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EXPERIMENTS WITH GREENHOUSE TOMATOES:

Varieties, Cultural Methods, and Relationship Between Yield and Vegetative Vigor

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SUMMARY OF RECOMMENDATIONS

Michigan State Forcing and a forcing strain of Marglobe are desirable varieties of tomatoes for greenhouse production in Oklahoma.

Yields can be increased by close spacing of plants. A spacing of 24 x 21 inches was found to be most desirable. A good type of soil, liberally fertilized, is necessary to support the greater number of plants per unit area.

It is generally possible to secure continuous production from the same plants throughout the entire forcing season. Such a practice appears practical in this region.

The use of a smaller number of plants per unit area and training them to two stems is less satisfactory than closer spacing of plants and training them to a single stem.

Proper management to maintain fairly vigorous vegetative growth, as indicated by the diameter of the stem, is desirable to maintain good production over an extended period of time.

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INTRODUCTION

The vegetable forcing industry in Oklahoma and surrounding states is at present relatively small, but the possibilities for expansion appear quite favorable because of climatic and economic factors. Mild, open winters coupled with the availability of natural gas at a very low rate provide conditions for minimum heating costs. Sufficient clear weather generally prevails to get tomato fruits set throughout the forcing season. Under such conditions production can be continuous, instead of being interrupted by the eight- to ten-week period of non-production during the winter which is usual where sunshine is more limited.

The existing markets for greenhouse tomatoes in Oklahoma, and in cities in northern states which are near enough to avoid excessive transportation costs, provide an outlet for the production from a considerable increase in acreage.

Most of the experimental work on greenhouse tomatoes has been done in northern and eastern states. Because of the difference in conditions in those areas as compared to this region it seemed desirable to conduct some tests to provide applicable information for local growers.

FACTORS STUDIED

The work reported in this bulletin included the following phases of greenhouse tomato production: (1) Variety tests to determine the most desirable variety or varieties; (2) spacing trials to determine the most economical spacing and planting arrangement for fall and spring grown crops; (3) comparison of the response from plants trained to one and two stems; (4) investigation of the possibility of continuous production from

* Appreciation is expressed to Earl F. Burk, formerly of this Station, who was in charge of the work for one year.

the same plants through the entire forcing season; (5) determination of the relationship between vegetative vigor and fruitfulness.

GENERAL PROCEDURE IN GROWING CROPS

The house in which all of the crops were grown is 100 feet by 30 feet. The soil was fairly heavy silty clay loam underlain with a hard-pan at a depth of 15 inches. Approximately two inches of medium sand was incorporated with the upper 10 inches of soil to improve the physical character. Each year a heavy coating of fresh strawy horse manure was applied and spaded into the soil preceding the fall crop. The soil was steam sterlized once a year by means of 4 inch tile lines spaced 24 inches apart. The sterilizing was done after the manure had been mixed with the soil.

Annual applications of 20 percent superphosphate at the rate of 1,000 pounds per acre, and muriate or sulphate of potash at the rate of 750 pounds per acre, were made after the soil had been sterilized. The fertilizer was mixed with the soil by spading before setting the plants.

Nitrogen fertilizers were applied as top dressings whenever the need was indicated by a light color of the plants and slowing up in growth. The first application was usually put on when the third or fourth clusters were setting fruits. Subsequent treatments were given at 10 to 15 days intervals, depending on the amount of sunshine prevailing. During cloudy periods the applications were made at the longer intervals. Ammonium sulfate was generally used because the soil reaction was neutral to slightly alkaline. The ammonium sulfate was applied at the rate of 200 pounds per acre. This was mixed with the top soil by shallow cultivation and then washed into the soil by watering.

Manganese deficiency symptoms developed in the plants from time to time throughout the course of the experimental work. Because manganese is unavailable to plants in soils having an alkaline reaction an attempt was made to correct the deficiency by applications of sulfur and iron sulfate to make the soil slightly acid. Changing the soil reaction was ineffective in correcting this trouble; but the addition of manganese sulfate at the rate of 150 pounds per acre cleared up the deficiency symptoms. Four applications of manganese sulfate were made during the six-year period covered by the experiments.

Seed was planted in flats and the seedlings were transplanted into four-inch standard pots three or four days after emergence. The plants were set in the bed when six to eight inches high, which was four to five weeks after seeding. Seed was planted around August 1 for the fall crops, and December 20 for the spring crops.

The temperature in the house was maintained at 60° F. to 65° F. at night, approximately 70° F. on cloudy days, and 75° F. to 80° F. on clear days.

Watering was generally done by running the water into the sterlizing tile lines. The presence of a hardpan just below the tile made subirrigation possible. Subirrigation was especially desirable during the winter months, as the surface of the soil remained relatively dry and helped materially in the prevention and control of leaf mold. As the spring season advanced, overhead watering was employed to maintain a higher relative humidity and prevent blossom-end rot. When a top dressing of fertilizer was applied, an overhead Skinner irrigation line was used to wash the fertilizer into the soil.

Blossom-end rot affected many fruits of the first two spring crops. Sudden and wide variations in outdoor temperature, humidity, and wind velocity made it difficult to maintain sufficiently uniform moisture and humidity conditions in the greenhouse to prevent blossom-end rot. For the fourth and subsequent crops, an automatically controlled humidifying system was installed; and this reduced the amount of blossom-end rot about 90 percent. The humidistat was set at 35 percent, which prevented the relative humidity from dropping below that level.

Tomato wilt and nematodes were both present in the soil at the time the tests were started. Both pests were effectively controlled by steam sterilization of the soil. The most troublesome insect pest was red spiders. These were controlled by the use of dusting sulphurs. Leaf mold appeared at various times but was prevented from becoming serious by turning on sufficient heat and ventilating at night to keep the relative humidity below 80 percent. During warm, damp periods, when leaf mold was likely to occur and spread rapidly, some heat was turned on in the house about an hour before dark to prevent dew from forming on the leaves. By keeping the plant leaves dry at night, this disease was prevented from developing to any serious extent.

Pollinating was done three times a week, by means of a door-bell buzzer, the vibrating arm of the mechanism being applied to the individual blossoms or clusters.

VARIETY TRIALS

To determine the most desirable variety or varieties for greenhouse production in this region, seven varieties were tested. The varieties grown were Marglobe Forcing, Michigan State Forcing, Lloyd Forcing, Grand Rapids Forcing, Break O'Day, Livington Globe, and Pritchard. Four crops were grown for this test: two spring crops, one fall crop, and one extending from October to July.

The house was divided into 28 plots, 6 by 14 feet, which allowed four replications for each variety. A plot accommodated 21 plants. Each variety occupied a plot in each quarter of the house. Variety arrangement in each quarter was at random. Buffer rows were placed at both ends of the house and on each side of the center cross walk to avoid any advantage due to placement. Plants were spaced two feet by two feet. All plants were trained to a single stem.

Yields obtained are presented in Table I and the average weight of fruits is given in Table II.

Lloyd Forcing was the highest yielding variety throughout the test. However, the low quality, variability in size and small average size, poor color, and green, rough shoulders of the fruits made it less desirable than some of the other varieties. The higher yield of Lloyd Forcing is more than offset by other desirable characteristics of Marglobe and Michigan State Forcing.

*TABLE I.—Average Yields of Greenhouse Tomatoes, by Varieties.**

(Pounds per Plant.)

	Spring '36	Fall '36	Spring '37	Winter and Spring '38	Average**
Lloyd Forcing	3.19	6.25	15.71	18.04	10.80
Marglobe	1.75	5.14	15.07	17.99	9.99
Michigan State Forcing	2.39	5.84	13.09	17.67	9.75
Livingston Globe	1.25	5.40	12.85	16.43	8.99
Break O'Day	1.77	5.08	12.66	15.74	8.81
Pritchard	2.14	4.81	12.48	14.30	8.43
Grand Rapids	2.77	5.02	11.83	14.93	8.64

* Fruits affected with blossom-end rot not included. See Table III.

** Difference required for statistical significance, 1.08 lbs.

TABLE II.—Average Fruit Size of Greenhouse Tomatoes, by Varieties.
(Weight per fruit, in ounces.)

	Spring '36	Fall '36	Spring '37	Winter and Spring '38	Average
Lloyd Forcing	3.0	4.1	4.3	3.8	3.80
Marglobe	4.1	4.2	5.2	4.9	4.60
Michigan State Forcing	3.9	4.2	4.7	4.6	4.35
Livingston Globe	3.8	4.1	5.1	5.0	4.50
Break O'Day	4.3	4.1	5.6	5.2	4.80
Pritchard	3.6	3.8	4.9	5.5	4.45
Grand Rapids	2.1	2.2	2.6	2.9	2.45

Marglobe and Michigan State Forcing both produced high yields of very desirable fruits. Because of the superior fruit qualities of these varieties as compared to Lloyd Forcing, and the higher yields in comparison with the other varieties tested, Marglobe and Michigan State Forcing are considered the best varieties for this region.

The fruits of Livingston Globe vary too much in size for greenhouse production, and this variety appears to be more susceptible to blossom-end rot (Table III) than most of the others in the test. Another objection to Livingston Globe is the tendency for the fruits to crack severely, especially during the spring. This was the only pink variety in the trials. If pink fruits are desired the Marhio, a pink strain of Marglobe, is recommended. The Marhio was planted in the border rows for two crops and appeared to be a satisfactory variety.

Although Break O'Day produced fruits of largest average size, puffiness was more common in this variety than any of the others. It also developed the most blossom-end rot.

The Pritchard plants are difficult to train due to their self-topping habit. For this reason, together with its lower yield record, it is not a desirable variety for greenhouse use.

The low yield, small size, and susceptibility to blossom-end rot give Grand Rapids Forcing the lowest rating of the varieties tested.

Yields from the spring crop of 1936 were very low, due to the large number of fruits affected with blossom-end rot (Table III) and the many plants killed by wilt (Table IV).

TABLE III.—Fruits With Blossom-end Rot, by Varieties.

	SPRING 1936		FALL 1936		SPRING 1937		WINTER AND SPRING 1938		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Lloyd Forcing	348	19.9	0	.0	85	1.7	8	.1	441	2.9
Marglobe	967	63.0	0	.0	220	5.4	17	.3	1204	10.0
Michigan State Forcing	757	48.4	2	.1	323	8.0	25	.5	1107	8.8
Livingston Globe	1303	74.5	4	.3	441	11.5	203	4.4	1951	16.5
Break O'Day	1406	72.2	15	1.0	559	15.6	18	.4	1998	18.0
Pritchard	632	45.0	3	.2	356	9.4	23	.7	1014	9.9
Grand Rapids	657	28.1	0	.0	1097	15.0	10	.1	1764	9.1

*TABLE IV.—Number of Plants Killed by Wilt, by Varieties.**

	Spring '36	Fall '36	Spring '37	Winter and Spring '38	Total
Lloyd Forcing	19	3	1	0	23
Marglobe	4	3	1	0	8
Michigan State Forcing	17	5	3	0	25
Livingston Globe	13	2	1	0	16
Break O'Day	13	3	1	0	17
Pritchard	23	0	5	0	28
Grand Rapids	9	2	3	0	14

* Each variety was represented by 84 plants in each crop.

TESTS OF CULTURAL METHODS

Spacing Plants

The proper spacing of tomatoes in a greenhouse is an important factor for profitable production, as high overhead costs necessitate maximum utilization of space. The amount of sunlight prevailing throughout the forcing season determines, to a large extent, how close plants should be spaced to produce the most fruit per square foot of soil area. Sufficient clear weather prevails in this region during the forcing season, in comparison with northern forcing areas, to expect that higher production can be obtained through closer spacing than is practiced in the north.

Four crops were grown to determine the most desirable spacing for greenhouse tomatoes in this area. Two of the crops were grown in the fall and two in the spring. Marglobe Forcing was the variety used for these tests. The house was divided into eight plots of approximately 225 square feet. Four different spacings were used and each treatment was duplicated. Buffer rows were placed between plots and at the ends. Plants were trained to a single stem. The spacings used and data secured are presented in Table V.

The highest yields were obtained where the closest spacing was used. In the spring crops, yields decreased as the space per plant was increased. Results from the two fall crops vary from the spring crops in respect to one treatment: the plants spaced 24″ x 24″ (4 sq. ft.) outyielded those spaced at 18″ x 30″ (3.75 sq. ft.). These results are probably due to planting arrangement, the block planting (24″ x 24″) providing more favorable light conditions around the plants than the row planting (18″ x 30″). It seems logical that such a factor would be of more importance in the fall season, when days are short, than in the spring.

The differences in yields from the various spacings as shown in Table V may appear small; however, if they are considered on an acreage basis, the increase in yields due to closer spacing amounts to several tons per acre.

Differences in average size of fruits and percentage of fruits placed in the first grade were quite small. In general, the wider spacings produced slightly larger fruits, although this difference was not sufficient to make up for the increased number of fruits produced, per area, by closer spacing.

The fruits were graded on the basis of defects other than size, except where they were very small (two ounces or less).

TABLE V.—Results of Spacing Trials, 1938 and 1939.

		1938			1939		
Planting distances (inches)	Sq. Ft. per plant	Pounds per square foot*	Percent in first grade	Average weight (ounces)	Pounds per square foot*	Percent in first grade	Average weight (ounces)
			Fall Crops				
21 x 24	3.50	1.85	89.04	4.15	1.85	94.48	3.33
18 x 30	3.75	1.66	88.45	4.05	1.58	94.39	3.33
24 x 24	4.00	1.78	90.51	4.32	1.65	95.25	3.44
20.5 x 30	4.28	1.61	88.85	4.28	1.53	94.45	3.39
			Spring Crops				
21 x 24	3.50	3.94	94.84	4.36	3.63	96.29	4.31
18 x 30	3.75	3.29	96.12	4.25	3.56	96.39	4.32
24 x 24	4.00	3.23	94.63	4.34	3.55	96.15	4.54
20.5 x 30	4.28	3.13	94.84	4.63	3.30	96.50	4.39

* Difference required for statistical significance, .12 lb.

The possibility of increasing returns by closer spacing than any used in the tests was indicated by the consistently higher yield from the plants spaced the closest. It was also indicated by the apparent effect of the block spacing, as compared to the row arrangement, in increasing yields of fall crops. To test this possibility, such spacings were incorporated into the 1940-41 test of continuous production throughout the season; and the results are reported in connection with that test (See below).

Training Plants to Two Stems

In the foregoing spacing trials, a limited number of the plants were trained to two stems. These plants were spaced to allow 3.25, 3.00, 2.75, and 2.50 square feet per stem. The results from the two-stem plants were somewhat irregular, but yields per square foot were lower than from the plants trained to a single stem. Unless conditions are favorable for very close spacing, it seems undesirable to reduce the number of plants and allow more than one stem per plant to develop, especially in view of the difficulties encountered in the care and training of such plants.

Continuous Production Throughout the Season

A test to determine the possibility of carrying the fall crop through the entire forcing season, and also to try closer spacings than had been used in the previous spacing trials, was run during the 1940-41 season. The house was divided into 12 plots to allow duplicate plantings of six treatments. The spacings used and results secured are presented in Table VI.

Yields were uniformly low from this crop, due to an exceedingly cloudy winter. Three and four flower clusters, per plant, which developed during the winter, failed to set fruit. The unfavorable weather conditions also reduced the average size of fruits. This was the first year since these tests were started that insufficient sunshine occurred during the winter to allow normal flower development and fruit set. No difficulty in this respect was encountered in the season of 1937-1938, when plants were set in October and carried through until the following July.

TABLE VI.—Spacing and Arrangement Test; Single Crop Carried Through Entire Season 1940-41.

	Square feet per plant	Yield in pounds per square foot	Average weight per fruit (ounces)
30-inch rows	3.25	3.72	3.33
	3.50	3.81	3.36
	3.75	3.92	3.48
24-inch rows	3.25	3.99	3.39
	3.50	4.01	3.35
	3.75	3.73	3.46

Where the plants were set in 30-inch rows the yields increased as the distance between plants increased. This was not the case where plants were set in 24-inch rows, as is shown in the table. The lower yield from the widest spacing, in 24-inch rows, was due to one plot being very low in production, apparently caused by some factor or factors other than spacing. For this reason it is felt that the results from this treatment are not comparable to the other two.

Considering the two closest spacings, a comparison of the yields from plants given the same space but arranged differently indicates a square or block arrangement is more favorable than close spacing in rows far apart. This is in agreement with results secured from the two fall crops grown previously.

Average fruit size and percentage of marketable fruits were affected only slightly by spacing.

Approximately 33 percent of the crop was harvested by January 31, which is the usual fall-crop period. Twenty percent was harvested from January 31 to April 15, the period which is generally unproductive due to changing crops. The spring harvest, April 15 to July 1, amounted to 47 percent of the total. The winter and spring harvests from this crop, taken together, accounted for about two-thirds of the year's production. This is about the proportion of the year's production usually accounted for by the spring crop. Therefore, since the fruits harvested during the winter have a higher value, a system of continuous production should be more profitable than the usual fall-spring cropping practice.

Conclusions from Cultural Tests

From the results secured from the five crops grown to determine the effect of spacing, it is concluded that yields can be increased by spacing plants closer than is practiced commercially and that a block arrangement is superior to distinct row planting. A spacing of 24 by 21 inches appears to be the most economical for this region.

From the limited experience gained in these tests and the results obtained by a commercial grower,* it would seem profitable to continue the fall-set plants through the entire forcing season. Such a practice would provide production during two

* R. Lee Carter, Oklahoma City, Oklahoma.

and a half months in mid-winter, when prices are high, which is ordinarily lost due to changing crops. The mild, open winters in this region would be favorable for such a practice.

Due to the difficulties encountered in the care and training of plants to two stems, and considering the yields, this method of training cannot be recommended as a commercial practice.

RELATION BETWEEN VEGETATIVE VIGOR AND FRUITFULNESS

The relationship between vegetative growth and flower and fruit production has been studied by many workers during recent years. The general conclusion that plants making moderately vigorous vegetative growth are most desirable for maximum flower and fruit production is well established. In growing such a crop as tomatoes in greenhouses, where most of the environmental factors (except light) can be controlled, the application of this knowledge is of considerable importance. The vegetative vigor can be fairly well controlled by the proper use of fertilizers and water, temperature control, etc. If some simple measurement or observation could be used as an indication of vegetative vigor, and if the size range were known within which the highest fruit production is secured, it is believed that the problem of proper management would be simplified.

To study such a possibility, two possible indexes of vegetative growth were used: leaf area; and the diameter of the stem.

Leaf Area and Fruitfulness

To measure the area of a sufficient number of leaves for an adequate sample by any method possible with equipment available seemed out of the question. The large size and general conformation of the leaves of greenhouse grown tomatoes makes it impractical to measure the area by ordinary methods. The method used by Khanmai and Brown* in their study on red raspberries, wherein fresh weights of leaves were used as a measure of leaf area, offered a very rapid procedure if the same relationship exists between weight and area of tomato leaves.

To explore this possibility, 60 mature leaves were taken from the lower part of the tomato plants throughout the green-

* Khanmai, M. A., and Brown, W. S., "Correlations between leaf area and leaf weight and between leaf weight and fruit production of red raspberries." *Proc. Am. Soc. Hort. Sci.,* 37: 589-592. 1939.

house. The plants had grown to a height of about five feet at the time the leaves were removed. Immediately after removing each leaf from the plant the leaflets were cut off, weighed to closest .01 gram, and a blueprint made. It was necessary to remove the leaflets from the petiole to secure good prints and to avoid overlapping of leaflets. The leaf area was measused to the nearest .01 sq. in. from the blueprint with a planimeter.

The correlation coefficient found between the fresh weight of the leaflets and leaf area was .967±.0041. When the measurements were rounded off to whole numbers the correlation was .9657±.0064. Both of these correlations are highly significant. To determine if it was necessary to remove the leaflets for weighing or whether the same relationship existed if the entire leaf were weighed, 15 entire leaves were weighed, then the leaflets removed and weighed separately. The correlation secured between leaflet weight and the weight of petioles and leaflets together was .9701±.0100. From these results it was concluded that the fresh weights of tomato leaves grown in a greenhouse are an accurate measure of relative leaf area and could be used for comparative studies involving this factor.

The ratio of area in square inches to weight in grams for the leaflets alone was 5.693 and for entire leaves, 3.146.

For the leaf area determination, five representative plants were selected in each of the twelve plots grown during the 1940-41 season for the spacing and plant arrangement test. The plants were selected in the second and third rows from the center walk, to avoid any border effects. The leaves used were taken from the lower portions of the stems.* They were quite mature and, in general, still were of good green color. There was no appreciable difference in the number of leaves per unit of stem length on the plants at different spacings.

A summary of the data secured is presented in Table VII. No direct relationship was found between leaf area and yield, under the conditions of this determination. The fact that the range in spacings used was quite small and the probability that too limited a sample was secured, along with possible errors in collecting and measuring the material, very likely account for the variability in the data.

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* As this crop was grown over the entire forcing season it was necessary to lower the plants when the stems grew up to the supporting wires. When the plants were lowered the leaves were removed from the lower portion of the stems so that no leaves touched the ground. The leaves pruned off the test plants at the time the plants were let down were the leaves used in this test.

A comparison of the leaf areas of the plants set in 24-inch rows with those set in 30-inch rows indicates a slightly greater area, 4.2 sq. inches on the average, for those set in 24-inch rows.

TABLE VII.—Relation of Leaf Area to Yield.

	Square feet per plant	Yield per sq. ft. (pounds)	Average area per leaf (sq. inches)
30-inch rows	3.25	3.72	105.72
	3.50	3.81	99.74
	3.75	3.92	103.71
24-inch rows	3.25	3.99	107.03
	3.50	4.01	99.34
	3.75	3.73	109.70

Stem Diameter and Fruitfulness

Results from Variety Tests.

In using stem diameter as a measure of vegetative vigor, the diameter measurements were taken midway between the peduncle and the node immediately below it. This measurement was made at the time the second flower of the cluster opened. The number of flower buds was counted at the same time. The number and weight of fruit per cluster was recorded as the fruit matured. These data were secured for six to eight clusters per plant on ten plants of each of the seven varieties, for the four crops grown for the variety test. No special attempt was made to vary the vigor of the plants as they were being grown especially for variety testing; however, variations did occur which provided data for this study. Extreme conditions of vigor were not present as the crop was grown on a commercial basis.

To investigate the relation between vegetative vigor and fruitfulness, correlations were determined between the stem diameter and number of flowers, number of fruits, and weight of fruit per cluster. The correlation coefficients found are presented in Table VIII, and the coefficients for stem diameter and weight of fruit are shown graphically in Figure 1. Averages of the units of measurements used in this study are presented in Table IX. Data on number of fruits and weight of fruit secured from the spring crop of 1936 are not included in this analysis because unsatisfactory growing conditions seriously affected fruit development.

It is difficult to draw any definite conclusions from the data secured because of variability between varieties and between crops. No satisfactory explanation is known for the wide fluctuations between the varieties which occurred in many cases. Variations between crops might reasonably be expected and are probably due to differences in light conditions which prevail at the different seasons.

Stem Diameter and Number of Blossoms.—The correlations between stem diameter and the number of blossoms which developed, for the fall and two spring crops, indicate that a closer relationship exists between the number of blossoms on a cluster and the diameter of the stem several nodes below it than exists between the number of blossoms and the diameter of the stem adjacent to the cluster. This would seem reasonable, because at the time of rapid stem enlargement at a given point, the buds are developing for the flower cluster several nodes above.

The importance of timely applications of nitrogen fertilizers, care in watering, and proper control of temperature is emphasized by this relation between stem diameter and blossoms per cluster. The general growth habit of tomato plants, as indicated by stem diameter, is an increase in size up to the location of the third or fourth fruit cluster and then a gradual decline (see Table IX). By proper care, it is generally possible to prevent or at least greatly reduce the extent of the decline in vigor and thus encourage the development of larger clusters on the upper part of the plant. The apparent lag in the decline of number of blossoms per cluster as compared to stem diameter indicates the necessity of applying nitrogen fertilizer before any appreciable reduction in stem diameter has occurred, if the size of succeeding clusters is to be maintained.

Varieties which were inconsistent with the general trend stated above were: Pritchard, fall 1936 and spring 1937; Break O'Day, spring 1937; and Michigan State, spring 1936. No trend is shown by the figures for the winter-spring crop of 1938. This crop was set in late October and the figures for stem diameter and number of flowers were taken from December 15, 1937 to February 15, 1938. The periods of time when these data were taken for the other three crops were: spring 1936, May 1 to July 1; fall 1936, October 10 to December 1; and spring 1937, February 20 to April 20. The short days during the winter period of the 1938 crop may have been the cause for the smaller number of blossoms to develop, as compared to the other crops,

TABLE VIII.—Correlation Coefficients Between Stem Diameter and Number of Flowers, Number of Fruits, and Weight of Fruit per Cluster.

		Number of Flowers	Number of Fruits	Weight of Fruit
		Marglobe		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	.396±.095†	−.004±.114	−.145±.123
Stem dia. adjacent to	1 cl. below	.001±.099	.024±.101	−.209±.103
Stem dia. adjacent to	cluster	.086±.090	.125±.090	.034±.096
Stem dia. adjacent to	1 cl. above		.014±.099	.342±.091†
Stem dia. adjacent to	2 cls. above		−.253±.105	.271±.104
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.566±.059*	−.029±.106	.409±.067*
Stem. dia. adjacent to	1 cl. below	.367±.069*	−.047±.095	.373±.065*
Stem. dia. adjacent to	cluster	.377±.064*	.174±.084	.378±.061*
Stem dia. adjacent to	1 cl. above		.176±.074	.226±.072
Stem dia. adjacent to	2 cls. above		.219±.077	.256±.075
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.241±.103	.321±.111	.334±.109
Stem dia. adjacent to	1 cl. below	.167±.095	.336±.095†	.359±.094†
Stem dia. adjacent to	cluster	.298±.081†	.338±.085†	.317±.086†
Stem. dia. adjacent to	1 cl. above		.121±.092	.420±.089*
Stem dia. adjacent to	2 cls. above		.087±.122	.182±.104
		Michigan State		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	.388±.095†	.270±.106	.014±.119
Stem dia. adjacent to	1 cl. below	.457±.069*	.416±.084*	.330±.094†
Stem dia. adjacent to	cluster	.386±.071*	.445±.075*	.576±.064*
Stem dia. adjacent to	1 cl. above		.353±.062†	.634±.089*
Stem dia. adjacent to	2 cls. above		.095±.099	.368±.113†
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.259±.082†	.232±.083	.439±.071*
Stem dia. adjacent to	1 cl. below	.148±.080	.137±.080	.361±.071*
Stem dia. adjacent to	cluster	.115±.074	.153±.074	.282±.069†
Stem dia. adjacent to	1 cl. above		.142±.080	.295±.074†
Stem dia. adjacent to	2 cls. above		.084±.087	.239±.083
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.109±.111	−.035±.123	.019±.123
Stem dia. adjacent to	1 cl. below	.673±.053*	.380±.091†	−.058±.107
Stem dia. adjacent to	cluster	.375±.077*	.358±.083*	.210±.091
Stem dia. adjacent to	1 cl. above		.236±.101	.080±.101
Stem dia. adjacent to	2 cls. above		.062±.123	.023±.119
		Lloyd Forcing		
		Fall 1936		
Stem. dia. adjacent to	2 cls. below	.475±.086*	.508±.119*	−.101±.139
Stem dia. adjacent to	1 cl. below	.609±.061*	.526±.105*	−.152±.118
Stem dia. adjacent to	cluster	−.309±.118*	.413±.097*	.381±.092†
Stem dia. adjacent to	1 cl. above		.111±.104	.543±.079*
Stem dia. adjacent to	2 cls. above		−.030±.127	.376±.108†

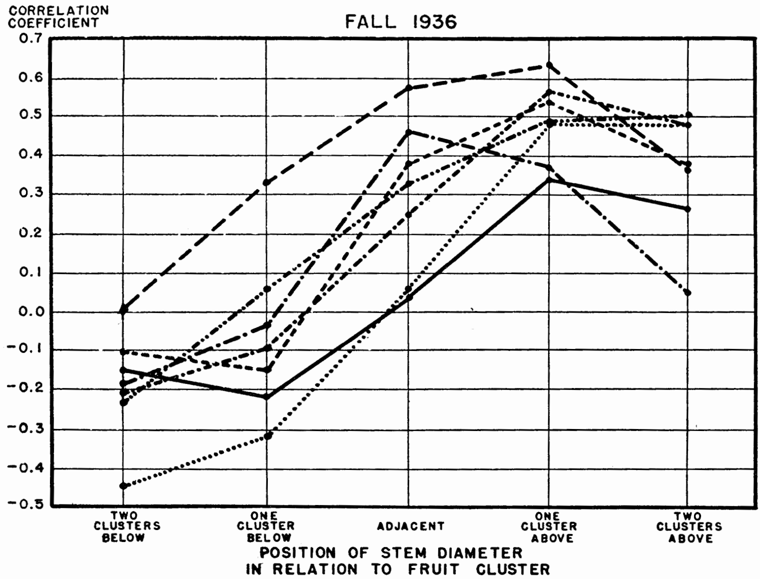
TABLE VIII (continued)

		Number of Flowers	Number of Fruits	Weight of Fruit
		Lloyd Forcing		
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.656±.049*	.323±.095†	.274±.099
Stem dia. adjacent to	1 cl. below	.367±.069*	.077±.095	.163±.093
Stem dia. adjacent to	cluster	.129±.074	.049±.087	.232±.082
Stem dia. adjacent to	1 cl. above		—.190±.092	.195±.092
Stem dia. adjacent to	2 cls. above		—.265±.099	—.210±.102
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.302±.102	.262±.119	.400±.107†
Stem dia. adjacent to	1 cl. below	.313±.090†	.192±.105	.416±.095*
Stem dia. adjacent to	cluster	.118±.089	—.034±.097	.144±.095
Stem dia. adjacent to	1 cl. above		.222±.104	.345±.096†
Stem dia. adjacent to	2 cls. above		—.018±.127	.281±.117
		Grand Rapids		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	.470±.084*	.325±.096†	—.444±.096*
Stem dia. adjacent to	1 cl. below	.073±.095	—.024±.095	—.315±.094†
Stem dia. adjacent to	cluster	—.123±.086	—.307±.080†	.057±.093
Stem dia. adjacent to	1 cl. above		.077±.096	.485±.094*
Stem dia. adjacent to	2 cls. above		.555±.075*	.480±.083*
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.534±.076*	.175±.084	.322±.078*
Stem dia. adjacent to	1 cl. below	.233±.090	.147±.079	.044±.081
Stem dia. adjacent to	cluster	—.045±.087	—.021±.075	.016±.075
Stem dia. adjacent to	1 cl. above		—.069±.071	—.354±.080*
Stem dia. adjacent to	2 cls. above		—.183±.065	—.501±.084*
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.197±.108	.195±.113	.329±.115
Stem dia. adjacent to	1 cl. below	.340±.088†	.295±.095†	.348±.092†
Stem dia. adjacent to	cluster	.349±.079*	.326±.084†	.289±.087†
Stem dia. adjacent to	1 cl. above		.287±.095†	.328±.091†
Stem dia. adjacent to	2 cls. above		—.001±.117	.018±.117
		Livingston Globe		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	.285±.099	.092±.107	—.186±.110
Stem dia. adjacent to	1 cl. below	.359±.095*	.317±.086†	—.036±.100
Stem dia. adjacent to	cluster	.128±.086	.350±.078*	.457±.076*
Stem dia. adjacent to	1 cl. above		.070±.097	.375±.086*
Stem dia. adjacent to	2 cls. above		—.217±.103	.052±.109
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.068±.106	.413±.073*	.367±.077*
Stem dia. adjacent to	1 cl. below	—.005±.095	.333±.073*	.407±.068*
Stem dia. adjacent to	cluster	.006±.087	.290±.070†	.326±.068†
Stem dia. adjacent to	1 cl. above		—.008±.082	.167±.079
Stem dia. adjacent to	2 cls. above		—.257±.081†	—.055±.087

TABLE VIII (continued)

		Number of Flowers	Number of Fruits	Weight of Fruit
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.009±.125	.073±.127	.174±.124
Stem dia. adjacent to	1 cl. below	.089±.107	.189±.107	.072±.110
Stem dia. adjacent to	cluster	.085±.096	—.015±.097	.242±.092
Stem dia. adjacent to	1 cl. above		—.090±.109	—.108±.108
Stem dia. adjacent to	2 cls. above		—.182±.123	—.073±.127
		Break O'Day		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	.282±.099	—.038±.108	—.206±101
Stem dia. adjacent to	1 cl. below	.264±.090†	.026±.096	—.094±.099
Stem dia. adjacent to	cluster	.053±.088	.217±.084	.248±.085
Stem dia. adjacent to	1 cl. above		.373±.081*	.562±.066*
Stem dia. adjacent to	2 cls. above		.273±.100	.482±.083*
		Spring 1937		
Stem dia. adjacent to	2 cls. below	—.088±.099	.046±.088	.188±.085
Stem dia. adjacent to	1 cl. below	—.085±.095	.004±.082	.154±.082
Stem dia. adjacent to	cluster	.260±.081†	.142±.075	.369±.076*
Stem dia. adjacent to	1 cl. above		.343±.072*	.272±.082†
Stem dia. adjacent to	2 cls. above		.432±.071*	.168±.088
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.363±.095†	.161±.120	.225±.117
Stem dia. adjacent to	1 cl. below	.365±.084*	.315±.097†	.370±.093†
Stem dia. adjacent to	cluster	.489±.067*	.027±.095	.109±.095
Stem dia. adjacent to	1 cl. above		—.067±.107	—.017±.107
Stem dia. adjacent to	2 cls. above		—.240±.116	—.140±.121
		Pritchard		
		Fall 1936		
Stem dia. adjacent to	2 cls. below	—.110±.112	—.018±.114	—.233±.109
Stem dia. adjacent to	1 cl. below	—.066±.101	—.031±.102	.054±.103
Stem dia. adjacent to	cluster	.198±.089	.244±.080	.324.±084†
Stem dia. adjacent to	1 cl. above		.227±.098	.495±.078*
Stem dia. adjacent to	2 cls. above		.126±.114	.502±.115*
		Spring 1937		
Stem dia. adjacent to	2 cls. below	.176±.106	.366±.078†	.141±.088
Stem dia. adjacent to	1 cl. below	.180±.094	.259±.077†	.087±.082
Stem dia. adjacent to	cluster	.311±.080†	.388±.066*	.277±.072†
Stem dia. adjacent to	1 cl. above		.307±.076†	.302±.076†
Stem dia. adjacent to	2 cls. above		.367±.078†	.056±.090
		Winter and Spring 1938		
Stem dia. adjacent to	2 cls. below	.145±.107	.109±.124	.162±.122
Stem dia. adjacent to	1 cl. below	.004±.097	—.078±.107	—.057±.108
Stem dia. adjacent to	cluster	.082±.130	—.007±.096	—.010±.096
Stem dia. adjacent to	1 cl. above		—.162±.080	—.129±.100
Stem dia. adjacent to	2 cls. above		.137±.123	.167±.122

* Statistically significant at the 1% level.
† Statistically significant at the 5% level.



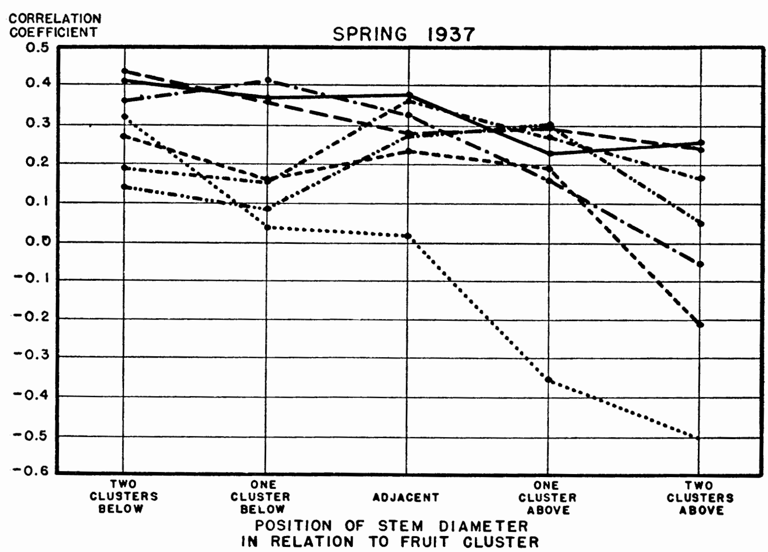


Figure 1-a.—Correlation coefficients of weight of fruit per cluster and stem diameters at various positions on the plant with respect to location of the clusters, fall crop 1936 and spring crop 1937. From data shown in Table VIII (For varietal key see Figure 1-b.)

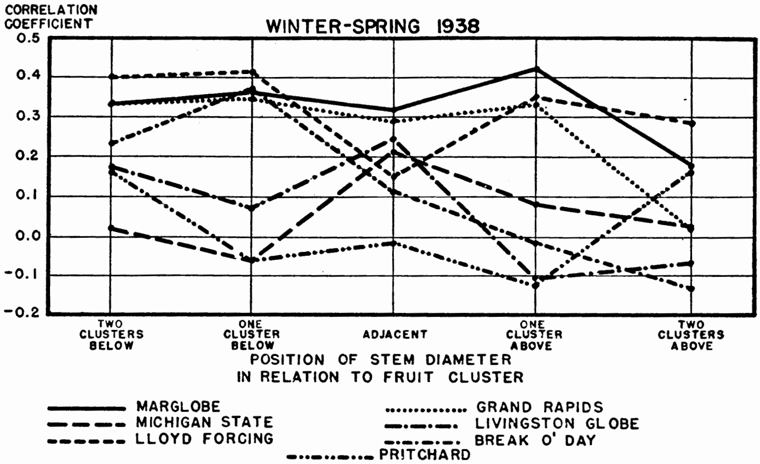


Figure 1-b.—Correlation coefficients of weight of fruit per cluster and stem diameters at various positions on the plant with respect to location of the clusters, winter-spring crop 1938. From data shown in Table VIII.

despite the usual trend in stem diameters. It is also to be noted (Table IX) that there was less variation in number of blossoms per cluster on the 1938 crop.

Stem Diameter and Number of Fruit Set per Cluster.—The correlations between stem diameter and number of fruit set per cluster are quite variable for the different varieties and also for the three crops considered. The necessity for sunshine just previous to and at the time of blossoming, to get effectiive pollination and fruit set, introduces a serious uncontrollable factor. Variations of the different varieties in time of flower opening on comparable clusters, and also variations between custers on different plants of the same variety, would cause an appreciable error in a study of this kind. Although the variability in time of blooming was only 10 to 15 days, a cloudy period of a few days is sufficient to prevent pollination and thus cause quite a marked difference in fruit set on the same clusters of different varieties or on individual plants of the same variety.

All of the varieties except Grand Rapids show a fairly similar trend in the fall crop of 1936. The opposite condition shown by Grand Rapids is due to an especially heavy set on the first clusters (Table IX), followed by a decline in number of fruits set per cluster up to the fourth and then an increase

TABLE IX.—Averages of Stem Diameters, Number of Flowers, Number of Fruits, and Weight of Fruit by Clusters.

	Marglobe				Michigan State			
Cluster	Stem dia. (mm)	No. flowers	No. fruits	Total Weight of fruits (ounces)	Stem dia. (mm)	No. flowers	No. fruits	Total Weight of fruits (ounces)
		Fall 1936				Fall 1936		
1	9.1	7.1	4.9	22.2	9.0	6.6	4.3	16.8
2	11.5	9.6	4.6	16.2	10.7	7.3	5.1	19.6
3	11.1	9.6	5.3	15.5	12.3	10.6	4.8	18.8
4	9.8	11.8	5.3	11.4	11.3	12.0	5.2	15.1
5	8.3	12.4	3.9	9.4	9.6	12.8	4.7	12.8
6	6.3	9.0	2.8	7.8	7.7	11.3	3.5	9.0
		Spring 1937				Spring 1937		
1	8.4	6.0	5.2	27.9	10.7	7.3	5.9	30.8
2	13.2	7.2	6.2	28.0	14.3	7.9	5.8	26.5
3	12.7	7.3	5.3	23.7	14.8	7.7	5.1	22.0
4	12.3	7.3	5.3	26.8	13.2	7.1	5.6	28.6
5	9.5	7.7	5.3	21.4	10.8	9.7	5.7	27.3
6	6.4	6.7	6.1	27.7	7.9	8.9	5.4	22.6
7	6.2	5.7	4.7	22.7	6.7	7.2	5.6	20.4
8	5.8	5.6	4.8	20.6	6.8	7.5	4.2	14.5
		Winter-Spring 1938				Winter-Spring 1938		
1	9.8	6.1	2.8	12.1	9.3	6.0	1.7	8.8
2	11.6	6.2	3.9	19.2	12.7	6.6	4.5	21.7
3	13.2	6.3	4.9	24.6	14.2	8.9	7.2	31.5
4	13.0	6.8	4.7	23.0	13.9	7.3	6.0	27.4
5	11.9	6.4	3.7	19.9	12.2	6.6	4.0	22.4
6	9.8	6.4	4.6	25.8	10.5	7.0	5.3	29.3

TABLE IX (continued)

	Grand Rapids				Lloyd Forcing			
Cluster	Stem dia. (mm)	No. flowers	No. fruits	Total Weight of fruits (ounces)	Stem dia. (mm)	No. flowers	No. fruits	Total Weight of fruits (ounces)
		Fall 1936				Fall 1936		
1	6.2	24.9	10.8	17.1	6.9	5.7	4.6	15.4
2	8.5	16.8	8.2	19.4	9.4	5.9	4.3	21.3
3	11.8	13.7	7.1	19.8	11.0	8.1	4.4	19.0
4	11.6	13.2	5.5	12.5	10.4	15.5	5.5	13.3
5	10.0	15.5	6.2	8.2	8.6	14.2	5.3	7.4
6	8.4	21.2	8.9	---	7.3	11.0	3.4	---
		Spring 1937				Spring 1937		
1	8.0	8.0	7.2	22.2	7.5	6.6	6.2	27.9
2	12.7	9.5	8.5	24.8	13.1	7.7	6.5	30.0
3	13.9	8.4	7.7	18.7	13.7	8.1	6.1	27.6
4	13.1	11.1	8.9	20.4	12.1	11.5	7.7	36.0
5	12.7	17.1	12.8	27.7	9.9	11.7	7.3	30.5
6	9.9	20.2	12.2	26.0	6.9	11.3	7.0	25.1
7	6.7	16.6	16.6	22.0	6.2	9.3	4.1	11.7
8	6.8	16.4	8.3	20.1	5.1	6.6	3.8	10.6
		Winter-Spring 1938				Winter-Spring 1938		
1	8.3	7.0	2.4	10.1	8.4	5.4	2.5	12.3
2	11.7	10.0	7.2	23.9	11.9	6.3	4.0	21.3
3	12.2	9.2	7.4	24.0	11.3	7.5	6.3	30.7
4	10.4	8.1	6.6	22.7	11.5	8.7	7.2	32.5
5	11.2	9.2	7.3	24.6	10.8	8.3	5.8	24.9
6	10.1	13.2	8.8	29.3	8.8	9.8	7.0	31.7

TABLE IX (continued)

Cluster	Pritchard Stem dia. (mm)	Pritchard No. flowers	Pritchard No. fruits	Pritchard Total Weight of fruits (ounces)	Break O'Day Stem dia. (mm)	Break O'Day No. flowers	Break O'Day No. fruits	Break O'Day Total Weight of fruits (ounces)
	Fall 1936				Fall 1936			
1	9.1	6.0	4.1	16.1	9.0	9.1	4.7	19.9
2	9.0	5.7	4.0	14.8	9.4	6.8	4.6	19.7
3	11.1	7.7	4.2	12.4	10.4	6.9	4.3	16.7
4	10.5	8.2	4.8	12.7	10.5	8.5	4.0	13.3
5	9.5	7.0	3.8	7.0	8.0	8.6	3.7	11.3
6	8.4	7.2	3.9	7.4	6.7	7.1	2.8	8.4
	Spring 1937				Spring 1937			
1	10.0	6.1	5.4	28.9	8.5	6.5	5.4	29.2
2	11.8	6.6	5.9	28.7	12.5	8.2	5.9	29.8
3	13.8	7.1	5.4	23.8	12.3	7.3	4.8	26.4
4	14.9	8.0	5.2	23.2	11.2	5.4	4.3	26.5
5	11.8	6.8	4.3	20.1	8.3	7.2	4.6	26.0
6	10.8	7.2	4.6	20.8	6.0	7.7	4.4	23.3
7	7.4	6.6	4.0	19.4	5.4	6.3	3.9	17.3
8	6.6	5.4	4.0	17.4	5.7	4.8	4.4	19.3
	Winter-Spring 1938				Winter-Spring 1938			
1	9.0	5.0	1.3	9.2	7.6	5.9	2.7	12.8
2	10.5	5.9	2.6	12.2	11.0	6.5	4.6	28.8
3	12.0	4.4	3.6	20.3	13.1	6.7	4.0	23.2
4	11.5	6.0	4.2	25.2	11.8	7.5	4.9	30.2
5	11.0	5.2	4.3	25.8	10.5	7.5	4.5	27.3
6	10.2	5.7	5.4	30.0	8.1	6.9	4.7	27.2

Livingston Globe

Cluster	Stem dia. (mm)	No. flowers	No. fruits	Total Weight of fruits (ounces)
	Fall 1936			
1	8.7	5.2	4.1	15.9
2	11.0	6.1	4.8	23.8
3	11.9	8.3	4.9	17.2
4	9.8	11.2	5.4	14.7
5	8.3	9.9	4.1	10.6
6	6.7	8.1	3.4	8.0
	Spring 1937			
1	9.1	4.8	4.5	27.5
2	13.3	6.1	5.0	24.8
3	13.1	6.6	5.3	25.0
4	12.4	7.4	5.8	27.6
5	8.5	6.2	4.6	20.5
6	7.0	8.2	6.0	24.8
7	6.0	5.7	3.9	17.3
8	5.4	5.2	3.8	12.1
	Winter-Spring 1938			
1		5.8	1.0	7.0
2	12.9	6.4	3.2	20.8
3	13.8	5.9	5.2	26.0
4	13.5	7.3	5.1	26.4
5	12.4	7.5	5.8	28.9
6	10.6	6.0	4.5	25.3

in set on the fifth and sixth clusters. The fact that this variety is a few days earlier in blooming than the others is very likely responsible for this difference. The number of fruit set per cluster on the other six varieties followed closely the trend of stem diameters; a gradual increase up to the third or fourth cluster and then a decline.

The cause or causes for the wide variations in correlations for the other two crops are unaccountable except for the possibility mentioned above in regard to the presence or absence of sunshine in relation to the variability in time of blooming of different varieties and plants. The fact that a large portion of the correlation coefficients are positive certainly indicates a definite relationship between plant vigor, as expressed in terms of stem diameter, and fruit set, within the size ranges of these factors which developed under the conditions of this test.

Stem Diameter and Weight of Fruit per Cluster.—The correlations between weight of fruit per cluster and stem diameters for the fall crop of 1936 show a definite trend, although the coefficients vary considerably for different varieties (Figure 1). The close relationship shown between fruit weight per cluster and the diameter of the stem above the cluster, in this crop, is simply due to the gradual reduction in yield, from the first or second clusters on up, which follows the trend in stem diameters from the second or third clusters (Table IX). The decreasing amount of light as the fall crop grows, due to days becoming shorter, would naturally provide less favorable conditions for fruit development on the upper cluster. It is interesting to note that this is in contrast with flower formation. Whether or not yields on the upper clusters would have been increased by increasing plant vigor with additional applications of nitrogen fertilizers is a question unanswered by the data secured.

The correlations found in the spring crop of 1337 show a slight trend but in the opposite direction from that found in the fall crop. In this case, light conditions were improving as days become longer, and yields per cluster were more uniform, especially on the first six clusters. The same question as to possible effect of nitrogen might be brought up here also. As most of the coefficients are positive for this crop, and also for the winter-spring crop of 1938 where no trend whatever is evident it seems safe to conclude that it is desirable to provide conditions as favorable as possible for continued development of good sized stem diameters as the plants progress in growth.

Results from Spacing Tests

Additional evidence on the relationship between stem diameters of tomato plants and yield was obtained from the two fall crops and two spring crops grown for the spacing test. Yield data were taken by individual rows within the plots. Stem diameter measurements were taken an inch below the place of attachment of the peduncle with the stem. These measurements were secured at six clusters per plant on the fall crops and ten clusters per plant on the spring crops. The diameter measurements were made just before the plants were taken out.

The total yields per row were converted to average yield per square foot and the average of all stem diameters, by rows, was calculated. The coefficient of correlation was determined between average yield per square foot and average stem diameter of plants, by rows, for the two fall crops combined, and the two spring crops.

The correlation coefficient found for the fall crops was $.562 \pm .070$, which is very highly significant. The coefficient found for the spring crops was $.113 \pm .089$. Although the correlation for the spring crops is not statistically significant, it shows a positive relationship and is in agreement with the conclusions expressed above.

Conclusions From Comparison of Vegetative Vigor and Fruitfulness

The fresh weight of tomato leaves, grown under the conditions of this test, was found to be an accurate measure of leaf area.

No consistent relationship was found between leaf area and yield with plants set at various spacings and arrangement. This is probably due to the small differences in spacing between the treatments.

Correlations between plant stem diameters and the number of flowers, number of fruits, and weight of fruit per cluster were found to vary considerably for different crops and varieties.

A closer relationship was found between the number of blossoms on a cluster and the diameter of the stem several nodes below it than existed between the number of blossoms and the diameter of the stem adjacent to the cluster.

Correlations between stem diameters and number of fruit set per cluster were quite variable for different varieties and crops. However, most of the correlation coefficients are positive.

Correlations between weight of fruit per cluster and stem diameters in a fall crop indicate a close relationship between fruit weight and the stem diameter above the cluster. An opposite trend is shown for a spring crop. This is thought to be due to differences in light conditions existing at the different seasons. No trend is indicated by data secured during the winter months. The correlation coefficients between fruit weight and stem diameter were mostly positive, which is interpreted as an indication of the existence of a positive relationship between these two factors.

SUMMARY

A test of seven varieties—Lloyd Forcing, Michigan State Forcing, Forcing Marglobe, Break O'Day, Livingston Globe, Pritchard, and Grand Rapids Forcing—in which four crops were grown, showed that Michigan State Forcing and Forcing Marglobe are the most desirable for greenhouse production in Oklahoma.

Plant spacing tests using 3.50, 3.75, 4.00, and 4.25 sq. ft. per plant indicated that the closest spacing was most desirable for this region. A block arrangement appeared superior to distinct row planting in regard to yield.

Training plants to a single stem, as compared to two-stem training, was found most satisfactory.

Continuous production from the same plants throughout the entire forcing season appears possible and practical in this region.

The fresh weight of tomato leaves, grown under the conditions of this test, was found to be an accurate measure of leaf area.

No consistent relationship was found between leaf area and yield with plants set at various spacings and arrangement. This is probably due to the small differences in spacing between the treatments.

Correlations between plant stem diameters and the number of flowers, number of fruits, and weight of fruit per cluster were found to vary considerably for different crops and varieties.

A closer relationship was found between the number of blossoms on a cluster and the diameter of the stem several nodes below it than existed between the number of blossoms and the diameter of the stem adjacent to the cluster.

Correlations between stem diameters and number of fruit set per cluster were quite variable for different varieties and crops. However, most of the correlation coefficients are positive.

Correlations between weight of fruit per cluster and stem diameters in a fall crop indicate a close relationship between fruit weight and the stem diameter above the cluster. An opposite trend is shown for a spring crop. This is thought to be due to differences in light conditions existing at the different seasons. No trend is indicated by data secured during the winter months. The correlation coefficients between fruit weight and the stem diameter were mostly positive, which is interpreted as an indication of the existence of a positive relationship between these two factors.

9/42—2½M.