T H E S I S

on

EFFECTS OF RUNNER PRODUCTION ON STRAWBERRY PLANTS

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George Leonard Rygg

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APPROVED:

Redacted for Privacy

Professor of Horticultural Research

In Charge of Major

Redacted for Privacy

Head of Department of Horticulture

Redacted for Privacy

Chairman of Committee on Graduate Study.

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George Leonard Rygg

INTRODUCTION

General

The strawberry is the most important of all small fruits grown in the United States. It is grown to some extent in every state in the Union, and berries are harvested in some part of the country every month of the year. Some of the more important strawberry producing states are Missouri, Louisiana, Arkansas, Tennessee, Maryland, Oregon, Virginia, Kentucky, and New Jersey.

Modern methods of marketing have not only increased the possible market for berries produced in any one community, but have also increased the competition of the producer since the produce from other sections are also placed on the same market. Consequently the grower who can place his product on the market most economically, the quality being the same, will naturally be the one who profits most.

One of the major factors in reducing the cost of production of strawberries is that of increasing the yield. The cost of preparing a piece of land, setting the plants, and tilling are fairly constant whether the plants are high or low yielding. Only the cost of picking becomes appreciably greater per acre when the yield is increased, outside of the cost of any fertilizers which may have been used. In general the cost of producing a pound of berries in a high-yielding field is less than in one which gives a low yield.

Increasing the yield can be accomplished in several ways, but this discussion will deal largely with the effect of the nature and treatment of the plant itself on its yielding ability.

Factors Influencing Runner Production

Varietal Characteristics. Different varieties exhibit marked differences in the number of runners produced. The Ettersburg 121 will under favorable conditions produce more than eighty daughter plants per mother plant, while the O. S. C. No. 7 produces very few runners without special treatment such as the application of water and removal of the flowers. Most cultivated varieties probably lie between these extremes in the prolificacy with which they produce runners.

Nutritional balance. The general relationship exists in the strawberry plant with regard to the balance of carbohydrates and nitrogen that Kraus and Kraybill (17) found to exist in the tomato. A plant low in carbohydrates and high in nitrogen is vegetative and when the carbohydrates accumulate in sufficient quantity the reproductive activities set in. The results of a number of workers indicate that this condition obtains in the strawberry. Gardner (15) has shown by defoliation that the accumulation of carbohydrates increases the yield of berries. Whitehouse (27) in working with the Howard 17 variety obtained ten runner plants per mother plant with high nitrogen, 4.2 with normal nitrogen, and no runners when nitrogen was omitted.

Tucker's (22) results show that the application of manure increased runner production, while the application of commercial fertilizers decrease the vegetative growth. Other workers (10) have also found that organic fertilizers favor runner production.

Time of application of fertilizers. Spring application of nitrogen fertilizers increased runner production more than summer or fall application in Loree's experiments (18). The runner growth was at the expense of the growth of the rest of the plant. This would seem reasonable in view of the anatomical studies of Mann (19) which show that runners are essentially elongated branch crowns. By feeding on the food materials taken in by the roots of the mother plant, they reduce the nitrogen supply available for the mother plant. Spring application of nitrogen affected the berry crop by increasing the size of the berries and the per cent set, but did not affect the number of flower clusters nor the number of flowers.

Summer application of nitrogen alone or in combination with phosphorus and potassium did not materially affect runner production, but promoted better crown growth (18). Phosphorus alone had no material effect on vegetative growth, but when used with nitrogen it increased both vegetative growth and fruitfulness.

Improving the Planting Stock

Numerous methods have been tried in an effort to improve the yield of strawberry plants, but the efforts have not always given the desired results.

Selecting plants from certain localities. Plants selected from different localities have been grown side by side for comparison. Some trials have given encouraging results, and others have not. Clark (7) obtained a difference of 2000 quarts per acre one year and 1403 quarts the next by using Howard 17 plants. In another trial with plants from four sources he obtained yields at the rate of 3,382.5, 4,661.2, 5,318.5, and 6,661.9 quarts per acre (6). He attributed a large portion of the difference in yield to the difference in the size of the plants, especially the crowns, and to the development of the roots system at the time of planting. Later experiments tend to justify this contention.

Schuster (24) found that with the Ettersburg 121 nothing was gained by obtaining plants from one place as against another, even if one field was much heavier in its bearing, provided the plants were healthy.

Card and Adams (5) planted Beverly plants from various sources and obtained yields of from 34.5 grams to 285.8 grams per plant. This was a ratio of 1 to 8.3. Similar results were obtained with other varieties.

Barker (3) tried plants of Royal Sovereign from twelve sources with the results given in Table I. All plants were treated similarly except for the plants from Norfolk and Scotland, which were planted late.

TABLE I

Productivity of Royal Sovereign from Different Sources (from Barker)

Source of plants	Yield in pounds		Total
	1914	1915	
Devon	18.875	57.5	76.375
France	21.94	43.0	64.94
Hampshire	21.69	47.75	69.44
Hereford	19.31	42.0	61.31
Ireland	16.19	55.5	71.69
Jersey	39.875	83.5	123.375
Kent (mid)	23.25	52.75	76.0
Kent (south)	16.94	71.5	88.44

TABLE I
(Continued)

Source of plants	Yield in pounds		Total
	1914	1915	
Norfolk	10.50	34.5	45.0
Scotland	15.81	58.5	74.31
Yorkshire	19.44	47.0	66.44
Yorkshire	20.81	55.0	75.81

The plants from Jersey yielded more than twice as much as those from Hereford during the two seasons. The reasons for these variations were not pointed out, but the differences were probably due more to the size and condition of the plants than to the locality from which they came except insofar as the locality influenced these characters.

In this connection it is interesting to note that the plants from Scotland which were planted late and gave a low yield the first year came back strong the second year, rising from eleventh the first year to third in the second. The plants from Norfolk gave the lowest yield both years, while those from Jersey gave the highest yields both years. These last groups acted in accordance with the findings of Mann and Ball (20), who described the consistency with which the march of growth during the second year followed that of the first as being "remarkable."

Later work by Ball (2) gave results of a different nature than those obtained by Barker. He planted vigorous, medium, and weak strains of Royal Sovereign side by side, and found that there was no inheritance of differences in yielding ability, though he advised roguing inferior plants. These results do not necessarily contradict those obtained by Barker.

The results of all these investigators can probably be related to the nutritional conditions within these plants. This does not mean their results are to be discarded, since if anything can be done in order to increase the yield of the plants, if for only the first year after setting, it may be worth while.

Runners from old and young plants. Runners from young plants are often considered better than those from old ones. Schuster (23) found that runners from young plants were more likely to be free from injurious insects and diseases, otherwise they probably were not better than those from old plants.

Runners formed early and late in the season. Runner plants formed fairly early in the season have generally proved to be better than those formed later. Differences here also are probably due to nutrition and size more than to any other cause. Goff (16) obtained a yield of 202.5 quarts from early formed plants as compared with 100 quarts from a like number of late formed plants. The following year the yields were 202.4 quarts and 161.1 quarts respectively. Although the lower yielding plants improved over their first year, they were still far behind the higher yielding early formed plants.

Davis (12) also obtained higher yields from plants formed fairly early in the season than those formed late. Those formed in October gave the lowest yield and those formed in July were next in order. The August and September formed plants gave the highest yields.

Strains. Although there is some evidence that strains of strawberry varieties are in existence, it is difficult to state how much of the variation noted is due to external conditions and how much is inherited. Ball (1) was able to obtain 50 per cent greater yields from some strains of Royal Sovereign than others, but the nature of the characters which brought about these differences is not stated. Colby (8) states that pedigree plants are no better than other stock which is well grown and healthy. Gardner (14) selected plants for ten generations from high and low yielding strawberry plants and failed to produce strains whose yields were higher or lower than the average.

These results do not preclude the possibility of desirable variations being produced which can be transmitted to the offspring and serve as the beginning of new strains.

Frequency of cutting runners. By removing the runners from the mother plants weekly some French investigators (9) increased the productivity of the plants to 916 berries from fifty plants as compared with 841 berries when the runners were removed bi-weekly and 482 berries when they were removed every six weeks. The yields were for the season following the runner removal.

These results are reasonable in view of the fact that fruit bud differentiation occurs at the time the late runners are formed. Waldo (25) found differentiation occured largely or entirely in the fall, depending on the variety. The production of runners at that time would drain the food supply and prevent the accumulation of carbohydrates in sufficient quantity to enable the plant to produce its maximum number of fruit buds.

Limiting the number of runners. The productivity of the daughter plants may possibly be increased by limiting the number of daughter plants which a mother plant is allowed to produce. This reduction may cause the mother plant to give more vigor to the plants which are allowed to remain. Ball (1) tried this method and obtained some interesting results. He used four groups of plants as follows:

1. Best runners) from parents layered to three
2. All runners) plants each.
3. Poorest runners)
4. All runners from parents allowed to make unlimited runners.

Of these, groups 1, 2, and 3 were nearly alike in yield, whereas the yield of group 4 was only about one-third of that of the others. Concerning his results he says "the smaller plants of 4 cropped earlier than did those of 1, 2, and 3, the first pickings being markedly heavier from 4 (more than twice as heavy). This is almost certainly due to the more dense foliage of the larger plants retarding the ripening of the berries."

Davis (12) found that the first plants to set were the most productive within limits. In addition to this, he found that the first plant on a runner gave a larger yield than the second in the series regardless of whether they were developed at a later date than some of the plants second in line.

Barker and Ettle (4) also found that the first runners from the parent plant were more fruitful than the second. Five varieties tested three years resulted in a difference of 20 per cent in favor of the first runners.

These results are doubtless traceable to nutrition and nutritional balances.

It should be pointed out in this connection that the strawberry plant differs radically from the normal woody plant with respect to cross transfer of sap. White (26) has pointed out that all parts of the plant are interrelated, and that cutting off one part will affect the whole of the remaining plant. Cutting the roots on one side will affect not only the part of the top directly above, but also the rest of the top and also any runners depending on the roots of the mother plant for support. E. M. Harvey has also shown the interrelationship of different parts of the strawberry plant by the use of dyes. In unpublished data he has shown that stains can be pulled across the mother plant by placing the cut end of one runner in the stain and applying suction on the cut end of a runner from the opposite side of the mother plant. The entire crown of the mother plant becomes stained, showing there is easy transfer across all parts of the plant.

EXPERIMENTAL

The phase of the study on the effects of runner production on which the writer has worked is limited to the last one under consideration, namely, the effect of limiting the number of runner plants. The study includes observations on both the mother and daughter plants. Plants were grown in the field, in water cultures, and in pots.

Material

Because of their popularity in Western Oregon, the varieties chosen for this study were the Ettersburg 121 and the Marshall, but due to the inroads of the strawberry crown borer in the Marshalls it was deemed advisable not to include figures on these plants in the study.

Methods

The plants were set in the spring of 1929 on well prepared fertile, uniform soil. After they had become established all plants appearing weaker than the others were rogued, thus leaving as uniform a stand of plants as could readily be obtained.

The plants were then divided into lots of approximately equal size. All lots were treated similarly with the exception of the number of runners allowed to remain. Unless otherwise stated, the runner plants left were the first to form. The treatment as to runners was as follows:

1. All runners to grow all season.
2. Three runner plants per plant.
3. Three runner plants per plant (formed after

September 1.)

4. Nine runners with one plant each.

5. Three runners with three plants each.

6. Fifteen runners with one plant each.

7. Three runners with five plants each.

8. (Lot not used in study).

9. All runners allowed to form until September 1.

10. No runners allowed to form until after September 1; all were left after this date.

11. No runners allowed during the season.

The daughter plants were not covered, but were allowed to root at will. The land was irrigated during the summer in order to promote growth and facilitate the rooting of the runners. The superfluous runners were cut once a week from July 11 until October 19, when runner growth had practically ceased.

In order to determine the effect of the production of runners on the growth of the mother-plant itself three plants of each of the ten lots were dug on May 6, 1930. and various measurements taken. These measurements are given in table III.

The runner plants produced in 1929 were dug and planted between March 28 and April 2, 1930, They were planted soon after digging, with no opportunity for drying out, and were washed and weighed before planting.

Fairly accurate weights were obtained by rinsing in water and shaking the surplus water off. One group of from 40 to 100 plants from each lot was weighed as a unit for bulk study, and 5 to 10 plants from each lot were weighed individually in order that individual records might be obtained for some plants.

In the lots where more than one plant was allowed per runner during 1929 the first and last plants were transplanted for comparative study; e.g., in Lot 5, plant No. 1 and plant No. 3 were used, and in Lot 7 No. 1 and No. 5 were used. In this way the effect of the position on the runner could be studied.

The plants were set out by the commercial method, using a hoe to make the hole and setting the plants after they were dipped in water. None of the plants were trimmed other than removing dead leaves, but it was later seen that the larger ones would have benefited by having some of their leaves removed before being planted. The smaller plants did not appear to suffer.

During the 1930 season the runners were removed from all the plants, both old and young. The one-year-old plants were again irrigated, but the 1930 planting was not. The flowers were also removed from the 1930 planting. It was interesting to note that even the plants formed after September 1 had flower buds which opened as soon as those of the larger plants.

The lots planted for bulk study were numbered as follows:

RE1A	field run of plants from Lot 1 of 1929.
RE1B	first plant on each runner in Lot 1.
RE1C	last available plant on each runner in Lot 1 (No. 4).
RE2	runner plants from Lot 2.
RE3	runner plants from Lot 3.
RE4	runner plants from Lot 4.
RE5A	first plant on each runner of Lot 5.
RE5B	third plant on each runner of Lot 5.
RE6	runner plants from Lot 6.
RE7A	first plant on each runner of Lot 7.
RE7B	fifth plant on each runner of Lot 7.
RE9A	field run of plants from Lot 9.
RE9B	first plant on each runner of Lot 9.
RE10A	field run of plants from Lot 10.
RE10B	first plant on each runner of Lot 10.

The lots planted for individual study were numbered as follows:

Etters A	Lot 1, No. 1.
Etters B	Lot 1, No. 4.
Etters C	Lot 2.

Etters D Lot 3.

Etters E Lot 4.

Etters F Lot 5, No. 1.

Etters G Lot 5, No. 3.

Etters H Lot 6.

Etters I Lot 7, No. 1

Etters J Lot 7, No. 5.

Etters K Lot 9, No. 1.

Etters L Lot 9, No. 4.

Etters M Lot 10, No. 1.

On October 27 and 28, 1930, from 6 to 10 plants from each of Lots RE1B to RE7B were carefully dug, retaining as much of the root system as could readily be had. These were washed and records taken of the number of crowns, and weights of the plants divided as accurately as possible between tops and roots. The plants were killed soon after digging by placing in an oven at 80°C. for two hours. This treatment stopped respiration and facilitated drying. Since only relative weights of the plants were needed, they were weighed after becoming air dry. The figures on these plants are given in Table V.

Some plants were grown in water culture in order that the effect of runner production on the plants might be observed more closely than would be possible with plants growing in soil.

The plants used were of the Ettersburg 121 variety. One-quart fruit jars covered with opaque paper were used for containers, one jar being used for each plant. Forty-eight plants were used.

Distilled water was used at all times.

Salts used in the solutions include K_2HPO_4, KH_2PO_4, $MgSO_4$, $Ca(NO_3)_2$, $CaCl_2$, KNO_3, $MgHPO_4$, $CaSO_4$, $NaBO_2$, ferric citrate, and ferric tartrate.

The plants were treated as shown in Table II.

TABLE II

Ettersburg 121 Plants in Water Cultures

Plant No.	Solution	Runner treatment
	Solution I	
1-6	5 cc molar KH_2PO_4 per liter	
	2 cc " K_2HPO_4 " "	
	5 cc " $MgSO_4$ " "	
	1 cc " $Ca(NO_3)_2$ " "	All runners left
	6 cc " $CaCl_2$ " "	
	1 cc 5% ferric citrate per liter	
7-12	Same as 1-6	All runners removed

TABLE II
(Continued)

Ettersburg 121 Plants in Water Cultures

Plant No.	Solution	Runner treatment
	Solution II	
13-18	5 cc molar KH_2PO_4 per liter	All runners left
	2 cc " K_2HPO_4 " "	
	5 cc " $MgSO_4$ " "	
	3 cc " $Ca(NO_3)_2$ " "	
	4 cc " $CaCl_2$ " "	
	1 cc 5% ferric citrate ""	
19-24	Same as 13-18	All runners removed.
	Solution III	
25-30	5 cc molar KH_2PO_4 per liter	All runners left
	2 cc " K_2HPO_4 " "	
	5 cc " $MgSO_4$ " "	
	7 cc " $Ca(NO_3)_2$ " "	
	1 cc 5% ferric citrate ""	
31-36	Same as 25-30	All runners removed

TABLE II
(Continued)

Ettersburg 121 Plants in Water Cultures

Plant No.	Solution	Runner treatment
	Solution IV	
37-42	5 cc molar KH_2PO_4 per liter	
	2 cc " K_2HPO_4 " "	All runners
	5 cc " $MgSO_4$ " "	left
	16 cc " $Ca(NO_3)_2$ " "	
	1 cc 5% ferric citrate ""	
43-48	Same as 37-42	All runners removed.

Stock solutions of these salts in molar concentration were used in making up the nutrient solutions. The solutions when made up had a pH of about 5.

The solutions were made up in quantities sufficient for one change, and fresh solutions made for each change. Solutions were changed twice a week for three months, then once a week.

Since distilled water contains little air, the solutions were aerated before using. This was done with an aerator made by Dr. E. M. Harvey. The apparatus draws air from the atmosphere, mixes it with the tap water, separates the air again, and forces it into the nutrient solution. All solutions were aerated 15 minutes when made up.

After having grown the plants in these solutions for several weeks, they began to produce yellow leaves, indicating a deficiency of iron. More iron was added till 6 cc of 5% iron citrate were used per liter, when the fault was remedied in plants 1-12, but the plants receiving the larger quantities of nitrate continued to grow poorly, the ones receiving the most nitrate being the poorest. A saturated solution of ferric tartrate was substituted for the citrate with similar results. The addition of 3 per cent of soil solution was necessary in order to maintain the life of the plants.

After the plants had grown in the given solutions three months, the solutions on plants 13-48 were discontinued in favor of one recommended by W. F. Gericke of the University of California, having the following composition:

8 cc molar KNO_3 per liter

1 cc molar $MgHPO_4$ per liter

Small quantity $CaSO_4$

1 ppm iron (tartrate, citrate, or sulfate): citrate was used.

Trace $NaBO_2$

pH adjusted to 5 with HNO_3.

The plants were set outdoors and the jars set in the soil in order to obtain a more nearly natural temperature for the roots. The solution was changed weekly, with water and iron added every second day. No chlorosis developed, but the plants did not thrive, and they could not be used in the study on the effects of runner production.

As a check on the results obtained in the water cultures, a series of plants was grown in potting soil in the greenhouse. These plants were under more favorable growing conditions than those in the nutrient solutions. The soil was composed of three parts compost, one part sand, and one part fine leaf mold. Since the object was to subject all the plants to similar conditions it was not considered necessary to make an analysis of the soil for the purposes at hand.

The plants were dug in the field on January 6, 1931, and sorted into two groups as nearly equal as possible and planted at once. One group of ten had the runners removed weekly, while the other group of the same size was permitted to retain all its runners.

At the time of this writing these plants have not made sufficient growth to warrant their being taken down, and are being held for later observations. The results will be given in a supplement after the data become available.

Results

As was stated earlier in this paper, all the experimental work reported in this discussion was carried on with the use of the Ettersburg 121 variety since the results obtainable from the Marshall were unreliable because of the serious crown borer injury.

The effect of runner production on mother-plant. Table III gives the measurements of three plants from each plot given different treatment as to the number of runner plants allowed. The third column gives the dry weight in grams of the crowns; they were dried 48 hours at 75°C. and a negative pressure of 25 inches of mercury. The leaf area was approximated by measuring the leaves of five to eight representative crowns of each plant and calculating the total area from the total number of leaves on the plant. All measurements of leaf area were made with a planimeter.

Although the number of plants used for these measurements was small for any definite conclusions to be drawn, especially concerning any fine differences, yet several interesting observations can be noted from these figures as indicating the tendencies of the reactions of strawberry plants to the production of runners. These reactions will be indicated in the sections which follow.

TABLE III

Measurements of Ettersburg 121 plants

Dug May 6, 1930.

Averages for 3 plants per lot.

Lot	No. of crowns	Wt. of crowns gm.	Av'g wt. per crown gm.	Av'g size of leaf sq.cm.	Total leaf area sq. cm.	No. of flowers	No. of clusters	Flowers per cluster
1	9.3	13.8	1.48	30.01	2524	285	31.7	9.0
2	26	27.6	1.06	31.49	4977	577	60.0	9.6
3	29	31.3	1.08	31.90	5562	682	65.3	10.4
4	19.7	30.0	1.52	31.38	3948	494	49.0	10.1
5	21	31.3	1.49	33.45	4534	467	51.0	9.2
6	21.3	28.8	1.35	31.14	4402	559	55.3	10.1
7	19.3	31.8	1.65	35.38	4671	566	53.3	10.6
9	18	22.2	1.23	35.23	4068	393	39.3	10.0
10	19	28.4	1.49	30.66	3956	527	53.3	9.9
11	29	38.2	1.32	32.51	7009	736	70.3	10.5

Effect of number of runners on number and size of crowns. Figure I shows the effect of runner production on the number of crowns produced by the mother-plant. The tendency is decidedly upward when the number of runners is limited, going from 10 in Lot 1 to 29 in Lot 11. The discrepancy of the figures obtained for Lots 4 and 6 is likely due to the small number of plants used; at any rate the difference in the drain of nine and fifteen daughter plants on the mother-plant probably was not great enough to show in the figures, even in larger numbers. The number of runner-plants per mother-plant in this comparison are all (average of 64), 15, 9, 3, and none.

Figure II does not show an increase, nor even an equal size of crown for those lots producing the larger number, in fact it shows some reduction in size. This is probably due to the fact that new crowns were being produced until late in the season in the cases where the runner growth was reduced, while in the others, most of the crowns had been produced earlier in the season and most of the mother-plant growth consisted merely in the enlargement of the already existing crowns. It will be seen in Figure V that the total weight of the crowns in a plant increases with the decreased runner production.

The effect of runner production on crown formation is of economic importance, as there is a definite relationship between the number of crowns in a plant and the number of berries it can produce.

Effect of number of runners on leaf size and total area. Figures III and IV show that not only did the plants with less runners produce a greater leaf area per plant, but also the individual leaves were larger. These results agree with results obtained by Darrow (11) working on several varieties at Bell, Maryland. This effect of runner production on the number and size of leaves is an expression of the drain on the energy of the plant by the growing runners and runner plants.

Effect of number of runners on number of flowers. The influence of runner production on the number of flowers is shown in Figure VI. The increase from 285 per plant in Lot 1 to 736 in Lot 11 is significant, and should ordinarily be indicative of the potential bearing ability of the plant. However, as Figure VIII shows, the ultimate yield of the plants in 1930 was not proportionate to the number of blossoms produced. Lot 1 was lowest, as was to be expected, and Lot 6 showed a marked increase, but from that point the yield became erratic, Lots 4 and 2 going down slightly and Lot 11, which one would expect to be highest, actually produced less berries than the lots with a limited number of runner-plants, though more than the lot producing an unlimited number of runners. That season was a bad one for strawberries generally, on account of the cold, wet weather during blossom time, and the bad condition may have been aggravated by the large amount of foliage on the plants in Lots 4, 2, and 11, especially the last.

Effect of number of runners on size of flower clusters. Limiting the number of runners did not have as marked influence on the size of the flower clusters as on other forms of growth. Figure VII shows the variation in size of clusters among the lots. Here again the increase was fairly pronounced (16%), from Lot 1 to Lot 6, but the variation among the lots with the runners limited was not greater than could be expected as the result of the small samples.

TABLE IV

Yield of Ettersburg 121 1930

Lot	1	2	3	4	5	6	7	9	10	11
Average yield per lot 28-30 plants. Pounds	.53	.91	.91	.94	.89	.98	.72	.69	.87	.71

FIGURE I

Effect of Number of Runners on Number of Crowns

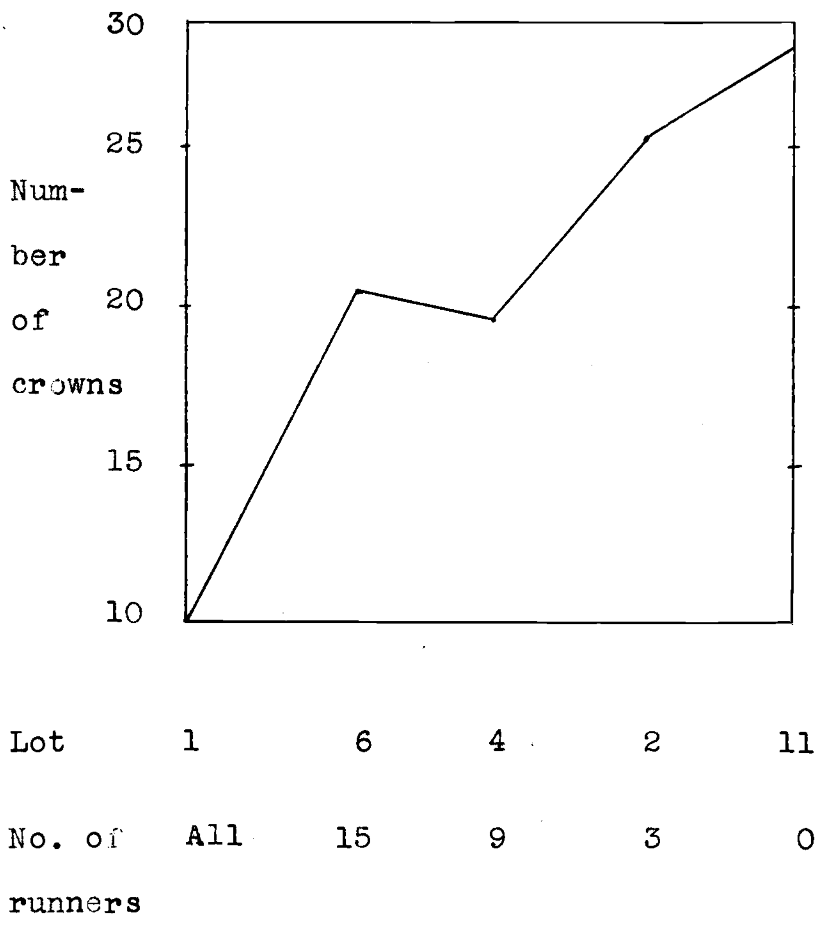


FIGURE II

Effect of Number of Runners on Size of Crowns

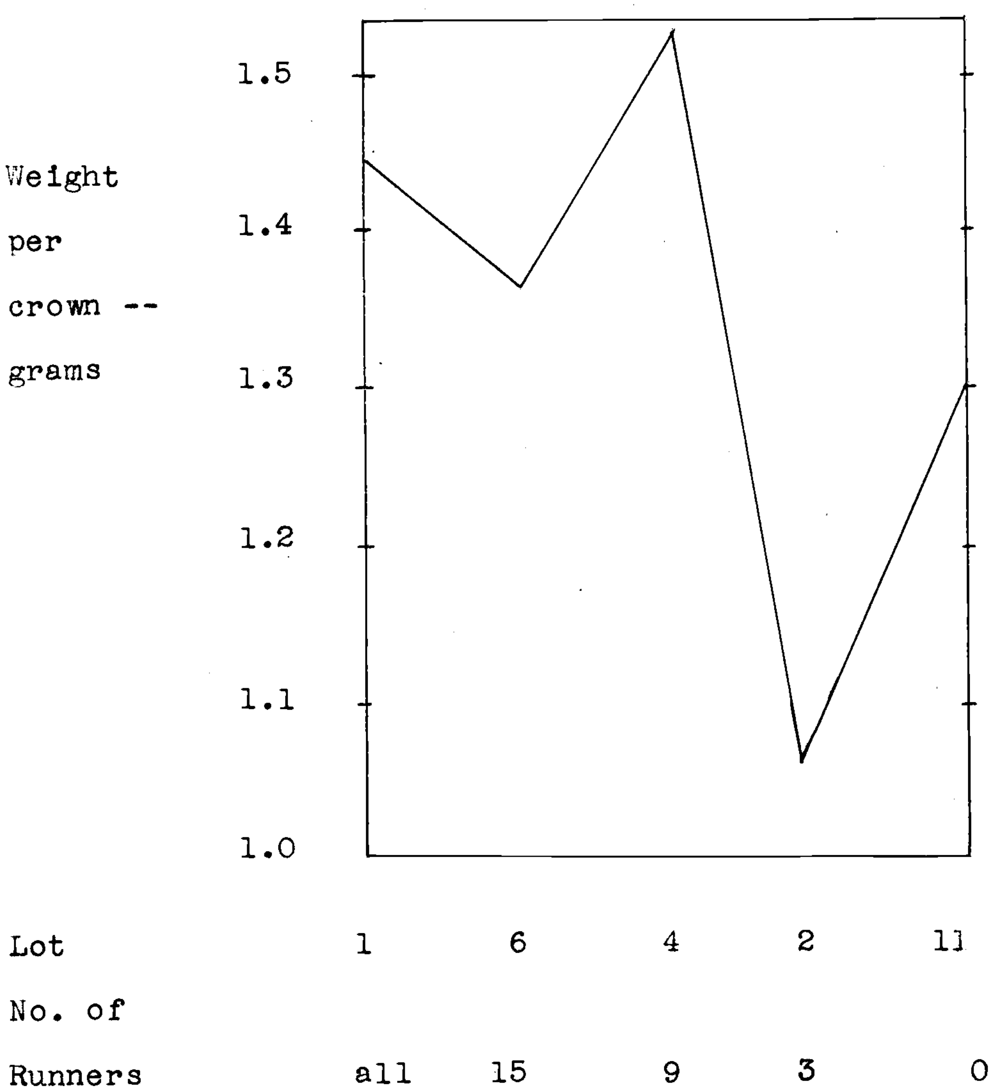


FIGURE III

Effect of Number of Runners on Size of Leaf.

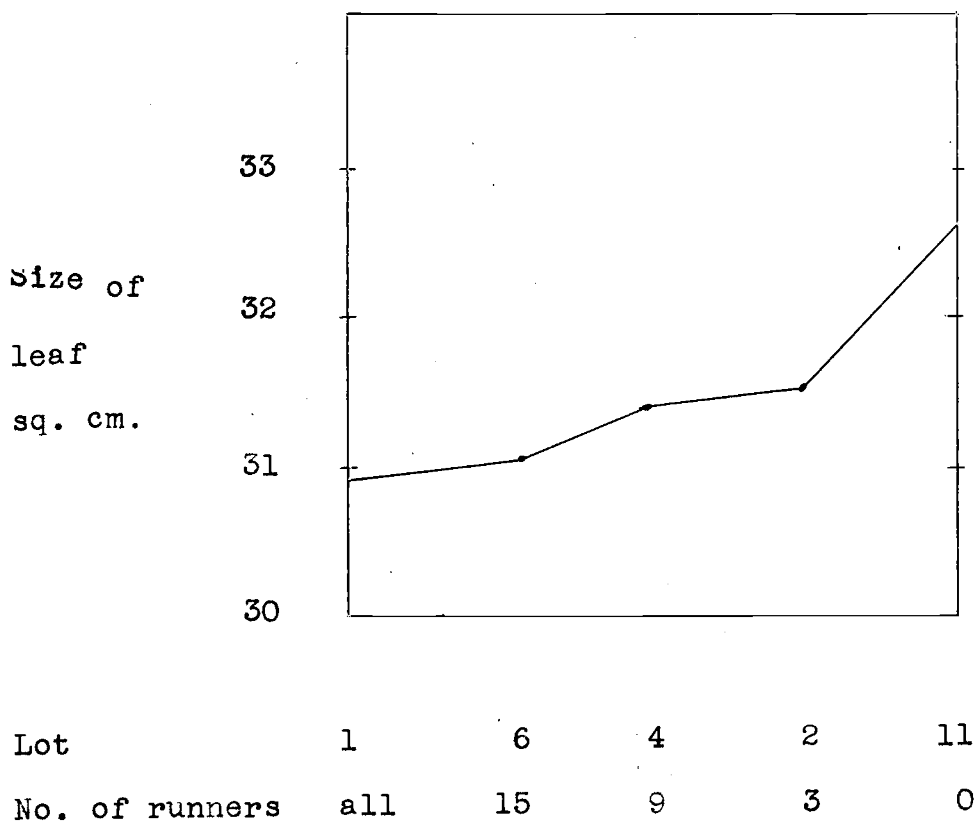


FIGURE IV

Effect of Number of Runners on Total Leaf Area.

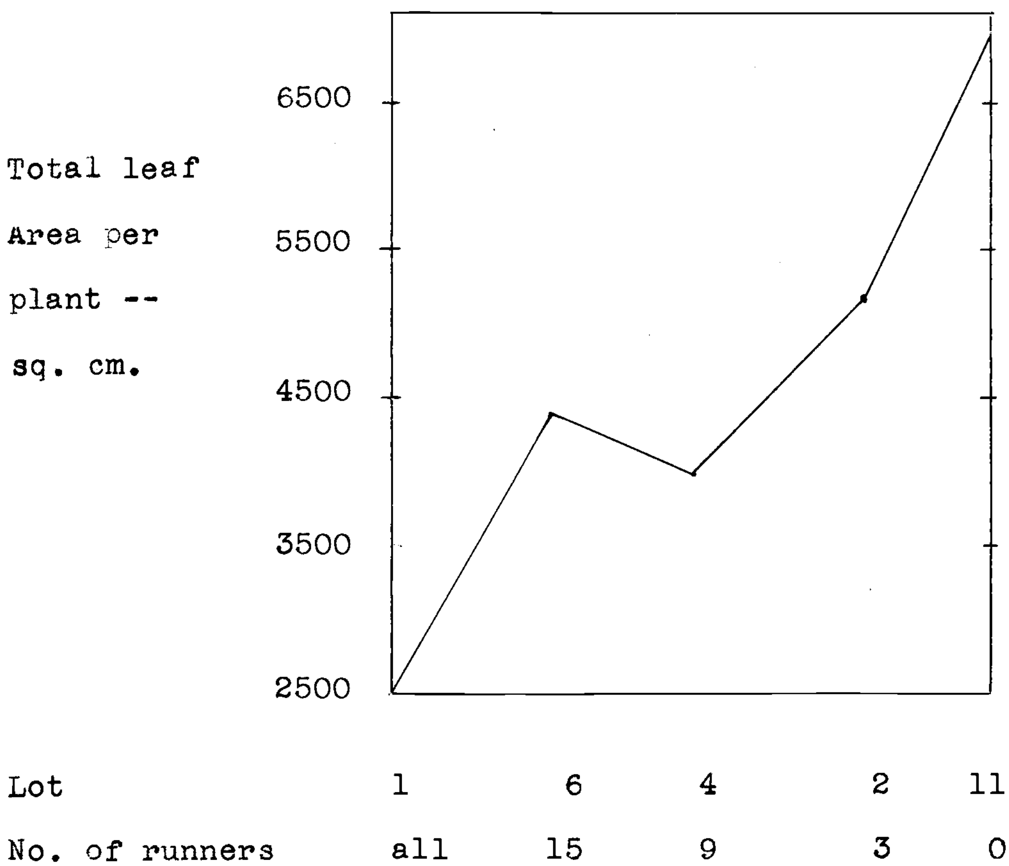


FIGURE V

Effect of Number of Runners on Weight of Crowns

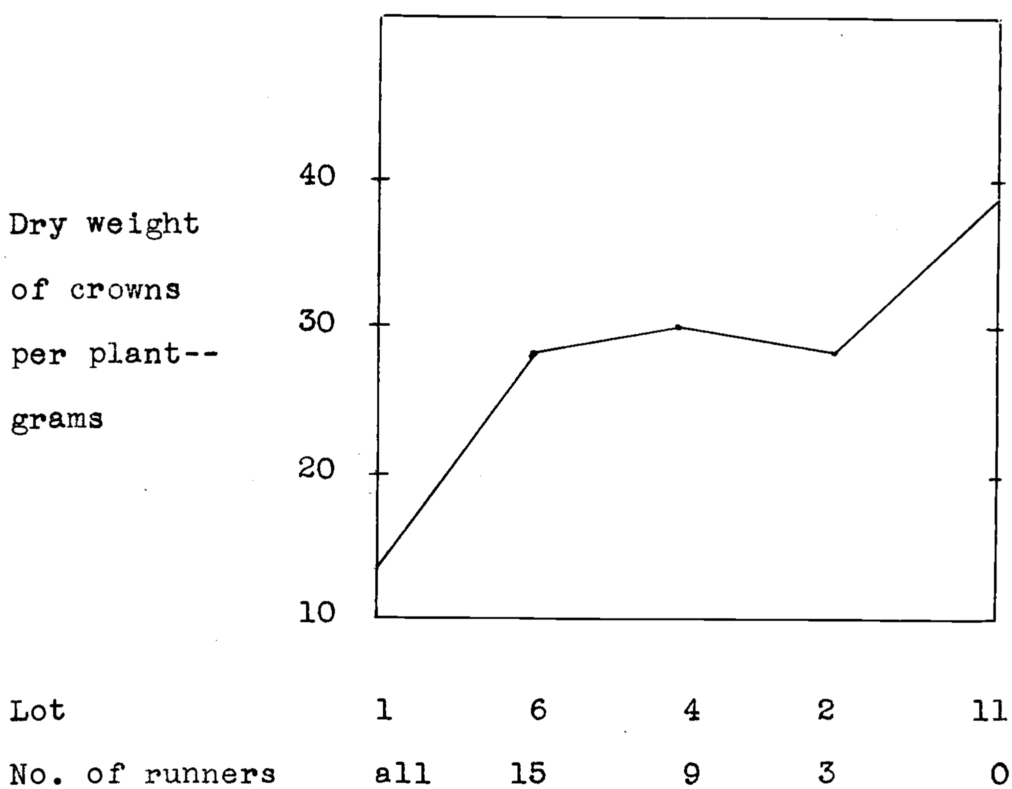


FIGURE VI

Effect of Number of Runners on Number of Flowers

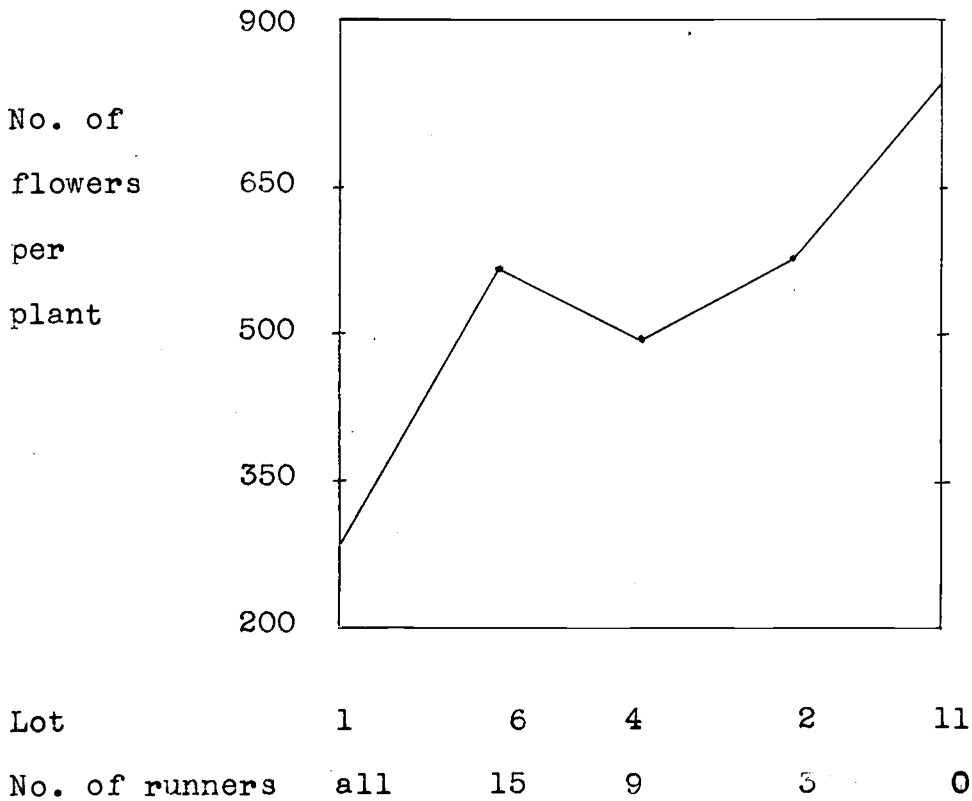


FIGURE VII

Effect of Number of Runners on Size of Flower Clusters

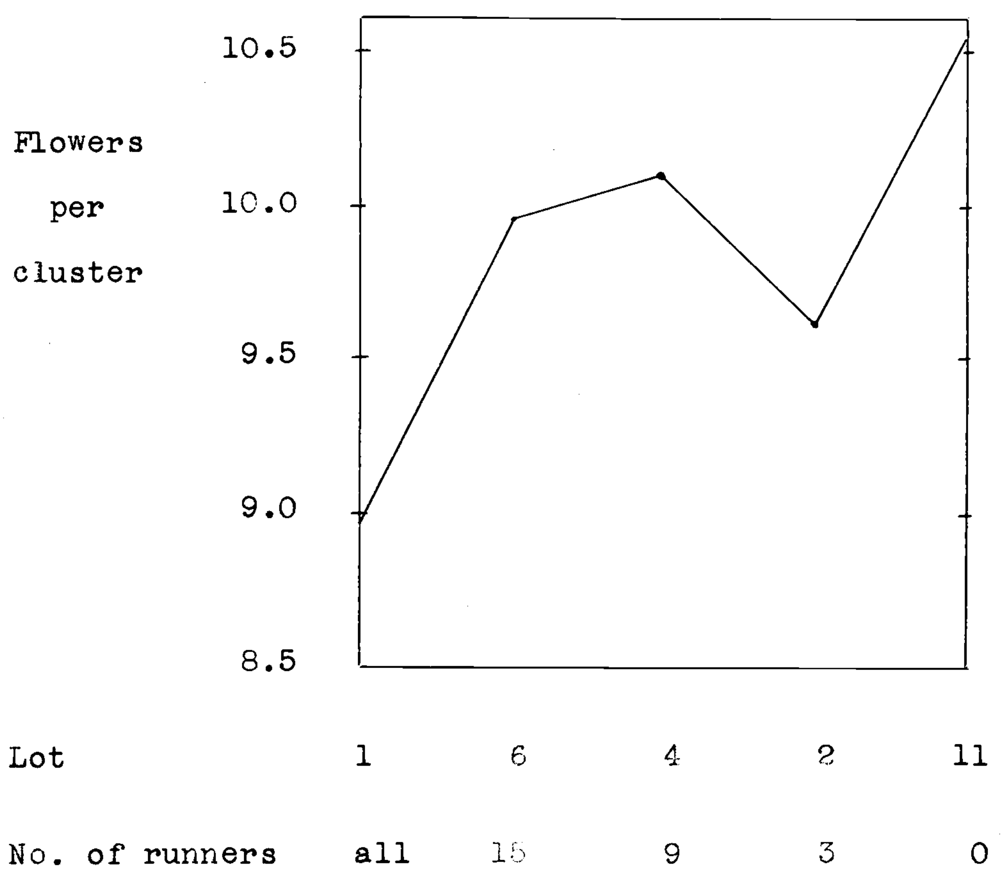
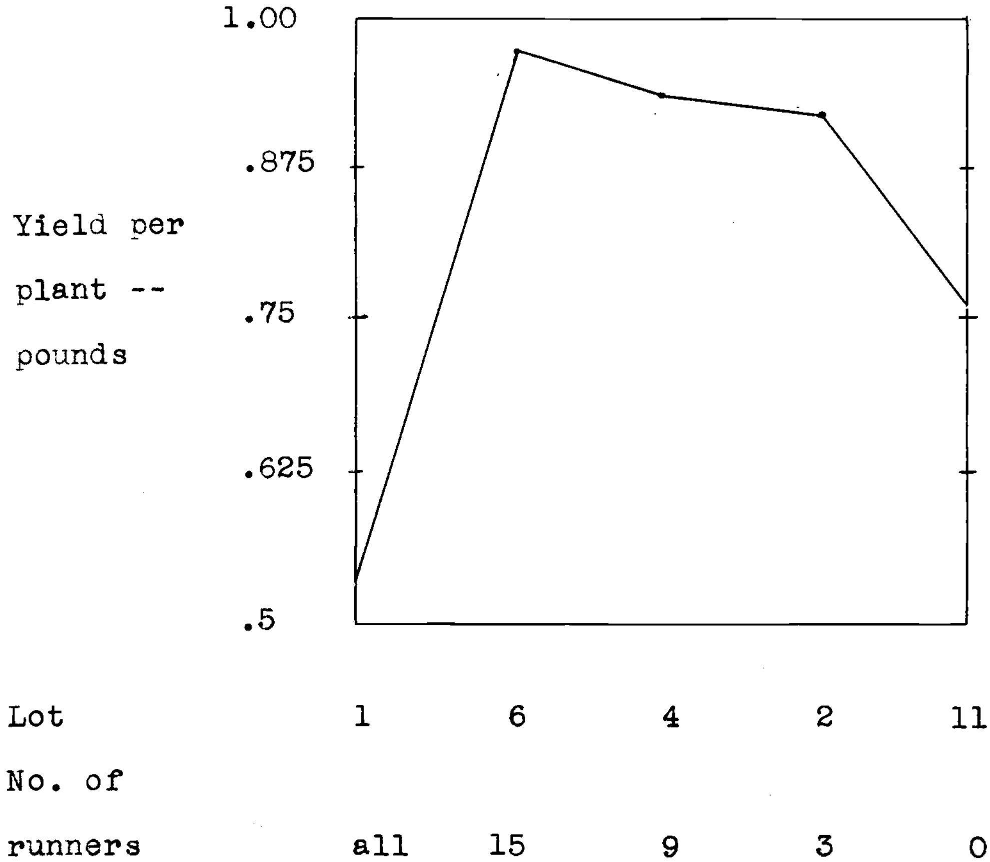


FIGURE VIII

Effect of Number of Runners on Yield.



The effect of the number of daughter plants on their size. Table V shows the size of the daughter plants set April 2, 1930, after one season's growth. They were dug for measurement on October 27 and 28, 1930.

The lots comparable with respect to the number of daughter plants produced by their mothers are 1, 2, 4, and 6, having produced respectively 64 (all), 3, 9, and 15 daughter plants each. It will be found that these plants, after one season's growth after transplanting are in the order 2, 4, 6, and 1B with respect to the number of crowns, weights of the tops, roots, and the plants as a whole. The weights of the plants at the time of planting are also in this order. The roots of the plants of Lot 6 are shown to be heavier than those of Lot 4, but this is so slight that it easily falls within the experimental error. Lot 6 also shows a slightly narrower ratio of top to roots than does 4; this also may be due to experimental error. It is especially interesting to see the great difference between the ratio of top to root in 1B and 2, being 4.8:1 and 3.2:1 respectively, Lot 1B having 50 per cent more tops to its roots, proportionately, than Lot 2, and this in spite of the fact that the tops of Lot 2 were over 25 per cent larger than those of 1B. Just what effect this greater proportion of roots will have upon the bearing ability of the plant remains to be seen. It should be mentioned that the reason for using Lot 1B in this comparison is that this lot consists of No. 1 runner plants, and were the largest plants in the lot with unrestricted runner growth, hence they correspond to the best plants that can be selected in a field producing plants under commercial methods. Lot 1C consists of smaller plants, and will be dealt with later.

<u>The effect of arrangement of daughter plants on their size</u>. In order to obtain the effect of the arrangement of the daughter plants on the mother-plant, the same number of daughter plants was allowed to be produced in two lots, but with different arrangements. Lot 4 had nine daughter plants, one on each runner, while Lot 5 also had nine daughter plants, but three on each of three runners. Likewise Lot 6 had 15 daughter plants, one on each runner, while Lot 7 had five daughter plants on each of three runners. In Lots 5 and 7 the daughter plants nearest the mother plants were labeled RE5A and RE7A respectively, while the third in Lot 5 became RE5B and the fifth in Lot 7 became RE7B.

At the time of planting, RE4 had larger plants than RE5A or RE5B, but at the end of the season RE5A had the largest plants. The ratio of top to roots in the three groups was nearly the same. In comparing RE6 with RE7A and RE7B, we note that the plants of RE7A were largest at the time of planting, but were equalled by RE6 after one season's growth. The root growth of RE6, however, had not yet reached that of RE7A. RE7B consistently remained below both RE6 and RE7A at the end of one season's growth.

The effect of the position of the daughter plant on the runner on its size. The daughter plants on the distal end of the runners were considerably smaller than the first ones when transplanted, and remained smaller thruout the season, although not proportionately. The ratio of top to root was the same for Lots RE5A and B, but in Re7B the ratio was 13.5% wider than in RE7A and in RE1C it was 18.3% wider than in RE1B. As was indicated previously, it will be interesting to follow the effect of this difference through the bearing season.

In Lot 1 also a comparison was made between the near and distant daughter plants. The first plants on the runners were labeled RE1B and the ones farthest away from the mother plant, in this case the fourth, were labeled RE1C. In order to compare these with the general run of plants, one lot of one hundred plants was set out with all the good runner plants taken field run. This lot was labeled RE1A.

Table V gives the weights of the plants when set in April. The plants of RE5A were 79% larger than those of

RE5B, while the plants of RE7A were 142% larger than those of RE7B. The plants of RE1B were 151% larger than those of RE1C.

It will be noted in Table VI that the weight of the roots of these plants after one season's growth are in the same order as were the weights of the plants in the spring, except Lot 3, and Lots 4 and 5A, which exchanged places. As a matter of fact, the general trend of all the lots was to remain in the same general positions with respect to one another in all measurements as the plants when planted held in weight. This was particularly true of the plants with the extreme treatment. Lot RE2 had the largest tops, largest roots, largest size of whole plant, lowest ratio of top to root, the largest number of crowns, and was largest when planted. At the other extreme RE1C and RE1B respectively held the two bottom positions.

<u>The effect of the date of formation of daughter plants on their size</u>. Lot 3 was not allowed to set any runner plants until after September 1, when three plants were allowed, one on each of three runners. This was done in order to compare their value with those set early in the season. The plants were strong and well-formed at the time of transplanting, but weighed only 27.3% as much as those of Lot 2 which were produced in early July. Their

TABLE V

Measurements of Plants Dug October 27-28, 1930.

Lot	No. of crowns per plant	Wt. of top per plant	Wt. of root per plant	Wt. per plant	Ratio top to roots x:1	Average wt. when planted gm.
RE1B	30.2	99.1	21.5	120.6	4.8	17.24
1C	28.2	96.4	16.6	113.0	5.7	6.86
2	45.2	139.0	40.4	179.3	3.2	85.70
3	35.1	119.5	27.1	146.6	4.5	23.50
4	44.3	129.0	30.8	159.7	4.2	53.00
5A	38.9	133.8	31.4	165.2	4.3	44.90
5B	30.3	109.9	25.9	135.8	4.3	25.08
6	34.1	120.9	30.9	151.8	3.9	38.19
7A	36.6	116.8	32.6	149.4	3.7	56.97
7B	33.5	106.7	25.0	131.7	4.2	23.56

Average of 10 plants per lot except:

Lot 4 -- 9 plants.

Lots 1C and 7B -- 6 plants each.

Weight of plants when planted is fresh weight, all others air-dry weights.

TABLE VI

Rank of Lots with Respect to Various Measurements

Rank	Size of tops	Size of roots	Size of whole plants	Size of plants when planted	Ratio tops to roots	No. of crowns	Av'g rank for all factors
1	2	2	2	2	2	2	2
2	5A	7A	5A	7A	7A	4	4
3	4	5A	4	4	6	5A	5A)*
4	6	4	6	5A	7B)*	7A	7A)*
5	3	6	7A	6	4)*	3	6
6	7A	3	3	5B	5B)*	6	3
7	5B	5B	5B	7B	5A)*	7B	5B
8	7B	7B	7B	3	3	5B	7B
9	1B	1B	1B	1B	1B	1B	1B
10	1C	1C	1C	1C	1C	1C	1C

weight was practically the same as the plants of Lot RE7B. As shown in Table VI this lot ranked eighth in size of plants when planted. By the end of the season it had risen to sixth with respect to weight of roots and weight of whole plants, and fifth with respect to weight of tops and the number of crowns. It still remained eighth with respect to ratio of top to root. The evidence thus far indicates that late-formed plants are not desirable, even when well-shaped and grown where a limited number of daughter plants are allowed to form. The plants in Lot 10 were allowed to produce runners after September 1 only, and the field run of daughter plants transplanted as RE10A. The No. 1 daughter plants were labeled RE10B. The plant size in both these lots was very small, being only slightly greater than that of RE1C.

Yield records will be taken on all these lots during the current season and will be given in a supplement to this paper. Results obtained by Davis (13) indicate that there is a high correlation between the dry weight of a plant in the fall and its yielding ability the following spring.

No chemical analyses have been made in order to determine the nutritional condition of the plants after the different treatments. Analyses by Richey and

Asbury (21) show that the total carbohydrate content of the daughter plants progressively decreased from the oldest to the youngest plant in a series. In October the total carbohydrates of the crowns and roots ranged from 40% in the mother plant and over 39% in the first runner plant to about 35% in plants number 4 and 5 in the series. Yield records at the same station showed that the yields were in the same order as the carbohydrat content.

Water cultures. The plants growing in water cultures indicated that runner production reduces the growth of the root as well as the top of the mother plant. After the plants in solution I (see Table II) had grown twenty weeks (April 10 to August 29, 1930,) they were dried and weighed in three portions, roots, top, and runners. The drying was done in a Freas electric vacuum oven at 75° C. and a vacuum of 27 inches of mercury for 24 hours. The figures on these plants are given in Table VII. The five plants which produced runners averaged eight daughter plants each, with 105.5 inches of runner growth. This is low for plants of the Ettersburg 121 variety, but sufficient to have some effect on the mother plants. The weights of the tops alone without runners was reduced from 8.09 grams to 3.70 grams each, while the total weight of tops plus runners was 9.89 grams each, or 22%

TABLE VII

Measurements of Plants Grown in Water Culture

April 10 - August 29, 1930.

	With runners Av'g of 5 plants	Without runners, Av'g of 7 plants
No. of runners	2.6	---
Length of runners - inches	105.5	---
No. of d. plants	8.2	---
Wt. of runners and d. plants-gm.	6.193	---
Wt. of tops -gm.	3.70	8.09
Wt. of roots -gm.	1.53	2.36
Wt. of top plus runners	9.89	---
Wt. of whole plants	11.42	10.45
Ratio top to roots	2.42:1	3.43:1
Ratio all top to roots	6.46:1	3.43:1

greater than the tops of the plants with the runners removed. The roots of the plants with runners averaged 1.53 grams while those of the plants without runners weighed 2.36 grams, or 54.2% more. The total weight of each plant with all runners attached was 11.42 grams as compared with 10.45 grams for the plants with no runners. The plants with runners had 9.2% more total weight than the plants without runners, while the latter had 54.2% greater weight of roots than the former and 116.3% greater weight of tops not including the runners.

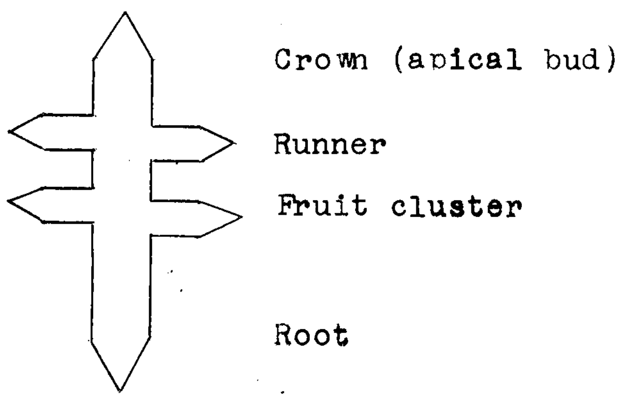
GENERAL DISCUSSION

The results thus far obtained indicate that the size of a strawberry plant at the time it is planted is an important factor in its potential yielding ability. Another factor which may be significant in determining the yielding ability in addition to its effect on the size is the proximity of a daughter plant to the mother plant. Work done by other investigators indicates that the nutritional condition of the plants near the mother plant is more favorable than in those more distant in the series. The growth thus far of the plants used by the writer indicate that the yields may correspond to these results, as the first plants in the series have made a greater growth than those fartherout.

The nutrition of the strawberry plant presents a problem quite different from that of many other horticultural plants. Translocation in the strawberry has been shown by other workers to be practically complete, whereas in the apple the nutritional materials are very limited in the regions to which they may move. In view of this fact it is evident that the production of runners by any part of the plant is going to influence all of the plant, not only the portion from which the runners develop.

In the growth of a strawberry plant the energy may be diverted into one of four channels, the production of runners, fruit, crowns, or roots. Antagonisms exist between these portions of the plant, and the question of which one or ones will develop at the expense of the others depends on several factors. With the Ettersburg No. 121 variety it appears that the runners are somewhat favored, since by their removal the other three are all increased. No attempt has been made to find how much influence fruit production has on runner, top, or root production, but the general impression must be that it is unfavorable to the general growth of the plant, as it is considered a good practice to remove the flowers until the plants become established. A quantitative study of this phase of the antagonism would be of interest.

The figure below is a diagrammatic sketch of a strawberry plant in the early portion of the season. The fruit clusters are produced in the axils of the leaves near the lower and of the crown and runners are produced in the higher axils. Later in the season fruit buds are differentiated above these runners, with runners the following season again being developed above the fruits clusters of that season.



In the early portion of the season the fruiting portion of the plant draws heavily on the food supply and few if any runners are produced. Later runners are produced, and if allowed to grow they retard the growth of the mother plant. If the runners are left on the mother plant in the fall of the year, during the time of fruit-bud differentiation they will reduce the number of such buds formed, indicating that the runners have better access to the available food supply than the potential fruit buds.

It seems evident that in the strawberry the terminal bud of the crown does not hold the same position with regard to the lateral buds as in the case of a pear tree. In the latter a long terminal growth occurs first and after this has been completed the laterals and the fruit buds are formed, whereas in the strawberry the presence of growing fruit and runners checks the growth of the terminal bud in the crown.

Additional information will be obtained during the current bearing season and will be added to this paper in a supplement.

SUMMARY

The data at hand are too meager to permit very definite conclusions to be drawn, but the results of this experiment can be summarized. Tendencies can be indicated, bearing in mind the limitation of their significance.

1. Limiting the number of runners to few or none had the following effects on the mother plant:

   a. Increased the number of crowns.

b. Increased the number of leaves per plant.

c. Increased the size of leaf.

d. Increased the number of flowers.

e. Did not markedly affect the size of cluster.

2. Limiting the number of runners increased the size of the remaining plants.

3. Limiting the number of runners tended to increase the proportion of root to the top of the daughter plants.

4. Daughter plants near the mother plant were larger than those farther out on the runner, and the ratio of root to top tended to be narrower.

5. Larger plants were obtained by leaving only the first plants on a runner than by leaving the same number of plants on fewer and longer runners.

6. Runner plants formed early in the season were more vigorous than those former late.

7. Runners stunted the growth of the roots of the mother plant, but not to the extent that they stunted the tops.

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SUPPLEMENT

On June 6 and 7 the flowers of the plants set for individual records were counted. The results obtained by this year's figures are unfortunately not reliable and can not be taken as conclusive. During April of this year at the time of high water a large portion of the field was flooded and the water remained on a portion of the field for a considerable length of time. Nevertheless counts were made and the results are given in Table VIII. The number of flowers was taken as an index of the size and productivity of the plants rather than the yield, as it was thought that this would more nearly represent the relative potential yielding ability of the plants in view of the unsatisfactory and abnormal berry season. The general yield and quality of strawberries for the season have been greatly reduced by the excessively high temperatures and warm winds which prevailed as the berries were developing.

TABLE VIII

Weight of Plants When Planted and Number of Flowers Produced During the First Bearing Season.

Lot and Plant Number	Weight When Planted	Number of Flowers	Average Number Flowers per Plant
Etters A 1	14	329	
2	30	401	
3	18	340	
4	20	303	
5	18	186	
6	14	235	
7	14	214	
8	20	286	
9	44	256	
10	20	304	285
Etters B 1	4	277	
2	10	237	
3	4	310	
4	8	472	324
Etters C 1	132	504	
2	120	522	
3	82	472	

	4	80	297	
	5	120	513	462
Etters D	1	34	492	
	2	20	595	
	3	22	624	
	4	34	489	
	5	28	591	550
Etters E	1	46	492	
	2	56	506	
	3	68	602	
	4	44	642	560
Etters F	1	40	503	
	2	36	581	
	3	54	579	
	4	40	630	
	5	56	721	603
Etters G	1	26	595	
	2	30	442	
	3	30	417	
	4	20	487	
	5	26	548	498
Etters H	1	20	457	
	2	31	640	
	3	34	819	
	4	38	651	

	5	40	699	643
Etters I	1	48	102	
	2	90	132	
	3	70	194	
	4	50	319	
	5	50	321	214
Etters J	1	26	561	
	2	30	658	
	3	22	630	
	4	20	609	
	5	20	471	586
Etters K	1	20	591	
	2	12	509	
	3	24	637	
	4	14	756	
	5	26	599	618
Etters L	1	14	640	
	2	18	600	
	3	32	622	
	4	10	517	
	5	18	628	601
Etters M	1	13	819	
	2	14	752	
	3	14	530	

4	5	776	
5	13	432	622

Effect of position of daughter plant on productivity. These figures show no consistent relationship between the position of the daughter plant on the runner series and their yielding power nor do they indicate any relation between the size of the plants when set and their yielding power. In Lot 1 where the mother plants were allowed to produce an unlimited number of runners the first runner plants in the series averaged 285 flowers per plant while the fourth plant in the series averaged 324. In Lot 5 where the mother plants were permitted three runner series with three plants per series, the first plants (Etters F) averaged 603 flowers while the third (Etters G) averaged 498 flowers per plant. In Lot 7 where the mother plants were allowed to produce three runner series with five plants per series the first plants averaged only 214 flowers per plant while the fifth averaged 586. In Lot 9 the mother plants were permitted to retain all the daughter plants produced before September 1. In this case the first plants on the series (Etters K) produced 618 flowers per plant while the fourth, being the last in the series, produced 601 flowers, being nearly equally productive.

Effect of limiting the number of daughter plants on their productivity. The plants produced where the mother plants were limited to three daughter plants (Etters C) did not retain the advantage which they had attained earlier in their lives. They produced an average of 462 flowers per plant. The first plants of the series where an unlimited number of runners were left produced only 285 flowers, but the first and last plants in the series produced by Lot R E 9 averaged over six hundred flowers.

In Lot E the plants averaged 560 flowers as compared with 462 in Lot C and Lot H produced 498 flowers. It will be remembered that Lot E consisted of plants where the mother plants had been limited to nine runners with one plant each, Lot C to three and Lot H to 15.

Effect of time of runner production on the productivity of the runner plants. The results obtained in this experiment show no detrimental effect of using plants produced late in the season. Lot C was formed in June and averaged 462 flowers per plant, while Lot D, also limited to three daughter plants, averaged 550 flowers. Also Lot K, the first plants in the series produced early in the season, averaged 618 flowers while Lot M, the first plants in the series produced after September 1, produced

662 flowers per plant.

Effect of weight of plants when set on their productivity. No relationship could be observed in this experiment between the weight of the plants when set and their productivity. In Table IX the plants are grouped according to weight when planted and the average number of flowers is given.

TABLE IX

Weight of Plants When Planted - Grams	Number of Flowers per Plant	Number of Plants in Group
up to 10	396	7
11 -- 20	521	22
21 -- 30	542	12
31 -- 40	608	10
41 -- 50	355	6
51 -- 60	650	2
61 -- 70	398	2
71 -- 80	297	1
81 -- 90	302	2
111 --120	517	2
131 --140	504	1

The lowest producing group was the one with weights from 71 to 80 grams while the highest producing one was the one ranging from 51 to 60 grams.

As was stated at the beginning of the supplement it must be borne in mind that these figures must not be taken as final because of the abnormal conditions which the plants were subjected to during a portion of the year. The results do not agree with the findings of other investigators but do not necessarily indicate that the results of the others are wrong nor that they do not apply in this locality. The results do indicate, however, that the problem should be given further attention in order that we may know how much value there is in limiting runner production and in selecting plants for size when planting.

Effect of runner production on the productivity of the mother plant. The flowers were counted on four plants each of the original Lots 1 and 11 in order to determine what effect runner production during the first year had on the plants' productivity the second crop year. The results are given in Table X.

TABLE X

Number of Flowers Produced by Plants the Second Season After Having Produced Runners.

Lot	Plant No.	Number of Flowers	Average for Lot
1	1	602	
	2	706	
	3	510	
	4	587	586
11	1	681	
	2	647	
	3	732	
	4	781	710

These plants were irrigated each summer and were grown under more favorable and uniform conditions than those previously discussed, and the results can be taken as being fairly indicative of the response of plants to runner production. Lot 1 was permitted to retain all its runners during the season of 1929 but all were removed in 1930. Lot 11 had the runners removed during both 1929 and 1930. As a result of the runner production during 1929 Lot 1 produced only 586 flowers per plant as compared with

710 in Lot 11. Lot 11 produced 21% more flowers during the second crop year than did Lot 1. These results show that once a plant is retarded in its growth it does not readily overcome the handicap. Although Lot 1 produced many more flowers in 1931 than it did in 1930, and gained considerable on Lot 11, still it lacked much in being as productive during the second crop year.

Effect of runners on top and root growth of potted plants. The growth of the potted plants was unsatisfactory from the standpoint of runner production. The pots used were too small to permit free normal growth of the plants. By limiting the space of the roots the plants were induced to continue developing fruit buds and many of the plants refrained completely from forming runners. Two plants of the lot which was to have produced runners produced one runner each soon after the plants were potted in January, and these with two plants without runners were washed and weighed on June 19. The fresh weights were as follows:

Plant No.	Wt. of roots grams	Wt. of top grams	Wt. of runners grams	Wt. of plant grams
1	45.3	31.3	13.8	90.4
2	31.1	32.4	9.5	79.0
3	56.5	58.4		114.9
4	38.4	51.2		89.6

The runner growth of the plants was so small that the influence on the plants was not extreme, and the results are not as distinct as they might have been with more extensive growth. The size of top was evidently reduced considerably by the runners, being reduced from an average of 54.6 grams to 31.8 grams. There is no evidence to show that this amount of runner growth reduced the growth of the roots of the mother plants.