a	37	7.7a	44

[x]Means not followed by the same letter are significantly different at the 1% level.

population from 5,800 to 11,600 plants per acre in either single or dual rows did not influence stem growth.

Broadcasting a complete fertilizer on a sandy loam, prior to planting, increased tomato yields, but the earliest once-over maximum yield of marketable fruit was delayed. Larger yields were obtained when spacing between plants was 18 inches or greater.

Fertilizer application did not influence fruit size, but high plant populations and later harvest reduced fruit size.

The length of time from when the stem stopped enlarging to the earliest maximum yield and the size of the maximum yield varied between Blacksburg and Painter. This may have resulted from differences in soil type, moisture, or the average minimum temperature.

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Increasing the Number and Crotch Angles of Primary Branches of Apple Trees with Cytokinins and Gibberellic Acid[1]

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Abstract. Cytokinins and gibberellins applied to dormant buds on young apple trees significantly increased the number of growing buds and the angle between the main trunk and the new shoot. Total shoot growth on treated trees was nearly double that of control trees. Nursery trees treated with growth regulators several weeks before planting produced branches with wide crotch angles from which good permanent primary scaffold limbs could be selected.

The first branches on an apple tree usually become the primary scaffold limbs and remain on the tree throughout its entire life. 'Delicious' apple trees grow vigorously, and the primary scaffold limbs develop narrow crotch angles that later become subject to winter injury, breakage, and disease (2, 13).

Various cultural practices and mechanical devices are used to increase the number and crotch angle of shoots on newly planted apple trees. Notching of the bark above a bud will encourage the bud to break, but may cause narrow crotch angles (13). Delayed and, especially, low heading of young trees increases bud break and crotch angle (11, 14). Plastic discs and other devices can also be placed above new shoots to increase crotch angles. All of these methods are helpful but often do not achieve the desired goal.

Cytokinins can stimulate the growth of apple buds when applied a month or so before spring growth is initiated, and will overcome apical dominance in actively growing apple shoots (15) and in other species (1, 7, 8). Indolebutyric acid (13) and 2,3,5-triiodobenzoic acid (2) have also been reported to increase branch angles on apple trees.

The present report describes the effect of cytokinins used alone and in combination with gibberellins on bud break, crotch angle, and total growth of the primary branches of standard 'Delicious' apple trees.

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Materials and Methods

We used 'Delicious' trees 4 to 5 ft in height on seedling rootstock, dug from the nursery in the fall and held in storage at 35° to 40° F until planting time. One and 2 months before planting, we treated the buds with lanolin paste containing cytokinins and gibberellins. The cytokinins, 6-benzylamino purine (BA), and 6-benzylamino-9-(tetrahydropyranol)-9H-purine (BAP[4]) and gibberellins A_4 and A_7 (GA_{4+7}) were dissolved in a small volume of 95% ethanol and blended with water and lanolin (1/3, v/v). The lanolin was an acetone soluble fraction of anhydrous lanolin (6). The mixture was applied by brush to individual buds or to the entire trunk area including buds and bark. We grew the trees treated 2 months before planting in the greenhouse, and those treated 1 month before planting, or at planting time, in the orchard. When the shoots from the treated buds were about 1 inch in length, we cut off or headed the trees at 2 buds above the treated area. Control trees were headed at the same height. Each treatment consisted of 8 trees with 8 buds per tree.

When growth ceased and all of the terminal buds were formed, we determined the percent of treated buds that had broken, the crotch angles and total shoot growth per tree. The data were analyzed by analysis of variance and

[4]Supplied by Shell Development Company as experimental compound SD 8339.