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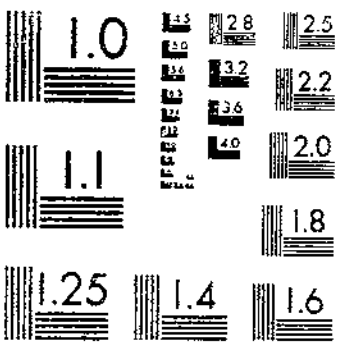

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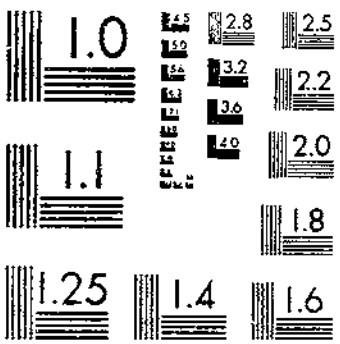

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DEVELOPMENT OF RUNNERS AND RUNNER PLANTS IN THE STRAWBERRY

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INTRODUCTION

The breeder, the plant propagator, and the grower are all interested in the influences that affect the production of runners[1] by strawberry plants. The breeder needs the information in order to judge the value of a new sort for the conditions under which it is being grown. The propagator is interested because he wishes the greatest number of salable plants per acre. The grower needs the same information as the breeder and the propagator, but in addition he needs much more information on the later development of the plants.

This bulletin presents the results of several studies dealing with different phases of runner and runner-plant production and development, together with a brief review of the information published on the subject. There is now a general interest in bud selection in all fruits. Negative results only have been obtained from all investigational work on the value of bud selection in the strawberry. Such results have centered interest in the causes for the very obvious differences in fruit and runner production of different runner plants of the same variety. This in turn has directed attention to the physiology and development of the strawberry plant. White (*18*)[2] has already published the results of studies of the anatomy of the

[1] A runner is a slender procumbent stem with elongated bare internodes which forms a new plant at its tip. In this bulletin the term "runner series" is applied to the several runners and runner plants which extend from the mother plant in any one direction, as from runners 1 to 11 in Figures 10 and 11.

[2] Reference is made by italic numbers in parentheses to "Literature cited," p. 27.

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strawberry from the physiological viewpoint and the writer[3] the results of studies of their growth and development. Additional information bearing on other phases of the physiological behavior of the strawberry is presented in a paper on sterility (4) and in a study of inflorescence types.[4]

THE RUNNER BRANCH

Seedling strawberries make their first top growth by means of a very slight elongation of the stem and by the addition of new leaves. Later, some of the buds located in the axils of the leaves begin to develop. These buds are new growing points which may produce any one of three types of branches—a secondary crown, a runner, or an inflorescence. Seedlings of the common horticultural varieties usually produce secondary crowns first, runners next, and inflorescences last from these new growing points. Seedlings of ever-bear-

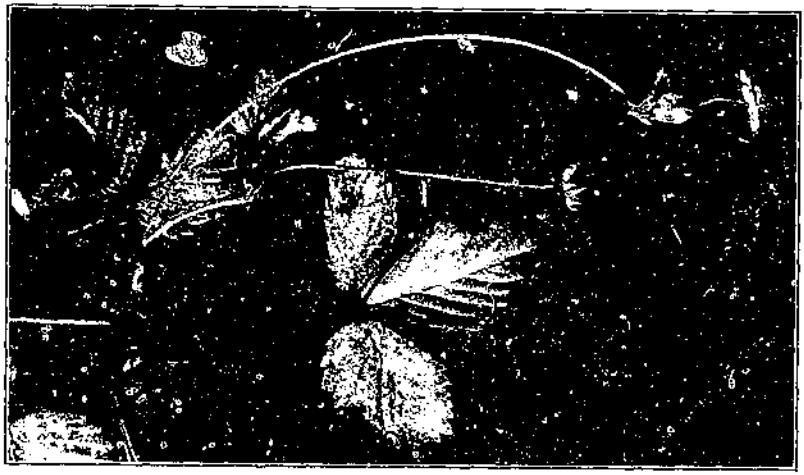

FIGURE 1.—Inflorescences of *Fragaria* sp. (from Manchuria) which apparently started as runners, the tips of which were transformed into flower buds. Photographed September 15, 1927

ing varieties, however, may produce inflorescences when a few weeks old, before any runners are produced. Among the ever-bearing seedlings grown in the breeding work of the Bureau of Plant Industry there have been many that produced no runners whatsoever. Such plants produced new crowns, which are merely branches of the primary stem and like it in structure rather than runners, which (though they are branches also) have a different structure. Similar runnerless plants have been grown from seed of *Fragaria vesca semperflorens*, the alpine strawberry of Europe. Runnerless varieties of the latter have long been in the trade.

Inflorescences which bear a remarkable resemblance to runners and which may be intermediate forms are sometimes produced. Figure 1 shows an inflorescence which apparently started as a runner but which changed to an inflorescence. Figure 2 shows an inflores-

[3] DARROW, G. M. EXPERIMENTAL STUDIES ON GROWTH AND DEVELOPMENT IN STRAWBERRY PLANTS. [Unpublished manuscript.]
[4] DARROW, G. M. INFLORESCENCE TYPES OF STRAWBERRY VARIETIES. [Unpublished manuscript.]

cence rooting at the nodes and Figure 3 an inflorescence which has produced adventive vegetative buds and new plants. Figure 4 shows another inflorescence that apparently started as a runner, then produced a berry, and finally became vegetative again. In this case the tip of what is known as the berry, but which is actually the receptacle, continued to grow and produced a new crown with several leaves.

In October, 1926, plants of several selections resulting from breeding work were sent to Florida for trial. When they began blossoming and fruiting, A. N. Brooks, of the Florida Agricultural Experiment Station, reported that many flowers and fruits were producing the same teratological form as that shown in Figure 4. Apparently, either the digging of plants in a certain stage of fruit-bud transformation or the conditions in Florida so affected the flower bud that its center was changed back to a vegetative bud.

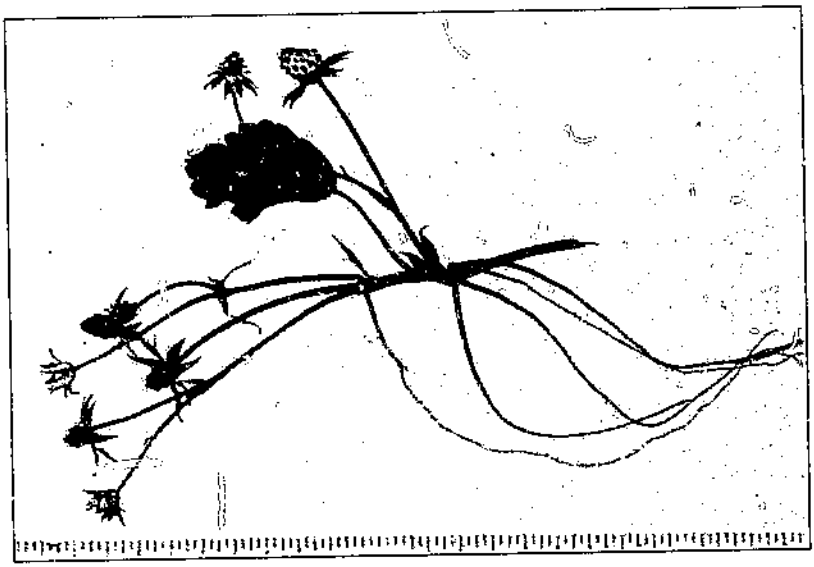

FIGURE 2.—An inflorescence of the Missionary strawberry which is sending out adventive roots at the nodes. Varieties are said to occur in which a runner is commonly produced in place of some part of the inflorescence

The same condition—that is, the transformation from a reproductive to a vegetative growth but expressed in a different way—is shown in Figure 3, where roots have been produced at the nodes of an inflorescence.

Branch crowns, runners, and inflorescences are simply different stem structures, any one of which may be produced by any of the growing points in leaf axils, depending on the genetic constitution of the variety and on the conditions influencing the plant, and it is not surprising that intermediate forms are produced.

In the vicinity of the District of Columbia the usual horticultural varieties commonly produce runners throughout the summer, although occasionally they produce branch crowns. Except very rarely, these runners are regularly two internodes in length and may be 40 or more centimeters long. (Fig. 5.) Occasionally a runner with one short internode is produced (fig. 6, B), usually underground. Such runners

may be produced experimentally by pinching off the ends of very young runners just beyond the first node. Although usually a branch runner appears, occasionally a plant is produced.

Runners produced by different varieties differ greatly in their length, thickness, time of production, and in other ways. Varieties with rather long runners are generally preferred over those with short ones because the plants in matted beds can be spaced more easily. The Dunlap and Klondike sorts have been and are widely grown in the North and South, respectively. They are characterized by long runners, although in both sorts their length lacks uniformity. The average length of 114 runners of Dunlap measured November 19, 1926, was 25 centimeters; that of 111 runners of Klondike measured on the same day was 25 centimeters also. The length of the first and

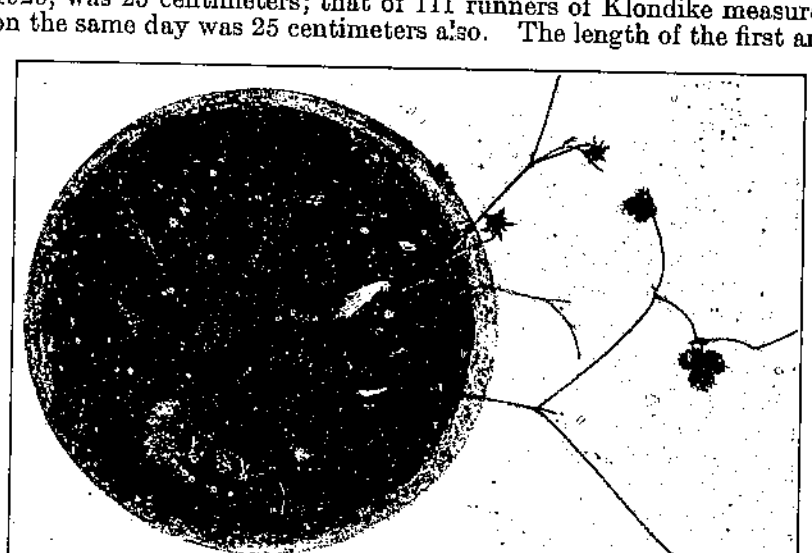

FIGURE 3.—A plant of a species of strawberry from Manchuria which produced on the inflorescence adventive buds that developed into new plants

second internodes of runners of these varieties was exceedingly variable, but on the average was approximately equal.

All varieties produce at the first node a scale, in the axil of which is a bud. Most of these buds do not develop, but those that do develop usually produce branch runners. Such runners may occur in any part of a clon, even on the last runners to form in the fall.

TABLE 1.—*Comparative number of branch runners produced by different varieties of strawberry*

Variety	Number of branch runners	Total number of runners
Howard 17	4	414
Klondike	49	388
Missionary	67	422

In some varieties branch runners are commonly produced; in others rarely. In a count made July 14, 1925, three varieties had produced branch runners, as shown in Table 1.

Of these three varieties, Missionary apparently produces branch runners most frequently. Branch runners are often very much smaller than the runners upon which they occur, and for this reason branching is apparently an undesirable genetical characteristic under ordinary conditions.

In all varieties roots and leaves are produced at the second runner node and a new runner plant is formed. (Figs. 6, A, and 7.) The first leaf appearing at the second node—the end of the runner—is usually small, often scarcely more than a bract. (Fig. 6.) Its axillary bud, however, is in an especially favorable place, for whenever growth is rapid in the mother plant or in the clon this bud may develop into a runner even before the second leaf (the first to function fully as such) has entirely unfolded. The new runner is a branch of the runner plant, not a mere extension of the runner from the mother plant.

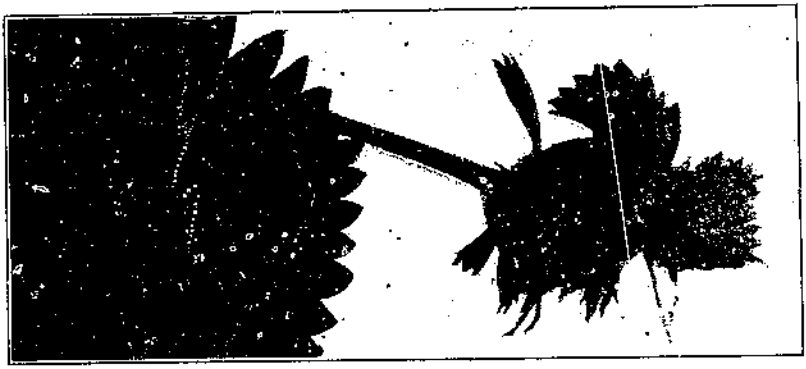

FIGURE 4.—A strawberry fruit from the apex of which a new plant is growing. In this case the fruit bud transformed into a vegetative bud. Photographed September 15, 1927. Species same as in Figure 1

(See Gay (*6*), White (*18*), and fig. 7.) Appearing in the axil of the first leaf and above it, the runner presses this leaf to the ground so that it soon decays.

According to Gay (*6*), *Fragaria viridis* (*F. collina*), a species from central Europe, differs from all other species in that, although the first runner from a mother plant has two internodes with a plant at its tip, the runner that extends the runner series farther produces a plant from each axillary bud. The second runner in each runner series of this species is therefore composed of several internodes, with an axillary plant at each node.

As would be expected from a knowledge of the phyllotaxy of the strawberry, the second leaf appears at an angle of about 144° to the first, and the second runner developing from its axillary bud extends in a different direction from that of the first, just as is the case with the runners of the mother plant.

During July, 1926, plants and clons of *Fragaria chiloensis* growing on the beaches of Washington, Oregon, and California were examined. The season had been drier than usual, so that little soil moisture was evident in the upper 12 inches of sand at many places where plants

were growing. Runner series more than 10 feet in total length were collected on which not a single plant had rooted. Moreover, several runner series nearly as long had been produced by single mother plants, and all the runner plants were entirely dependent on the mother plants for nutrients and water. (Fig. 7.) In the latter part of September, 1926, additional collections were made by G. F. Waldo, among which was one runner series 16 feet long with a few small roots on some of its 10 runner plants.

In the ever-bearing varieties of the strawberry fruit buds often form in leaf axils in place of runners. This may occur on runner plants that have not yet rooted, and such runner plants may have as many as three inflorescences and bring fruit to maturity without having rooted. Sometimes all buds on a runner plant, or all except those in the axils of the first leaves, become flower buds. (Figs. 8 and 9.) When all buds

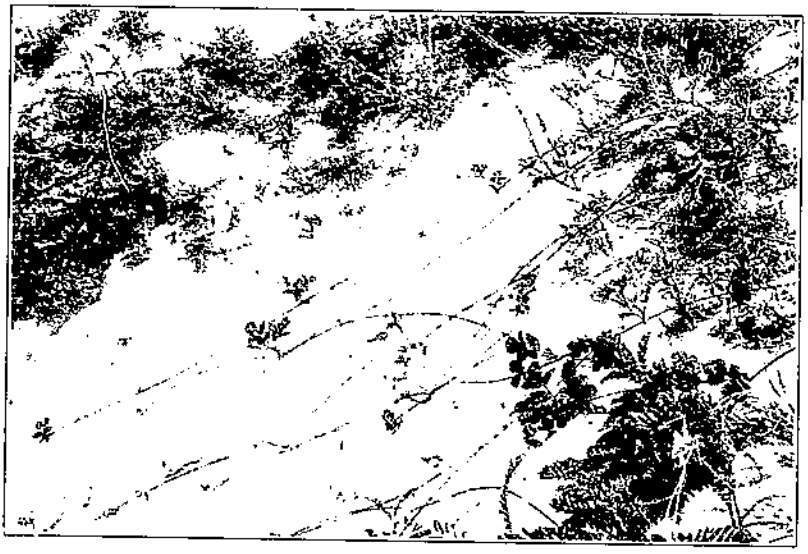

FIGURE 5.—Long runner series of *Fragaria chiloensis* on sand dunes of the beach near Saltair, Oreg. Runner series 10 feet long were found on which no plants had rooted. All of the runner plants in the illustration are entirely dependent on the mother plant

develop into inflorescences or runners there can be no further development of the plant unless an adventitious bud should be produced.

To determine whether the relation between runner and mother plants was similar to that between different crowns on the same plant, several plants each having two crowns were selected in which the supporting roots were produced directly from the base of each crown. All the roots from the base of one crown of each plant were removed and the plants reset. No effects of this treatment could be observed in the development of the two crowns. Those having their roots removed developed fully as rapidly as their sister crowns, and after some weeks new roots pushed out to replace those removed. Mother plants may have their roots cut off and be entirely supported for months by water and nutrients from rooted runner plants. As pointed out by White, the vascular systems of both runners and crowns have ample connection with that of the parent crown to furnish such support.

TIME OF APPEARANCE OF RUNNERS

Development of strawberry plants set in the spring takes place not only by the production of leaves but also by the production of runners and runner plants. In spring-set plantations in northern regions runners begin to appear in May or June, and with most varieties runner production continues until the end of the growing season.

FIGURE 6.—A, A strawberry runner plant, showing its small first leaf from the axil of which has been produced the runner to the left. New roots are pushing out from the base of this leaf. B, A strawberry plant with a short runner with a single internode (at the right) and at the left a runner with the usual two internodes

In 1-year-old fruiting plantations, however, runner production does not usually occur until toward the end of the cropping season or afterwards. If the climatic conditions are favorable for a vigorous leaf development runners may be produced by the time the first fruit is mature, or this may occur even earlier with many varieties.

In Florida and southern Louisiana, where growth may continue throughout the year, the crop of the Missionary and Klondike varieties is produced by plants set in the preceding fall. If the planting is done after a somewhat definite date (about October 1 to 10 in central Florida) few runners are produced even though growth is vigorous. Earlier set plants, however, may produce runners. Apparently some condition, such as length of day or temperature, affects the plants in such a way as to inhibit runner formation on most plants set after this time in the fall. On the other hand, plants of these varieties in Florida when set in February may start forming runners in March, and these may continue to form until the following fall.

In the greenhouse at Johns Hopkins University in Baltimore, Md., plants of several varieties set in February have produced runners freely as early as April. When brought into the greenhouse in Washington in October some of the *vesca* group (alpine varieties, *Fragaria vesca americana alba*, and a species from Manchuria) produced runners

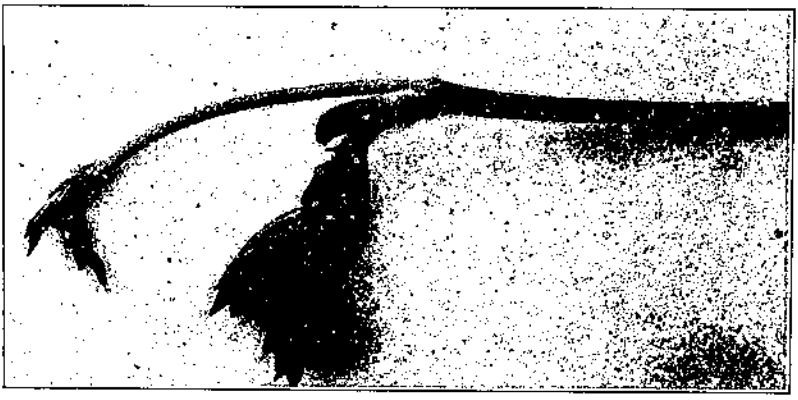

FIGURE 7.—A strawberry runner tip which has formed a new plant with a runner in the axil of its first leaf (picked off). The new runner is in an especially favorable place for food supply

freely from December to March. *F. chiloensis* from the coast of Oregon and Little Scarlet also produced some runners in December, whereas varieties such as Dunlap, Howard 17, Marshall, and many others produced none whatever during the winter.

In England, Mann and Ball (*14*) noted on May 28, 1925, the appearance of runners on plants set September 2 of the previous year. These were produced from axils of leaves that had opened in early spring. On June 26 the average number of runners on deflorated plants of this lot was 5.4. On the same date the average number of runners on plants set April 7, 1925, was 1 per plant.

Goff (*9*) states that the runners begin to form as early in the spring as the new leaves begin to grow, although they do not attain sufficient length to attract attention until some time afterwards. However, runner development is not evident in the field, at least usually, for several weeks after setting and is apparently correlated with the appearance of new leaves produced by new growing points, as well as with the size and vigor of the plants.

EFFECT OF NUTRIENTS ON RUNNER AND RUNNER-PLANT PRODUCTION

In an experiment on the effect of nitrate of soda on runner production, Macoun (*13*) has recorded the number of plants formed on several plots of the Parsons variety at Ottawa, Canada, on July 15, August 1, August 15, and September 1. His plots comprised three rows each 15 feet long, and these were replicated three times. On August 1 the plots receiving nitrate of soda at planting and one month after planting did not contain as many runner plants as those to which it was not applied until after that date. Plots receiving nitrate of soda on August 15, September 15, and later were relatively no better than the check. In this experiment this variety had formed 5 per cent of its runner plants by July 15, 25 per cent by August 1, 54 per cent by August 15, and nearly all the rest by September 1.

FIGURE 8.—Terminal bud of a runner strawberry plant (at the right) which developed into a flower bud as soon as the first leaf had been differentiated. The runner plant at the left developed a second leaf before the terminal became a fruit bud. June, 1926

Tucker (*17*) obtained somewhat similar results with fertilizer on the Howard 17 variety in New Hampshire. In green-manure plots not as many new plants (14.4 plants each) were formed as in the control plots (20 each) or in the plots to which chemical fertilizers were added. Plants given stable manure alone at the rate of 32 tons per acre produced the largest number of new plants (48.7), whereas plants given 8, 16, and 24 tons of stable manure per acre to which complete fertilizers were added produced an average of only 23.9, 25.3, and 36.9 plants each, respectively. He concluded that chemical fertilizers were injurious to the vegetative growth of strawberries.

Loree (*11*), in his studies of nutrient requirements of the strawberry, records the runner production of potted plants of Dunlap which were given different fertilizer applications and from which

runners were picked each time records were taken. Runner production was first recorded on June 8 and the last on September 5. Few runners appeared after September 1. All plants to which nitrogen (in the forms of nitrate of soda and sulphate of ammonia) was applied on May 10 produced runners freely throughout the season. Nitrogen applications on August 1, when none had been applied earlier, were not effective in stimulating runner production. Phosphoric acid, or phosphoric acid and potash, likewise was not effective in stimulating such production. The two lots producing the most runners formed 12 per cent of the total number in June, 35 per cent in July, 57 per cent in August, and 2 per cent in September.

It is evident from Loree's work that some nitrogen is needed for runner-plant production, but the tests of Tucker and Davis indicate that if applied in an inorganic form there is danger of making ap-

FIGURE 9.—Two runner strawberry plants each of which having produced a runner from the bud in the axil of the first leaf and an inflorescence from the axillary bud of the second leaf then produced a fruit bud from the terminal. No further development of plants can take place, as there are no growing points left on either. June, 1926

plications too heavy. Tucker found stable manure to be the only fertilizer that increased plant production. Because green manure hindered plant production it is possible that his soils were not properly aerated and that toxins were produced. In describing the use of fertilizers to stimulate plant production a member of a large strawberry-plant propagating firm of Maryland stated that in their experience bone and fish meal were helpful but nitrate of soda was injurious. Apparently, organic sources of nitrogen for plant production have given best results.

RUNNER AND RUNNER-PLANT PRODUCTION BY VARIETIES

In the study of the growth and development of strawberry plants heretofore referred to,[5] 10 plants of nine varieties which were rooted the previous year at about the same date were set on April 1, 1925, at the United States Plant Field Station at Bell (near Glenn Dale),

[5] DARROW, G. M. Op. cit.

Md. Runner and runner-plant production records were taken on these during the following summer and are given in Tables 2 and 3. Runners were also removed on July 14 and at intervals thereafter until August 31 from a larger number of plants of the same nine varieties which were also set April 1 and in the same rows. Records of runner production by these mother plants are given in Table 4. Runner plants were allowed to develop on alternate plants in a part of each row, and the average total number of runner plants formed in each clon are given in Table 5.

TABLE 2.—*Runner and runner-plant production of Howard 17 and Klondike strawberry varieties at Glenn Dale, Md., in 1926*

Average of five plants in each lot except in September, as noted. In the record of runner production from mother plants, runners were removed June 24 and at each date of record thereafter]

Date of observation	Number of runners or runner plants produced—			
	Howard 17		Klondike	
	By mother plants	In clon	By mother plants	In clon
May:				
21	0		0.2	
27	.4		1.0	
June:				
10	4.6	1.4	3.0	1.2
17	5.8	2.6	5.0	3.0
24	7.2	5.4	6.0	5.8
July:				
1	10.0	8.2	8.4	9.0
8	13.2	12.8	10.8	13.0
23	17.4	21.6		
July:				
24			13.6	18.6
29	10.0	24.6		
30			15.6	22.6
Aug.:				
6	22.4	32.6		
19	25.8	48.2		
24			22.2	52.8
Sept.:				
15	[1] 38.0	[1] 94.0		
18			[2] 24.0	[2] 127.0

[1] 2 plants.

[2] 1 plant.

Table 2 records 25.8 runners per plant for five plants of the Howard 17 on August 19, with an average of 38 for two plants observed until September 15. Records (not given in the table) for five alternate plants allowed to root their runners gave 10.2 each on August 19 with an average of 11 runners on two plants observed until September 15. The five Klondike plants with runners removed as they appeared had produced 22.2 runners per plant by August 24, whereas the five alternate plants allowed to form clons had produced but 8.6 each.

TABLE 3.—*Runner production of nine strawberry varieties at Glenn Dale, Md., in 1926*

[Average of 10 plants each, May 6 to June 11, and of 5 plants each, June 18 to July 2]

Variety	May 6	May 13	May 20 and 21	June 10 and 11	June 18 and 19	June 24	July 1 and 2
Aroma			0.1	1.4	2.7		
Dunlap			.2	4.0	5.8	8.2	11.8
Gandy			.4	2.4	3.6	5.0	
Howard 17				5.2	7.8	12.2	16.4
Klondike			.5	4.7	8.2	10.4	14.4
Missionary	0.1	0.5	1.3	6.7	8.0	11.4	15.2
New York			.3	2.3	3.6	4.2	5.4
Parsons		.4	1.0	5.6	7.0	9.2	12.4
Sample		.5	.7	2.6	4.1	6.0	

Table 3 gives a record of the runner production of nine varieties during the early part of the season of 1925. Runner production was begun first by the Missionary variety on May 6. By May 13 two other varieties had produced runners, and by May 21 they were recorded on all except Howard 17. By July 1 and 2, however, Howard 17 had produced more runners (16.4) than any other variety. The New York variety had produced the fewest (5.4).

TABLE 4.—*Runners produced by nine strawberry varieties, the runners being picked at each date of record, at Glenn Dale, Md., in 1925*

[The number of plants varies slightly, owing to injuries received by some of them]

Variety	Number of mother plants and average number of runners produced—												Total on alternate plants allowed to form runner plants
	July 14		July 25		Aug. 3		Aug. 15		Aug. 31		Total		
	Mother plants	Runners	Mother plants	Runners	Mother plants	Runners	Mother plants	Runners	Mother plants	Runners	Mother plants	Runners	
Parsons	69	5.9	52	3.8	52	3.5	52	3.6	51	5.1	51	21.9	8.7
Missionary	56	5.8	42	3.1	42	2.7	42	2.4	42	3.1	42	17.0	11.3
Sample	68	4.8	53	2.2	53	2.9	53	2.4	53	3.9	53	16.2	6.8
Klondike	58	5.2	27	3.1	27	2.2	27	2.2	27	3.8	27	16.1	8.3
Howard 17	60	6.1	32	3.5	32	2.8	31	2.4	31	1.7	31	16.1	7.5
Gandy	58	4.3	47	2.3	47	3.8	47	3.2	47	3.4	47	15.8	6.5
Dunlap	57	4.7	42	2.5	42	2.3	42	2.1	42	3.6	42	15.7	8.4
New York	66	4.0	51	1.7	51	2.6	51	3.0	51	4.1	51	15.2	6.9
Aroma	59	4.3	47	2.2	47	2.0	47	1.7	47	3.0	47	13.0	5.9
Average												16.3	7.8

Table 4 gives the number of runners produced by plants of the nine varieties of Table 3, all the runners being picked off as they appeared. At the first date of record, July 14, the number of plants for each variety was approximately the same, though Howard 17 had the highest average (6.1) and New York the lowest (4). By August 31 Parsons had produced the highest average (21.9) and Aroma the lowest (13). Alternate plants which had been allowed to form clons averaged less than half as many plants.

Table 5 gives the average total number of runner plants formed per clon by the same nine varieties from July 13 to September 8 and 9, together with the range for each variety. Thus, Dunlap formed an average of 48.5 plants each and the New York only 9.2 each. All varieties had a good start July 13, and it seems probable that under the conditions of this experiment the later marked differences were due to different varietal responses to environmental influences. In view of these marked differences it is well to remember that eight of these varieties are leading sorts of the country.

Missionary and Howard 17 responded in a similar manner, both making new plants slowly, although the cause of this behavior is not likely to be the same for each sort, for the latter variety succeeds best from New England to Maryland and the former from Delaware south to Florida. In the case of the New York, which made few new plants per clon, the soil may not have been sufficiently fertile or the disease incidence may have been too high for the best develop-

ment. When the runners were removed at stated intervals from the New York, as shown in Table 4, it made almost as many runners as Howard 17, which is the leading variety for the section around Washington, D. C. This response of the New York may indicate the need for a large nitrogen supply for the proper development of clons of this variety.

TABLE 5.—*Average total number of runner plants per clon formed by nine strawberry varieties, at Glenn Dale, Md., in 1925*

Variety	Number of clons and average number of runner plants produced—							
	July 13		Aug. 13		Sept. 8 and 9			Runners formed by alternate plants not allowed to form runners
	Clons	Runner plants	Clons	Runner plants	Clons	Runner plants	Range of runner plants	
Dunlap	15	6.6	15	19.5	15	48.5	21-80	15.7
Aroma	15	7.1	15	13.2	15	45.0	6-72	13.0
Sample	15	9.6	15	28.1	15	42.7	18-82	16.2
Parsons	15	8.4	15	18.3	15	40.5	12-91	21.9
Gandy	12	5.6	12	15.2	12	37.5	17-76	15.8
Klondike	28	8.4	28	13.6	28	24.8	9-544	16.1
Missionary	14	12.6	14	18.6	14	24.4	6-41	17.0
Howard 17	29	8.6	30	11.4	30	24.4	10-65	16.1
New York	15	3.5	15	5.3	15	9.2	2-16	15.2

The increase in number of runner plants of the Dunlap and Aroma, as shown in Table 5, is striking, especially when compared with the number of runners made by the same varieties shown in Table 4. Aroma made the fewest runners of any when they were removed, but it made the most runner plants of all except Dunlap when allowed to root its runners. Under the conditions of this test apparently old plants of the Aroma in sandy soil did not function as well as young plants, due possibly to aeration of the soil, moisture conditions, available nutrients, or to some condition of the roots. As runner production by the Aroma was especially rapid between August 13 and September 8, it is possible that stimulation of an especially early production of runners on heavier soils in the East might prove profitable with this sort.

Table 5 shows the actual number of runner plants in clons of several varieties on July 13, August 13, and September 8 and 9. Most varieties, however, produce runners well into or through October at Glenn Dale, Md., so that the total number of plants produced by some of these varieties may have been double the number recorded on September 8 and 9. In Table 2, records are given of five plants of Howard 17 which had produced 48.2 rooted plants per clon by August 19, two of which had produced 94 plants per clon by September 15. Five plants of Klondike had produced 62.8 plants per clon by August 24, one of which had 127 plants on September 18. Howard 17 forms few plants after September 15 at Glenn Dale, Md., whereas Klondike continues to produce runners until nearly the end of October.

It is evident from these records that runner production commences earlier with some sorts than with others, and for particular conditions, such as those obtaining at Glenn Dale, Md., in 1925, the pos-

sible number produced by the original plants set in the spring varies with different varieties. If the runners are allowed to root, less than half as many are produced as when they are picked off as they appear. Primary runner plants in turn produce runners and runner plants, and these produce still others until clons of more than a hundred plants may be formed.

DEVELOPMENT OF A CLON AND OF A PLANT WITH RUNNERS PICKED OFF

The entire development of a clon is dependent on runners which develop from the buds in leaf axils. To illustrate this development, a plant of Howard 17 was set April 1, 1925, and records were made of the development of this and of all its runner plants until September 15. From these records a diagram (fig. 10) was made showing

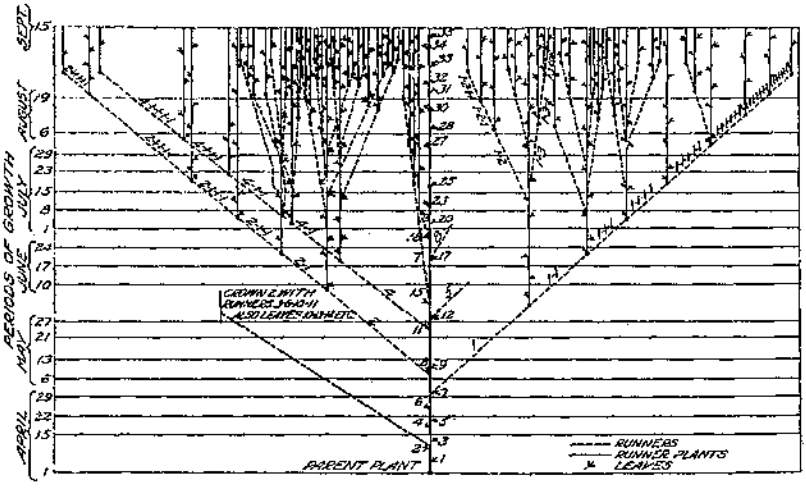

FIGURE 10.—Diagram showing the development of a plant of the Howard 17 strawberry and of the clon produced by it. The heavy vertical line at the center represents the original crown of the mother plant. A second crown was produced from the axil of leaf 2, but together with all runner series (runners 3, 6, 10, and 11) arising from it this is omitted from the diagram. As an illustration of the development of this clon the development of the parent plant may be followed: Between April 15 and 29 leaves 4, 5, and 6 were produced. The buds in the axils of leaves 7 and 8 developed into runners 1 and 2, but these were not visible until May 27 and June 10, respectively

the time of appearance of its leaves, the axillary buds which produced runners, the time when the runners formed runner plants, the runner series produced by the runners, the leaves and runners produced by each runner plant, as well as the runners, runner series, and runner plants produced in turn by these, which formed the entire clon. To simplify the diagram, crown 2, together with leaves and runners produced by it and runners 5, 8, and 9, were omitted.

The development of the same plant including crown 2 is shown again in Figure 11. In these the tendency of the strawberry to develop runner series is evident. Notes made at the time of taking the records indicate that the tips of runner series 2 and 5 were injured, and these injuries probably hindered the extension of these series.

The mother plant had 11 leaves on May 27, when runner 1, produced from the axil of leaf 7, was first visible. (Figs. 10 and 11, A.)

By June 10 (figs. 10 and 11, B) runner 1 had rooted, the mother plant had produced 15 leaves and two more runners, 2 and 3 from the axils of leaves 8 and 10, respectively; on June 17 (figs. 10 and 11, C) the mother plant had produced 16 leaves and 5 runners, runners 4 and 5 coming from axils of leaves 11 and 12; on June 24 (figs. 10 and 11, D) 17 leaves and 6 runners, runner 6 from the axil of leaf 13; and on July 1 (figs. 10 and 11, E), 19 leaves and 7 runners, runner 7 from the axil of leaf 15.

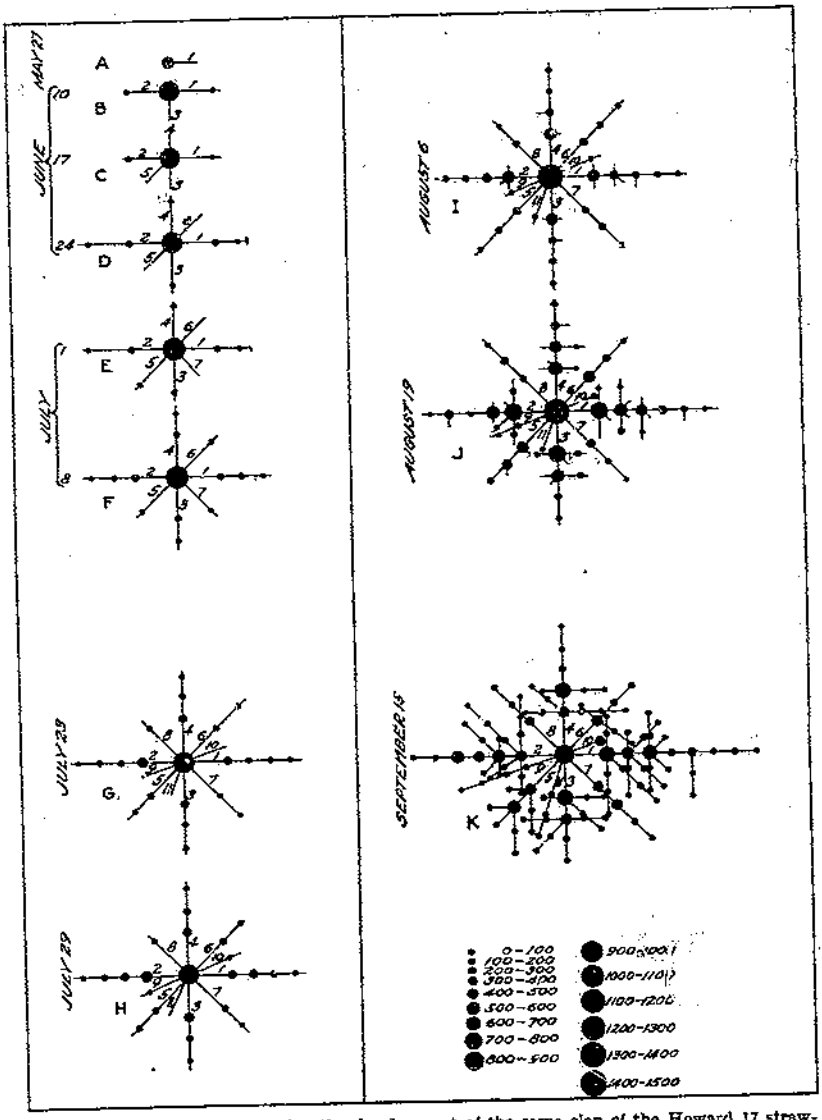

FIGURE 11.—Diagrams illustrating the development of the same clon of the Howard 17 strawberry that was illustrated in Figure 10: A, Development of mother plant May 27 when runner 1 first appeared; B, first formation of a clon June 10; C, D, E, F, G, H, I, J, and K, the clon as it appeared on June 17, 24, July 1, 8, 23, 29, Aug. 6, 19, and Sept. 15. The relative size of the plants as measured by leaf area is shown by the size of the dots

By July 1 it was apparent that crown 2 had been formed, that leaves 8, 9, 11, 12, 15, 17, 18, and 19 and runners 1, 2, 4, 5, and 7 were produced by crown 1, and that leaves 10, 13, 14, 16, and 19 and runners 3 and 6 were produced by crown 2. As heretofore stated, it would tend to obscure many details to show the later development of the entire clon produced by this plant, and the development of crown 2 has been omitted in Figure 10, although its development is noted below and shown in Figure 11, F to K. By July 8 crown 1 had produced leaf 20 and crown 2 had produced leaves 21 and 22. By July 23 crown 1 had produced leaves 23 and 25, and crown 2 had produced leaf 24. Runners 8 to 11 had appeared, runner 11 (the last one) from the axil of leaf 21 on crown 2. By July 29 no new leaves or runners had appeared. By August 6 crown 1 had produced leaf 27, and crown 2 had produced leaf 26. By August 19 crown 1

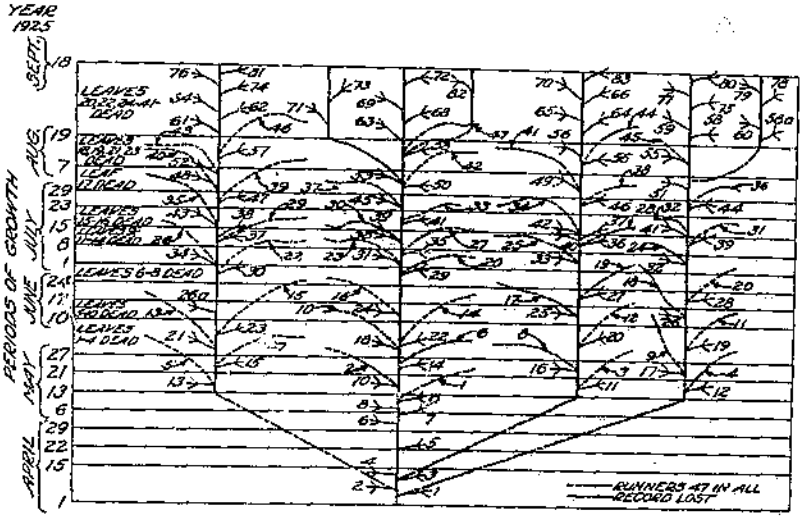

FIGURE 12.—Diagram showing the development of a plant of Howard 17 strawberry the runners of which were removed June 24 and as they appeared thereafter. The heavy vertical line at the center represents the original crown, the other solid vertical lines the branch crowns

had produced leaves 28 and 30, and crown 2 had produced leaves 29 and 31. By September 15 crown 1 had produced leaves 33 and 34, and crown 2 had produced leaves 32 and 35.

In contrast with the above plant, the development of a plant of Howard 17 from which the runners were removed June 24 and as they appeared thereafter may be followed. The development of such a plant is shown diagrammatically in Figure 12. A runner appeared May 27 when the plant had 17 leaves. By June 10 it had produced 23 leaves and 8 runners, by June 17 it had produced 26 leaves and 10 runners, and by June 24 it had produced 27 leaves and 13 runners.

Plant 1 in Figure 10 produced a total of 2 crowns, 11 runners, and 35 leaves. Twelve of the leaves were still alive on September 15. Plant 4 in Figure 12 produced 7 crowns, 53 runners, and 83 leaves, and 42 of its leaves were still alive on September 18. Plant 4 used its foliage as a factory to manufacture food with which to produce additional foliage and runners, while plant 1 used its food supply in

producing fewer leaves and runners, but it also assisted in the development of all runner plants formed by the clon—a total of 112.

The mother plant in a clon such as that formed by plant 1 still assists in the development of the new clonal plants, even after runner plants have been forming for three or more months. All the roots of one of the runner plants may be killed, yet it can still produce runners that root and that in turn produce runners. Nutrients and water used by such a plant must be supplied by the mother plant and the rooted runner plants. The result of the dependence of the runner plants on the mother plant is to hinder its development. Thus, the mother plant illustrated in Figure 10 had produced only 35 leaves by September 15, whereas the plant illustrated in Figure 12, from which the runners had been removed, had produced 83 leaves by September 18. Records presented later indicate corresponding differences of such plants in capacity for fruit production.

RELATION OF AGE OF RUNNER PLANT TO RUNNER PRODUCTION

The first activity of strawberry plants set in the spring is the development of the overwintering leaves and the inflorescence, both of which had remained dormant in an arrested state since the end of the previous growing season. Next, new leaves appear on new growing points, and later runners and runner plants are produced. Davis (*5*) at Ottawa, Canada, has reported a correlation between the runner production of plants and the period during which the plants rooted the previous year. Plants of the Parsons variety rooted as late as October 29, 1919, and when transplanted in the spring of 1920 had formed an average of less than 1 runner per plant by July 7, whereas those rooted July 23, 1919, and transplanted at the same time as the late-rooted ones had formed 2.5 runners by July 7, 1920. Apparently the later development of the spring-set plants is correlated to some extent with the time they rooted the previous year.

In order to study this phase further, runners of three varieties, Howard 17, Portia, and *Fragaria virginiana* selection 27, were rooted at the Bell station during July, August, September, and October, 1923. Runner tips ready to root (those having visible roots or a second unfolded leaf on the runner plant) were pressed into soft moist soil and held in position by means of a wooden pot label. This label recorded the date on which each runner plant was pegged down. Runner tips which had already rooted but which had not been large enough at the previous date of record were also pegged down with a label.

These runner plants were transplanted on April 17, 1924. At this time the plants that had rooted earlier differed greatly in size, depending largely on the extent to which they had themselves formed runner plants in 1923. Plants formed from August 15 to October 6 were more uniform than those still older. Plants rooted during October were much smaller than the earlier formed ones.

As a further test, the 83 plants of Howard 17 which had rooted between August 15 and September 10 were divided into two lots of 41 and 42 plants each, according to size, considering thickness of crown and extent of root systems. The 41 smaller plants were set adjacent to the 42 larger ones. All flower buds were picked off as they appeared. Records were taken on June 30, when runners were

being produced freely. The runners varied greatly in length and in the degree of development of such runner tips as had rooted. Some runners had even formed runner plants which in turn had produced runners. The record taken, therefore, included both the number of runners and the number of runner plants in the clon formed by each mother plant. Any node having produced roots or a well-developed second leaf was considered as a plant. All branch runners were included as separate runners. The records of this test are given in Table 6.

TABLE 6.—*Average number of runners and runner plants of Fragaria virginiana selection 27, Howard 17, and Portia varieties of strawberries produced in May and June, 1924, by plants rooted during certain intervals in 1923*

Interval of rooting, 1923	Runner plants set Apr. 17, 1924	Average production by June 30, 1924	
		Runners	Runner plants
Selection 27:	*Number*	*Number*	*Number*
On or before July 4	18	6.7	5.8
July 5 to 14	21	4.7	3.2
July 15 to August 2	19	3.5	2.5
August 3 to 14	10	3.0	2.4
August 15 to September 12	38	4.7	4.1
September 13 to October 6	32	3.3	3.7
October 7 to 30	11	2.2	1.8
Total	149		
Howard 17:			
On or before July 4	5	5.6	2.0
July 5 to 14	6	3.0	1.2
July 15 to August 2	15	3.5	1.9
August 3 to 14	16	3.8	1.7
August 15 to September 10 (small)	41	3.1	2.2
August 15 to September 10 (strong)	42	4.5	3.0
September 11 to October 6	39	4.0	3.1
Total	163		
Portia:			
July 15 to August 2	26	5.7	4.4
August 3 to 14	19	5.4	3.9
August 15 to September 10	41	4.0	2.9
September 11 to October 6	37	4.6	4.2
October 7 to 30	6	2.3	1.8
Total	129		

AVERAGES OF RUNNERS AND RUNNER PLANTS BY VARIETIES

Variety	Interval of rooting, 1923													
	By July 4		July 5 to 14		July 15 to Aug. 2		Aug. 3 to 14		Aug. 15 to Sept. 12		Sept. 13 to Oct. 6		Oct. 7 to 30	
	Runners	Runner plants	Runners	Runner plants	Runners	Runner plants	Runners	Runner plants	Runners	Runner plants	Runners	Runner plants	Runners	Runner plants
Selection 27	6.7	5.8	4.7	3.2	3.5	2.5	3.0	2.4	4.7	4.1	3.3	3.7	2.2	1.8
Howard 17	5.6	2.0	3.0	1.2	3.5	1.9	3.8	1.7	3.8	2.6	4.0	3.1		
Portia					5.7	4.4	5.4	3.9	4.0	2.9	4.6	4.2	2.3	1.8
Average	6.4	5.8	4.4	2.8	4.5	3.2	4.3	2.8	4.1	3.0	4.0	3.6	2.2	1.8

These records seem to indicate little difference in the runner or runner-plant producing ability of plants formed the previous year

from July to September which are themselves allowed to form runner plants. It is evident, however, that the small plants formed late in the season of 1923 were not as vigorous as those formed earlier and were not so satisfactory for planting stock. Plants formed by July 4 produced an average of 6.4 runners and 5.8 runner plants; those formed from August 15 to October 6 produced an average of about 4 runners and nearly as many runner plants, while those formed in October produced only 2.2 runners and 1.8 runner plants.

When plants of the Howard 17 of the date of September 10 were graded according to size, it was found that the larger plants produced more runners and more runner plants than the smaller ones. Careful grading to size is probably the most satisfactory means of selecting uniform propagating stock.

As a further test of the relation of the age of the transplant to its later development, records of runner and runner-plant production were taken in July, 1925, on 50 to 75 plants each of seven varieties (Aroma, Howard 17, Klondike, Missionary, New York, Parsons, and Sample) which had rooted at specific periods from July to October, 1924, and which were transplanted April 1, 1925. Each variety was planted in a single row. By July 14, 1925, the first date of observation, other influences, such as soil heterogenity and insect attacks, had so modified differences due to the time of plant formation in 1924 that they no longer appeared.

Goff (7) reported results from an experiment in Wisconsin in which he compared the later behavior of three sets of plants of the Wilson variety, one taken from new beds that had not produced fruit the previous year, a second from a bed that had fruited the previous year and was severely affected with leaf spot, and a third from healthy cropped beds. In 1892 the healthy plants from uncropped beds each produced 5.1 runner plants, which survived the following winter; the healthy plants from cropped beds produced 4 runner plants each, and the diseased plants from cropped beds 1.7 runner plants each. The difference in fruit production was less marked than that of plant production, but sufficient to be noticeable. He repeated his experiments (8), setting in adjoining rows plants from beds that had not borne the previous year and plants from a bed that had borne two crops. The plants from uncropped beds produced an average of 19.3 plants for each one set and those from the cropped beds 13.3 plants each. The difference in yield of 1894 was reported as less marked than in plant production. In a test comparing the healthy and the diseased plants, it was found that the healthy ones produced 18 plants each, and the diseased ones 9 each. It is likely that the difference in plant production between runner plants from cropped and uncropped fields was partly due to the difference in the time the plants rooted, the rooting taking place much later in cropped than in uncropped fields.

Although under many conditions the time of plant formation during the previous year may be influential in the development of transplants, it is probable that an especially fertile or sterile soil, attacks by pests, and unfavorable moisture or other conditions may soon efface such differences.

It should be remembered that the comparisons of Davis and those reported here are between plants from beds where runner and runner-plant production is unrestricted. Unrestricted runner production

is the usual practice in plant nurseries. In a country with as varied soil and climatic conditions as the United States and with such extremes in the production of this crop as are found where it is grown as a market garden crop and as a field crop, for example, practices in plant production vary greatly, and a comparison of early-formed and late-formed runner plants might give different results under some conditions. For instance, a comparison might be made between early and late plants produced by a mother plant, the runner plants of which are not allowed to form runners. Likewise, different results might appear if the comparison were between plants from clons formed early in the summer which were not allowed to form runner plants in late summer or fall, and plants from clons formed late in the summer. Results of such tests are given later in Table 8.

RELATION OF AGE OF RUNNER PLANT TO YIELD

The relation between the time of runner-plant formation in one year and its behavior in the production of runners the following year has been hereinbefore described. A relation between the time of runner-plant formation and fruit production also has been reported by Davis (*5*). In 1919 he recorded the dates on which runners of the Parsons strawberry rooted, and in 1920 he obtained the yields from these plants. Runner plants formed before the middle of August produced 9 to 10 fruits each, those formed about the middle of August an average of 16 fruits, and those that rooted as late as October 20 produced an average of only 5 fruits. His interpretation was that the early-formed runner plants became depleted of energy because they assisted in the development of large numbers of later runners and runner plants. He concluded that the most profitable period of runner formation was between the latter part of July and the first of September. It would seem that the conditions in the fall of 1919 must have been somewhat unusual, for 39.22 per cent of the plants formed during October, an unusual occurrence with most varieties even at Glenn Dale, Md., where the growing season is usually longer than at Ottawa, Canada.

In reporting the results of some fertilizer experiments, Macoun (*13*) records the number of blossoms produced on 511 plants of Parsons in 1924 which rooted at various dates in 1923. The average number of blossoms produced ranged from nearly 40 for plants rooted in July to about 10 for those rooting in October. Straight (*16*) has reported yields for one season from the first, second, and third runner plants of runner series where 1, 2, and 3 runners from the mother plants were allowed to root. The first runner plants on the average were slightly more productive than the second and third runner plants. No significant difference in yield was observable between plants produced by the mother plants rooting 1, 2, or 3 runner series.

To test the influence of time of runner formation on crop production, two pistillate varieties, Portia and *Fragaria virginiana* selection 27, were used. Pistillate varieties commonly set all their flowers, and the number of flowers produced may be considered a measure of crop production. Such a measure may be more accurate even than weight of crop unless irrigation is available, for drought and lack of water to individual plants in the spring often prevent full development of the berries.

Plants were set in the early spring of 1923, and wooden pot labels were used to peg the runner into loose soil and to mark the date by which a runner plant had already rooted or on which the second leaf had unfolded. Runner plants were pegged July 4 and 14, August 2 and 14, September 10, and October 6 and 30, in 1923. In 1924 these plants produced flowers as shown in Table 7.

TABLE 7.—*Influence of time of runner formation on the production of flowers of strawberry varieties*

Date rooted	Selection 27		Portia	
	Number of plants	Average number of flowers	Number of plants	Average number of flowers
To July 4	18	11.3	2	8.0
July 5 to 14	26	14.0	6	10.5
July 15 to Aug. 2	21	12.0	32	13.4
Aug. 3 to 14	14	10.8	30	10.8
Aug. 15 to Sept. 10	43	5.5	73	8.7
Sept. 11 to Oct. 6	40	7.0	71	6.7
Oct. 6 to 30	13	5.2	10	1.7

These results are similar to those obtained by Davis in Canada in 1920 with the Parsons variety. *Fragaria virginiana* selection 27 produced an average of 12.6 flowers on plants rooting during July and August and an average of 6.3 flowers on those formed during September and October, whereas corresponding Portia plants produced an average of 11.9 and 7.3 flowers, respectively. Selection 27 tends to form several crowns on plants rooting in July and August, whereas Portia forms few crowns on such plants. Late-rooted plants rarely form extra crowns. This difference in branching habit may account for the relatively larger yield of the early-rooted plants of selection 27.

In a report on sterility and fertility in the strawberry (*4*) a table was given showing the average number of fruits and of flowers not set on many varieties in 1926 which included records on plants of six varieties rooted at certain dates in 1925. In every instance there were fewer fruits per plant from the earlier to the later formed, a difference apparently due to differences in the development of the plants as a consequence of the date they rooted. Figure 13 shows the plants on a runner series of the Dunlap variety after the onset of freezing weather. The runner plant at the extreme right undoubtedly rooted in October. Such a plant is liable to winter injury and may bear a few small fruits or none. The first runner plants of the series at the left would probably have borne the most and largest fruit.

Because runner plants rooting at the earlier dates usually in turn produce runners in the succeeding weeks of the same season and are thus weakened, an attempt was made to limit the period of runner production to specific periods and to note any difference in the effect on fruit production. The *Fragaria virginiana* selection 27 was used for this test. Four series of plants were grown to correspond with possible commercial practices. In series A all runners were removed throughout the season; in series B the runners were picked off until September 1 and later ones rooted; in series C the runners were picked off until August 1 and later formed ones rooted on specific

dates; in series D the runners were rooted until September 1 and later ones picked off. Table 8 gives the results.

TABLE 8.—*Production of Fragaria virginiana selection 27 plants in 1925 given different treatments in 1924*

Series and treatment	Number of plants	Average number of—				
		Crowns	Trusses	Fruits	All other [1]	Runner plants
Mother plants:						
Series A, runners kept off throughout season	12	0.4	13.4	131.9	7.7	
Series B, runners kept off until Sept. 1	4	6.2	7.0	63.8	2.6	4.5
Series C, runners kept off until Aug. 1	2	3.4	5.0	48.5	5.0	33.5
Series D, rooted until Sept. 1	4	3.0	4.8	42.8	4.6	18.8
Runner plants from series D:						
Rooted to Aug. 1	45	1.9	2.7	30.4	2.9	
Rooted Aug. 2 to 15	19	1.2	2.0	20.0	2.2	
Rooted Aug. 16 to Sept. 1	50	1.2	2.1	19.4	2.1	
Runner plants from series C:						
Rooted Aug. 1 to 15	20	1.7	2.4	21.9	2.1	
Rooted Aug 16 to Sept. 1	36	1.6	2.0	18.9	1.8	
Rooted Sept. 2 to 15	44	1.2	1.9	15.7	1.8	
Rooted Sept. 16 to Oct. 1	21	1.1	1.6	13.5	1.2	
Runner plants from series B:						
Rooted Sept. 2 to 15	13	1.6	2.4	21.8	2.1	
Rooted Sept. 16 to Oct. 1	7	1.3	2.1	17.7	1.6	

[1] "All other" includes buds missing, injured, etc.

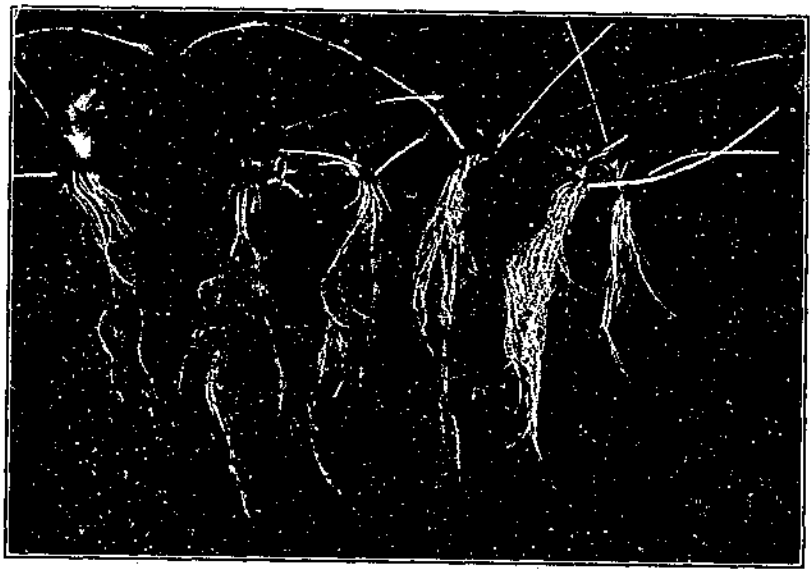

FIGURE 13.—Relative size and root branching of the plants on a runner series of the Dunlap strawberry (from left to right). The last runner plant to root is at the extreme right. Its roots are unbranched, and such a plant is very liable to winter injury. November 13, 1926

It should be noted that mother plants from which runners were removed until September 1 produced but 4.5 runner plants, as compared with 33.5 runner plants produced by those rooting runners subsequent to August 7. Other tests in which the runners were removed from mother plants of other varieties until September 1 have given similar results. The production of even 4.5 runners,

however, so affected the mother plants that they produced less than half the number of fruits produced by plants whose runners were kept off throughout the season.

When the number of fruits produced by runner plants in the different series is considered, several points may be noted. In each series that produced runner plants the earliest ones to root have the most fruit and the later ones successively less and less fruit. In series B, where runners were picked off until September 1, few new runner plants were produced, and these bore but little more than runner plants rooted during the same intervals in series C, which also produced runner plants during August. From an inspection of the yields in series D it is also evident that after allowing runners to root up to September 1 it is doubtful whether it will pay to remove them later. All plants in each series bore more than plants rooted at corresponding intervals in 1923, as given above. Conditions were

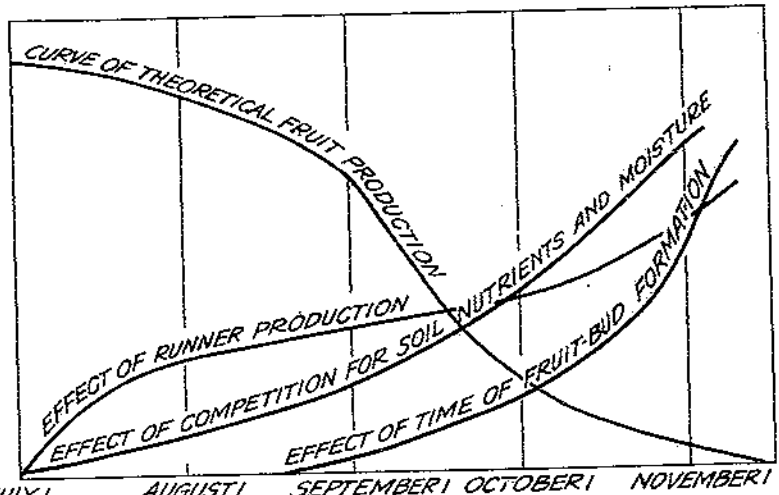

FIGURE 14.—Theoretical curves for fruit production and for conditions modifying fruit production of strawberry plants

so different in the two seasons, however, that the lots are not comparable.

The yield from plants of different ages is dependent on the interrelation of a number of conditions. With no modifying conditions, the earlier the plant roots the larger the yield the following year. However, the actual result is modified by runner and runner-plant production, the relation between time of fruit-bud formation and the end of the growing season, and competition between adjacent plants for soil moisture and nutrients and light as well as on the march of these and other influences. If a theoretical curve of fruit production is established, such as that made by plants of the same variety, of the same initial vigor and composition, planted in uniform soil, and set at regular intervals from July 1 to November 1, it may be supposed to have a production curve such as that given in Figure 14, the yield being governed by its leaf and stem growth before winter.

Curves such as are given in this figure are suggestive only and obviously represent conditions that are rarely exactly reproduced in practice. Under field conditions each of the effects shown varies

from season to season, from field to field, and with the varieties grown. The purpose of the curves, however, is to suggest the relative importance of conditions in modifying production.

If production were affected only by the length of the season after the plant had formed, it might be represented by an inclined straight line. In reality, however, production of runners by plants has an effect that may be represented by the theoretical curve for this characteristic shown in Figure 14. For the first part of the season the curve for "effect of runner production" is shown as more effective than the other conditions that modify fruit production. The "effect of competition for soil nutrients and soil moisture" obviously is effective later in the season than is the effect of runner production, whereas the effect of the time of fruit-bud formation is effective still later in most fields.

EFFECT OF REMOVING RUNNERS OF STRAWBERRY PLANTS

The effect of the removal of runners on fruit production has been studied by different workers in connection with the growing of strawberries in hills, in which case the original plant produces the entire crop, all runners being removed as they form. This practice obtains in the Pacific Northwest, where almost the entire acreage is produced under the hill system. In a report of the superintendent of the experiment station at Sidney, British Columbia, for 1925, the production for two years from hills, hedge, half-matted, and full-matted rows is given as follows, it being noted that the yields in two were below normal: Hill system, 7,613 pounds; hedge row, 6,878 pounds; half-matted row, 7,804 pounds; full-matted row, 5,117 pounds.

The full-matted row, which was supposed to represent the system commonly used in the eastern United States and Canada, gave the lowest yield of any—about 35 per cent less than that of the hill system.

Quaintance (*15*), in Georgia in 1899, comparing hills and matted rows 12, 18, and 24 inches wide with rows 4 feet distant, reported that the plot under the hill system yielded only one-third as much as that under the matted rows. Considering the yield of his 12-inch matted row as 100, the 18-inch row yielded 134.2 and the 24-inch row yielded 282.

Table 8 gave the yield in 1925 of 12 mother plants of selection 27 from which all runners were removed as they appeared during 1924. They produced an average of 131.9 fruits per plant, as compared with less than half that number, 63.8 produced by adjacent plants, which also produced 4.5 runner plants each during September and October. The production of 10 mother plants of the Portia and Howard 17 varieties in adjoining rows which likewise had had their runners removed, is shown in Table 9.

TABLE 9.—*Production of 10 mother plants of the Portia and Howard 17 varieties of strawberry, runners removed*

Variety	Average number of—				
	Leaves	Crowns	Trusses	Fruits	All other
Portia	41.6	10.2	8.6	76.7	12.1
Howard 17	82.8	8.5	0.1	63.4	15.0

In 1899 Dammer (*3*) reported on an experiment made by Duerkoptf in 1897 and 1898 on the value of frequent removal of runners, as shown in Table 10.

TABLE 10.—*Effect of removing runners of strawberry plants grown in 50-plant rows*

Row No.	Removal period	Average number—		
		Leaves	Fruit stalks	Fruits
1	Weekly	23.50	3.54	18.32
2	Every two weeks	22.74	3.18	16.82
3	Every three weeks	22.78	3.34	17.20
4	Every four weeks	20.18	2.54	12.56
5	Every five weeks	19.40	2.10	12.36
6	Every six weeks	18.56	1.46	9.04

Frequent removal of runners when plants are grown in hills is apparently important.

Jordan (*10*) in New Jersey in 1900 reported an experiment on the effect of distance between plants on their yield in hills (i. e., with runners removed throughout the season) from 12 to 24 inches apart and in matted rows. Maximum yields were obtained from plots with plants 12 inches apart and maximum yields per plant with plants 15 inches apart. Plants 12 inches apart in the plot yielded more than any in matted rows. In 1900 and 1901, 34 varieties were tested under the hill and matted-row systems. In 1900, 11 gave heavier yields under the hill system, 7 about the same, and 16 more under the matted-row system. Some produced more than twice as much under the hill system as in matted rows, whereas others bore twice as much in matted rows as under the hill system. In 1901, 19 produced more under the hill system, 3 about the same, and (although it was not stated) 12 presumably produced more under the matted-row system.

Butz and Pillsbury (*1*) in Pennsylvania reported in 1899 on a comparison in size of fruit between the matted-row and hill systems. A little more than half of the varieties grown gave larger fruit under the hill system, and the remainder produced larger fruit under the matted-row system.

The experience and practice of strawberry growers in Oregon, Washington, and British Columbia indicate that it is undoubtedly the best practice for that region, under prevailing conditions and with the present varieties, to set out the full number of plants in the spring from which berries are to be picked the following spring and early summer, removing all runners as they appear. The experimental results in British Columbia tend to show that this is the best practice, although the half-matted row gave good results. The varieties grown in that region make very large plants, with many crowns and many trusses. For example, on July 7, 1926, more than 120 trusses were counted on a single plant of Ettersburg 121 grown in this way in the Willamette Valley of Oregon.

In eastern regions the experience and practice of growers indicate that keeping the plants in hills with the runners off is not generally good practice with the varieties used. Little definite experimental evidence is available, but that of Quaintance in Georgia indicates that

the matted-row system of culture gives largest yields of any there. The results with many varieties in New Jersey indicate that they differ in their response to the hill system of culture, some kinds producing best under one, others under the other system, and still others being adapted to either system. In the Pacific Northwest the plants are commonly set 3 feet apart each way, growing to very large size and occupying the land quite fully. Plants do not ordinarily grow so large in hills under eastern conditions and practices. The incidence of diseases and insects may perhaps be too great for good results. The results in New Jersey indicate that for some varieties 12 inches between plants under the hill system would give largest yields. The results of Duerkoptf and those reported here for Glenn Dale, Md., indicate the importance of frequent removal of runners from plants grown in hills. Plants from which runners are frequently removed grow to larger size than those from which runners are picked less frequently. It is probable that different varieties or different practices in growing plants in hills would make the system adapted to some eastern conditions.

DISCUSSION

Several effects of conditions on the development and yield of plants have been considered. Mother plants that produce and support many runner plants were found to be much weaker and produce much less fruit than plants producing none or few runner plants. A runner plant may be weaker than the average because it was produced by a branch runner, because it was formed late in the season, because of insect or disease attacks, or because of other unfavorable conditions. It is not known for just how long an inferior plant may produce weak runner plants and continue weaker than the average after being given favorable conditions.

Two recent reports give further evidence of important differences in planting stocks. Clark (*2*), in New Jersey, planted stocks of the Howard 17 variety from four sources in 1926. In 1927 in adjoining rows the yields of plants from three sources were respectively, 80, 70, and 51 per cent of that of plants from the fourth source. At the Devon County Experimental Station in England (*12*) many similar tests have been made. In a test of 13 strains of Royal Sovereign, the leading variety of England, from different sources, the yields ranged from 2.7 to 43.8 hundredweight per acre in 1928. In a much more extended test of two strains of the same variety the yields from early-set plants of the two strains were as follows:

	1927	1928
Strain A	24 cwt.	40 cwt.
Strain B	8 cwt.	70 cwt.
Runner plants from A	------	39 cwt.
Runner plants from B	------	38 cwt.

Strains A and B showed striking differences in yield in both 1927 and 1928, but strain A yielded much the most in 1927 and strain B much the most in 1928. The runner plants produced by A and B at the experiment station produced almost equal crops. It would seem that there were hold-over effects of the conditions under which the plants developed at the two sources, which were important in their effect on the first crops and which were in the one case very

unfavorable. The plants of the most productive strain (A) apparently exhausted themselves the first year and produced a relatively smaller crop the following year.

It is not yet possible to explain fully differences in yields such as these. Differences in the amount of virus diseases in strains or differences in infestation by insects and nemas certainly often influence the yield of strains. However, the fact that runner plants from two strains produced approximately the same and the reversal of position of the two strains indicates a hold-over effect and not a permanent difference.

SUMMARY

Branch runners are produced commonly by some varieties and rarely by others. Missionary and Klondike produce many runner branches.

In the vicinity of Washington, D. C., runners are produced during the growing period from about the end of the fruiting season until freezing weather. In the greenhouse, runners may be produced as early as April by horticultural varieties, and throughout the winter by *Fragaria chiloensis* and by species of the *vesca* group.

Organic sources of nitrogen apparently are most effective in runner-plant production.

Varieties differ greatly in the number of runners produced and in the time of producing runners.

Plants with runners removed as they appear produce many more runners than plants allowed to form clons.

The Howard 17 variety forms few runner plants after September 15 in the vicinity of Washington. Its development is illustrated in detail.

There seems to be little difference in the runner-producing capacity of runner plants rooting from July to September and allowed to form runner plants that season.

Runner plants formed in October produce fewer runners than those formed earlier.

Careful grading as to size seemed to be a satisfactory means of selecting uniform propagating stock.

Runner plants formed during July and August produce more fruit than plants formed later.

When runner plants were allowed to form at stated intervals only, in any series, the earlier formed plants produced the most fruit and the latest the least fruit.

Plants that formed no more than four runner plants and these only after September 1 produced about half the number of fruits as compared to plants from which all runners were picked off throughout the season.

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