FRUIT BUD DIFFERENTIATION AND GROWING HABITS IN CERTAIN TYPES OF STRAWBERRIES

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FRUIT BUD DIFFERENTIATION AND GROWING HABITS IN CERTAIN TYPES OF STRAWBERRIES

by

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THESIS

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Fuller (9) has called attention to the variable growth habits of the different varieties of strawberries, particularly their mode of branching and production of roots, necessitating different cultural treatments. Miller (19) cautioned against the planting of strawberries on very rich soil, as it would cause the plants to spread (i.e. to make many runners) and flourish but be less fruitful than upon moderately fertile soil. According to Duhamel du Monceau (6), cultivated strawberry plants bear little, and the majority of the crowns do not grow, without a doubt because the substances necessary to perfect them have been appropriated by the runners.

Investigations (10) have shown that continual removal of runners from the individual plants doubled the yield of fruit over plants where the runners had not been removed. The hill system of culture, now in rather general use in some sections, is maintained by cutting away the runners as they appear. Hill plants become very large and have many crowns. This, according to Fletcher (8), is due to the, "branching of the main stem from adventitious buds; the common result from heavy pruning with nearly all kinds of plants."

Chandler (3) reports that fertilization of strawberry plants with nitrogen resulted in earlier runner formation and decrease in number of fruits borne. He also found that removal of fruit stems early in the season caused runners to be formed earlier and also lead to a more abundant runner formation. Investigations carried on by Loree (17) has shown that spring applications of nitrogen, alone or in combination with phosphoric acid and potash, caused a vigorous runner production. Summer applications of nutrients in the same quantities resulted in less abundant runner formation, but better development of the crowns.

Besides a knowledge of the factors contributing especially to the formation and development of the runner, information as to the time of fruit-bud differentiation seems essential to an understanding of the nutrition of the plant and may have an important bearing on some of the cultural practices. Rather careful studies have been made of the fruit-bud differentiation process in a number of the deciduous fruits.

Gardner, Bradford and Hooker (11) conclude that, "at certain critical periods in the life of the plant, its activities are directed into one channel or another depending on the nature of the conditions affecting its equilibrium at that particular time." Kraus and Kraybill (16) believe that conditions for the initiation of the floral primordia and even for blooming are probably different from those accompanying fruit setting. Experimental evidence supporting this view has been presented by Murneek (20). Bradford (1) reports that applications of nitrogenous fertilizers to apple trees increased shoot growth, leading to more abundant spur formation and greater fruitfulness than characterized unfertilized trees.

Gardner (12) reports that the maximum production of flower clusters, flowers, and berries of strawberry plants was associated with those summer and fall treatments that lead to the greatest accumulation of starch and total carbohydrates at the time of fruit-bud differentiation. The accumulation of starch at this time also caused better setting of the individual pistils and slightly better setting of the flowers. He reports also that the size of berry is closely correlated with number of pistils per flower and with setting of these pistils and that low starch content at the time of fruit-bud formation lead to the production of female flowers in a variety that is normally hermaphroditic. Loree (17) found variations in the nitrogen content of strawberry plants at the time of fruit-bud differentiation had a greater effect on the yield of fruit than variations in carbohydrate content. Low nitrogen was associated with low yields, high nitrogen with high yields. Plants with a high carbohydrate content were most productive.

Studies in fruit-bud formation in the strawberry have been reported by Goff (13) of Wisconsin, working with the Clyde variety. He showed that differentiation took place about September 20, with very rapid development following. Chandler (3) reports that he was unable to find flower parts of strawberries earlier than February or March and states that experience indicates that the number of fruit stems sent up from any crown can be influenced by spring treatment of the strawberry plantation.

From a survey made in 1923 by Darrow (4) of the relative time of fruit-bud formation in several varieties from several experiment stations in the northern part of the United States, he concluded that fruit-bud differentiation took place during the latter part of September in all sections of northern United States, occurring slightly earlier in early than in late varieties. Recent investigations by Ruef and Richey (21) in Iowa, show that the initial differentiation in the Senator Dunlap strawberry takes place on the first runner plant in early September and a gradual morphological change continues from the time of differentiation until the middle of December. Furthermore the time of differentiation of the various buds on a fruit stalk depends on their relative position on the stalk, the development being progressive from the primary to the secondary, tertiary, etc. The time of differentiation in the individual plants of a runner differs according to the relative position in age and the time of formation of the plants in relation to the mother plant and to one another.

No recorded attempt has been made to study, minutely the anatomy of the plant, and no information is available as to the time of the fruit-bud differentiation process in the everbearing strawberry. The objects of this investigation have been (1) to study the development of the stem, runners, leaves and roots of the strawberry plant in general and (2) to discover the time of fruit-bud formation in the everbearing type in comparison with the standard type.

METHODS AND MATERIALS

The investigations reported here were made with the Progressive, an everbearer, and Senator Dunlap, a standard spring bearing variety. The Senator Dunlap is one of the parents of Progressive, which comes from a cross of Senator Dunlap and Pan American, which is an everbearer. Runner plants of both these varieties were set side by side in the field in May, 1924. The soil was a sandy loam. They soon began to produce runners, though Progressive produced only a limited number. Young runner plants of both varieties were dug and reset about the first of August. The plants made a good growth during the autumn. In the spring of 1925 more runner plants of the Senator Dunlap and Progressive were set out in a similar soil. During the early part of the summer, these plants suffered much from drought, but grew well after the middle of July.

Studies were made of sections of the stem, roots and runners cut from fresh material which had been preserved in 95% alcohol. Most sections of the stem were made 20 to 40 microus in thickness with a sledge microtome. Free hand sections were made of the runners and the roots. As soon as sections were made they were put in 95% alcohol followed by Delafield's Haematoxylin and allowed to stand in the stain from 12 to 24 hours. Excess stain was removed from the sections by several washings in water and water made acid by a few drops of hydrochloric acid with several washings in water following before being placed in alcohol. From water the material was passed through 25, 50, 70, 95 percent and finally absolute alcohol; it was then cleared in xylol and mounted in balsam.

Collection of material for microscopic study of fruit-bud development began July 1, 1924, and continued during the summer and autumn at 10 to 15 day intervals. In 1925, the first material was collected April 20 and other collections followed at varying intervals of from 10 to 20 days, until November. Samples were taken from both the old and the new plots. Whole plants were dug and taken immediately to the laboratory, where the plants were washed in water to remove the dirt. The outside leaves were removed from the crown so that only the rudimentary leaves encircling the central axis remained.

Material was killed in stock chrom-acetic solution of the following composition. Each sample was placed in

Chromic acid------------- ----1 g.

Glacial acetic acid----------1 c.c.

Water------------------------100 c.c.

25 C.C. vials containing the killing solution. In order to get maximum penetration, the vials were exhausted by means of a water pump. Material was allowed to remain in the killing solution from 12 to 24 hours and then washed for the same length of time in vials covered with muslin in a pan of running water. After washing each sample was passed through a series of 10, 25, 35, 50 and 70 percent alcohol, standing from 4 to 12 hours in each strength of alcohol. All material was allowed to remain in 70 percent alcohol until a considerable amount had been collected.

Previous to embedding the buds were passed through 85 percent, 95 percent and absolute alcohol and two changes of pure xylol, remaining in each from 2 to 4 hours. To the last xylol, paraffin was gradually added and the xylol allowed to evaporate in the paraffin bath for about four days; this paraffin, containing traces of xylol, was then poured off and fresh paraffin added. Paper trays were used for embedding the material in paraffin. From one to several buds were embedded in each tray, according to the size of the buds.

Each bud was sectioned separately with a ratary microtome. Sections were cut from 7 to 15, usually from 10 to 12, microns in thickness. Occassionally, when the material seemed particularly brittle, thicker sections were made. Mayer's fixative of the following formula was used in fixing the sections

White of egg	50 c.c.
Glycerin	50 c.c.
Salicylate of soda	1 gr.

to the slide. At first the sections were fixed by smearing a small drop of the above fixative on the slide, then placing the ribbon of paraffin containing the sections on the slide and adding water and gently heating to float out the wrinkles in the ribbon. However, more satisfactory results were obtained by using a 1 percent solution of the above fixative and adding enough potassium bichromate to make the solution a pale yellow. The ribbons were floated out in this solution and the slides allowed to dry from 12 to 24 hours.

The first step in the staining process was removal of the paraffin from the sections by placing the slides in coplin jars containing pure xylol. After the paraffin was removed the slides were flooded with absolute alcohol before placing in the stain. At first the slides were put in coplin jars containing alcohols of different strengths. This was found to be less satisfactory than flooding with absolute alcohol. Staining was always done in coplin jars containing Delafield's Haematoxylin. The slides remained in the stain from one to five minutes. Following staining two methods were tried, that of flooding and that of placing in coplin jars. The sections seemed to be less disturbed by flooding than by immersion in the coplin jars. Excess stain was removed by first using water and 50% alcohol to which a few drops of concentrated hydrochloric acid had been added. The slides were then passed through a series of 35, 50, 70, 95 percent and absolute alcohol, remaining in the absolute alcohol several minutes. Sections were cleared in xylol and mounted in balsam.

PRESENTATION OF DATA

STEM-- More than two centuries ago Duhamel du Monceau (6) mentioned the stem of a strawberry plant as having a diameter of about one-half an inch and reaching naturally about two or three inches in height. Fuller (9) has called attention to the fact that the crowns, instead of adhering together, often separate as they become old. The stem of a strawberry plant is described by Goff (13) as grown mostly below ground and the leaves growing from its summit. The very short stem of the cultivated strawberry is considered by Fletcher (7) to be a form of rhizome.

The stem of a strawberry plant varies in gross structure according to the type and variety, and also, with the treatment it has received. The most striking variations are expressed in the number of branches and runners produced. The branching of crowns in strawberry plants has been noted by Fuller (9), who also observed in Triomphe de Gand, that new roots start from the base of the side crowns above the soil and the new crowns are produced almost on top of the old; the plants consequently are continually becoming higher until at last the new roots cannot reach the soil and the plant languishes and dies. Similar observations have been made by Fletcher (7) who states that the crown is a fleshy stem and bears buds like any other stem; some of these buds become runners; others become fruit stalks.

Plants of the Alpine type generally fruit continuously during the summer. One variety of this type, the Bush Alpine, (so named because of its bushy habit of growth) produces no runners. Our present varieties of everbearing strawberries, which are not of Alpine origin, present a situation that somewhat approaches this condition in that they are not prolific runner producers and generally have a much branched stem (Fig. 1). Varieties of the Senator Dunlap type are generally more prolific runner producers and normally the stem is less branched, (Fig. 2 and 3). Chandler (3) states that normally there is one crown to each plant; however, if the runners are kept removed a number of crowns will be formed on each plant, sometimes a large number.

Strasburger (23) states that in Phanerogams new shoots generally arise in the axils of the leaves and in the generative or flower producing regions the formation of shoots follows directly upon that of their subtending leaves, or the shoots may even precede the leaves. Sachs (22) assigns the cause of branching to (1) lateral budding which occurs when the producing member, after its previous increase in length at the apex, forms outgrowths below it, which at their origin are weaker than the portion of the axial structure which lies above them and to (2) dichotomy caused by the cessation of the previous increase in length of a member at the apex and by two or more apices in close proximity at the apical surface.

Sections of a crown of a Progressive strawberry plant taken early in December (Fig. 4), show that in this variety the branches usually begin as lateral buds in the axils of the leaves and at the base of the terminal bud which has differentiated flower parts. Branches also begin lower down on the stem (Fig. 5 and 6). The cause of this branching seems to be the arresting of growth of the main stem by flowering. No study was made of the immediate cause of branching in Senator Dunlap due to runner removal. It appears that runners seem always to originate from buds in the axils of leaves, as do branches (Fig. 7).

Cross sections of a branched stem at different levels show that the vascular system of the branch merges with that of the main stem. As the vascular system ascends it tends to complete the vascular cylinder of the stem and finally does when the branch becomes separated from the main stem (Figs. 8, 9, 10 and 11).

ROOTS- The strawberry is a typical fibrous rooted plant. In the newly-formed runner plant the roots spring from the base of its stem. As the plant becomes older new roots spring laterally from points higher on the stem. This is illustrated in (Figs. 12, 13 and 14). They thus have the appearance of being adventitious on the stem.

As has already been noted, all roots on older stems arise near the attachment of the lower leaves to the stem. They even push their way out through the stipules of growing leaves. In the material examined, the xylem region of the stem seems particularly thick in the region of the root attachment to the stem (Figs. 15 and 16). Sections of the nodes and terminal buds of runners show rudimentary roots arising in the same region as in the stem. Root development takes place in the runner node soon after the growing point has appeared which becomes the crown of the new plant.

Examination of old stems indicates that the lower portions die while the plant is still vigorously growing. Not only the outer leaf scars and the stipule remains but also the cambium regions are black. Cambium does not seem to be alive except relatively near the growing points. This probably accounts for the stem being largest in the region where the leaves are still attached and where new roots are being produced. Particularly is this apparent in unbranched stems in which the lower part of the stem is so much smaller that it has an appearance suggesting a tap root.

The strawberry plant therefore has a stem that is perennial in one sense, but is annual or near-annual in another. The older and basal portion dies as new apical growth is made. Similarly the older roots die and new roots develop from the younger portions of the stem.

LEAVES- The leaves of the strawberry, according to Duhamel du Mondeau (6), develop in a spiral arrangement around a stem. Examination of the leaf arrangement on strawberry crowns shows that they are more or less pentastichous or five-ranked; five leaves are formed in a spiral line making two turns round the stem and the sixth leaf originating over the first one and the seventh over the second, etc. Each new leaf arises above the last one formed and its attachment to the stem is a little higher.

Duhamel (6) states that the stem of the leaf bears on either side of its base a thin transparent membrane constituting a stipule which persists after the death of the leaf itself. The attachment of each stipule extends the full circumference of the stem and the nodes makes the stipules overlap. Goff (13) speaks of the leaves of the strawberry plant as growing from the summit, and of the leaf stalk as having broad stipules which completely encircle the growing point or center where new leaves are formed.

Sachs (22) states that the leaf never has its origin in the interior of the tissues of the stem and is never covered by layers of tissue. Tissue of the leaf is continuous in its formation with that of the stem. If leaves are formed quickly one after another they envelop and overarch the end of the shoot and thus form a bud. According to Strassburger (23) a leaf never arises directly from older parts of the plant. In cases where it apparently does so, its development has been preceded by the formation of a growing point of a new shoot, The unsegmented protuberance of the primordial leaf, first projects from the vegetative cone of the shoot. This is followed by a separation of the primordial leaf into leaf base and upper leaf. The leaf base, or the part of the rudimentary leaf which immediately adjoins the vegetative cone, either takes no further part in the succeeding differentiation of the leaf, or develops into a leaf sheath or into stipules.

In the strawberry, as in all Phanerogam. plants, the leaves originate at the growing point. Apparently a layer of the undifferentiated tissue pushes out from the side of or around the growing point and grows up over the point (Fig. 17). Still younger leaves, forming beneath the arch, though higher on the stem push it upward and outward (Fig. 18). As the leaf elongates and the stem thickens, vascular bundles appear in the parenchyma of the cortex. Three bundles appear for each leaf in those leaves having three leaflets situated at about one third of the circumference of the stem from one another. Upon further differentiation a partition then appears in the parenchyma opposite that vascular bundle, which becomes the central and largest bundle of the petiole. This partition gradually extends in each direction around the stem and takes in another vascular bundle on each side (Figs. 19 and 20). The two lateral vascular bundles of the stipules gradually bend toward the central one and come together to make the three vascular bundles of the petiole.

A part of the rudimentary leaf seen above the growing point apparently differentiates into the upper leaf which finally elongates on the side in which the central vascular bundle appears and later unfolds into leaf blade and petiole. The stipules develop on each side of the leaf blade and petiole. The stipules develop on each side of the leaf blade and petiole and continue to cover the growing point and the later differentiated parts, until pushed apart by them.

RUNNERS- Lyte's "Dodoen's Herbal" (18) describes the strawberry plant as "having small and tender branches, creepeth along the ground and taketh root and holdfast in divers places of the ground." Duhamel du Monceau (6) calls attention to the buds which form in the axil of each leaf which produce stems or make vigorous shoots called threads or runners cylindrical, very long, sometimes two or three feet, and furnished in their length with several nodes, each node bearing a bud. These buds produce a strawberry stem which takes root and forms a new plant.

With most of our common varieties the principal means of reproduction is by runners, yet among Alpine and wood species there are varieties which produce none or at least very few. Therefore Fuller (9) points out these differences as bases for different cultural treatment. Fletcher (7) says that the runner at first sight appears as different as possible from the ordinary leaf-bearing stem; it becomes very plain, however, upon closer examination, that it is merely an elongated branch dissimilar to the original one simply in the great length of the internodes and in the diminutive size of the leaves, which are mostly reduced to mere bracts, but the runners show their identity with the normal branches in producing from their nodes exactly the same appendages as the primitive stems do. Kerner and Oliver (14) state that one portion of the bud developing at the node of the runner forms an axis, another part even the first year forms a long axis which again assumes the form of a runner.

Reference has already been made to the formation in the axils of the leaves of buds which give rise either to branches or to runners. The bud of a runner appears as a protuberance in the axil of a leaf (Fig. 21). No leaves develop at its base to enclose its growing point, but rudiments of leaves soon appear near the growing point (Fig. 22), later developing into bracts enclosing the end of the runner. Cross sections of a stem at different levels show the vascular cylinder of the stem. At the lower levels in the stem, the vascular cylinder has a projection on one side toward the outside of the stem (Fig. 23). On the outer portion of this there is a large vascular strand which as seen later is the central strand of a leaf. At a higher level a new vascular cylinder is forming; the outside portion is still a large vascular strand, and the side next to the pith is partly enclosed (Fig.24). At a still higher level the cylinder is almost complete and no connection between it and the large vascular strand in the cortex outside of it or with the vascular system of the main stem (Figs. 25 and 26) can be found. Eventually partitions form in the cortex separating the leaf from the main stem and also the runner from the stem and leaf (Fig. 27).

Runners have one or many nodes. In the terminal bud and probably in the node of the runner a new growing point may appear (Fig. 28 & 29). It is thought that this new growing poi continues as a runner and the older growing point becomes the stem of the new plant. Roots soon appear which, when they reach the soil, draw the new plant down to it. This kind of growth has been pointed out by Kerner and Oliver (14), "the roots springing from stem nodes of runners e.g. as those of strawberry plants, draw the nodes a centimeter below the ground."

When a plant is formed by the terminal of the runner new leaves are developed immediately by the new growing point. Often, however, no new plant is formed immediately; instead bracts or leaves appear at the nodes. Sections of such nodes show how the vascular strands of the leaf are connected to the main vascular cylinder (Figs. 30, 31 and 32).

Development of a new runner plant is generally rapid, probably due to its connection through the runner to the old plant. Sections of a plant of this kind show the new plant to have a short thick stem, a runner passing to the plant and the new runner extending beyond (Figs. 33, 34 and 35).

FRUIT-BUD FORMATION- Although it is impossible to establish an exact date when the changes or processes that are designated as fruit-bud formation are initiated, there are certain characteristic stages which the growing point, as seen in longitudinal section, passes through that are generally recognized as the beginning of the reproductive process. Goff (13) regarded the broadening of the crown or growing point of the strawberry plant, accompanied by the assumption of an irregular outline, as an indication of an early stage of flower development. The appearance of corrugations on the crown were thought by Drinkard (4), in a study of the apple, to be an indication of the initiation of fruit buds. Kraus (15) believed that the first observable indication of the flower in the apple is a thickening of the axis. It is reported by Bradford (1) that the first evidence of fruit-bud formation in the apple is the rapid elevation of the crown into a narrow conical form, rounded at the apex, with fibrovascular connections and pith areas advancing concurrently. Wiggons (25) considered fruit-bud formation, in the Bartlett pear, as beginning when the growing point of the bud had ceased to give off bud scales and had become elongated by a lengthening of the crown and showed in longitudinal section, a large primary and two smaller secondary primordial flowers in the form of blunt protuberances. In the several fruits, principally drupes, which he investigated, Tufts (24) considered the definite broadening and thickening of the floral axis as evidence of the first differentiation of the flower parts. The formation of slight protuberances on the main axis which eventually become calyx, corolla, stamens and pistils follows almost immediately.

In investigations here reported, clear evidence of floral differentiation is considered to be a thickening and elongation of the growing point along with corrugations appearing on it. However, from careful microscopic examination of materail whic did not show any evidence of differentiation according to the above standards there appeared to be other differences suggesting still earlier stages. In these the pith cells underneath the growing point have the appearançe of being compressed or under pressure from above, and the cells lengthened at right angles to the axis of the stem. In Senator Dunlap just before flower formation became evident (Figs. 36 and 37), several layers of pith cells showed an unusual arrangement, in that the cells were elongated at right angles to the axis and the layers curved downward at the center.

A plausible explanation of this condition is that elongation has ceased except around the outside of the axis and development of the meristematic cells in the growing point into floral parts exerts pressure on the pith cells below. This flattening out of the cells immediately below the growing point may also be conceived to be due to a temporary and very localized resting stage of the growing point itself, that is antecedent to the actual differentiation of the floral structure--a resting stage not shared by the adjoining or surrounding stem tissues. In the succeeding steps of the process of differentiation the floral axis elongates, releasing the pressure on the pith cells in this area. This accounts for the absence of compressed cells in the pith when the floral parts have become well developed.

The amount of material examined does not warrant assertion that this is a universal occurrence, particularly as no previous investigator has reported anything of this sort. However it was so clear in the material studied and, as evidence of a similar nature was found in connection with runner production, it is considered worth reporting. The condition may be described or designated as a kind of pre-differentiation stage.

SENATOR DUNLAP- A slight compression in the pith beneath the primordia appeared in material collected September 1 (Fig. 36). Material collected September 12, showed considerable compression in the pith area (Fig. 37). By September 22, floral differentiation had taken place to the extent that the central axis had become elongated and rudiments of lateral primordial flowers were appearing near the base of the central axis. After September 22 development was very rapid (Fig. 38).

Runner plants of Senator Dunlap show differentiation parallel with that in the parent plants. Fruit-bud development in these runner plants during the autumn corresponds with that of the older plants and proceeds at approximately the same rate. This observation is in accordance with that of Goff, (13).

PROGRESSIVE- The first material collected for fruit-bud formation studies was taken July 1, 1924. At this time fruit-bud formation had already taken place in the Progressive. Material collected May 18, 1925, after blossoming had begun, showed the flower parts in the bud. After this date further differentiation was observed. Following June 6, well developed flower buds could be found at any date during the summer and autumn and buds could be found at almost any date with rudimentary flower parts just becoming distinguishable (Figs. 39 and 46).

Runner plants of Progressive produced during the summer and reset August 4, 1924, had all the flower parts well developed by September 1. Following this date blossoms appeared on the plants and fruits had begun to develop before the advent of killing frosts in October. Material collected at various times during the autumn showed fruit buds well developed and on the same plant, other buds in the earlier stages of fruit-bud differentiation. These data seem to show that in this variety flower bud formation is continuous during the growing season.

SUMMARY

1- New branches of the crown of the everbearing type of strawberry usually originate as buds at the bases of the crowns that have differentiated flower parts but they may also originate from latent buds lower down on the stem.

2- Roots originate in the pericycle of the stem in the region of the leaf attachment. Often the root forces its way out through the stipule of a leaf.

3- The strawberry plant has a stem which is perennial in the sense that it lives as an individual plant from year to year, but is annual in the sense that the older and basal portion of the plant dies as new apical growth is made and the older roots die off each year and new roots develop from the younger portions of the stem.

4- The runner always originates in the axil of a leaf and after a period of elongation, its terminal thickens and becomes the stem of a new plant. A new lateral growing point then appears which usually develops into a new runner.

5- Leaves originate in the growing point of a stem or runner; the stipules of each leaf clasp the stem and function as protectors of the growing point and rudimentary portions of the plant.

6- Fruit-bud differentiation apparently is first indicated by a compressed appearance of the pith cells directly beneath the

growing point.

7- Differentiation of floral parts in Senator Dunlap becomes apparent first in early September and is clearly evident by September 22.

8- Fruit-bud formation in runner plants of Senator Dunlap corresponds with that in the old plants.

9- Fruit-bud differentiation in the Progressive is a continuous process during the growing season.

10- Apparently the floral parts are differentiated in the Progressive as soon as the runner plants have rooted.

EXPLANATION OF FIGURES

Fig. 1- Old Progressive strawberry plant, having a many-branched stem.

Fig. 2- Old Dunlap strawberry plant, having a long stem with only three branches.

Fig. 3- A young Dunlap strawberry plant with no branches.

Fig. 4- Longitudinal section of the crown of a young Progressive strawberry plant. The section is cut so that only the lower part of the fruit truss remains at its apex. The new branches are appearing on each side of the truss.

Fig. 5- Young Progressive strawberry plant with new branches appearing on the stem at (a) below the origin of the remaining leaves.

Fig. 6- Longitudinal section of a Dunlap strawberry crown showing new branch arising somewhat below and to one side of the central truss at (a).

Fig. 7- Longitudinal section of a Dunlap strawberry crown; (a) remains of a runner in the axil of a leaf; (b) portion of an older runner.

Fig. 8- Cross section of a Progressive strawberry stem; (a) branch of the main stem b.

Fig. 9- A cross section of the same plant at a higher level.

Fig. 10- A cross section of the same plant at a still higher level. The vascular ring of both old and new stem is tending to

complete the ring.

Fig. 11- Cross section of the same plant at a still higher level. The vascular ring has completed the circumference in both the old and new branch.

Fig. 12- Young runner plant of the Senator Dunlap strawberry all young roots arising in the same region as the leaves.

Fig. 13- An old Senator Dunlap strawberry plant. The lower part of the stem with the attached root blackened and apparently dead. The younger roots arising in the region of the attachment of the remaining leaves.

Fig. 14- An old Progressive strawberry plant with roots arising on the truss of the plant.

Fig. 15- Cross section of a strawberry stem showing a new root.

Fig. 16- Cross section of a strawberry stem having xylem particularly thick in regions where roots are produces at (a).

Fig. 17- The growing point of a stem of a strawberry plant enclosed by rudimentary leaves.

Fig. 18- Stem of a Senator Denlap strawberry plant with the remains of the leaves along the sides at (a) and (b).

Fig. 19- Partition appearing between the runner and main stem. The central vascular strand of the petiole appears as part of the vascular cylinder of the new runner.

Fig. 20- Cross section of a stem where runner has fallen out. A cross section of a leaf completely encloses the stem.

Fig. 21- The first appearance of a runner in the axil of a leaf.

Fig. 22- The terminal of a young runner with rudimentary leaves enclosing its growing point.

Fig. 23- Cross section of a strawberry stem showing first indication at (a) of a runner being formed by the vascular ring of the stem appearing as a projection outward attached to a vascular strand.

Fig. 24- Cross section of the same stem at a higher level. The side of the projection is becoming curved and the vascular ring of the main stem is nearly completed.

Fig. 25- Cross section of the same stem at a still higher level. The vascular ring of the runner is nearly complete as is that of the main stem. Partitions in the parenchyma are beginning to appear at (a).

Fig. 26- The vascular cylinder of the runner in the above section much enlarged.

Fig. 27- Showing leaf surrounding the main stem and runner between the leaf and the stem.

Fig. 28- A new growing point appearing on the terminal of a runner.

Fig. 29- Two growing points in the terminal of a runner which

has begun to enlarge.

Fig. 30- Cross section of a runner at the node, showing indications of the three vascular strands which are found in the petiole of the leaf at (a, b, c).

Fig. 31- Cross section of a runner node showing the vascular strands branching out from the main vascular ring.

Fig. 32- Showing a single vascular strand in the parenchyma of the cortex of the runner.

Figs. 33, 34, 35- Young runner plants showing connections with both the runners coming to the plant and the ones leaving it.

Fig. 36- The growing point of a bud of Senator Dunlap collected September 2, showing cells beneath growing point having the appearance of being compressed.

Fig. 37- Senator Dunlap bud collected September 12. Cells beneath the growing point also appear to have been compressed.

Fig. 38- Senator Dunlap bud collected October 2. The secondary flowers appearing and also the rudimentary stamen and petals.

Fig. 39- Bud of Progressive collected May 18 showing the truss elongated with a broadened growing point.

Fig. 40- Bud of a young Progressive runner plant, collected May 30, showing an elongated and broadened growing point with corrugations appearing on it.

Fig. 41- Progressive bud collected June 16, showing fruit-

bud differentiation.

Fig. 42- Progressive bud collected July 8; fruit-bud differentiation is apparent.

Fig. 43- Progressive bud collected August 18; secondary flowers are appearing on the truss on each side of the primary flower.

Fig. 44- Flower buds from young Progressive plant collected September 1. The pistils and anthers are well developed.

Fig. 45- Fruit buds in process of differentiating in a Progressive plant, collected September 14.

Fig. 46- Fruit buds differentiating in Progressive, collected September 22.

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Fig. 1

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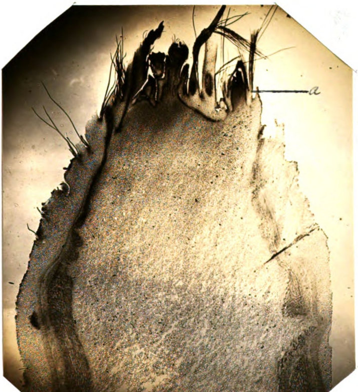

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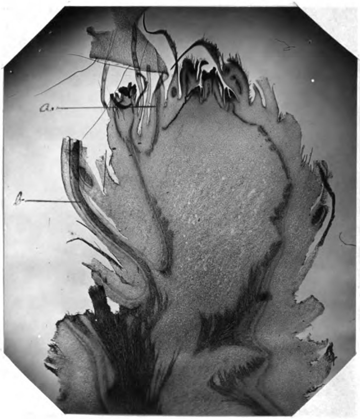

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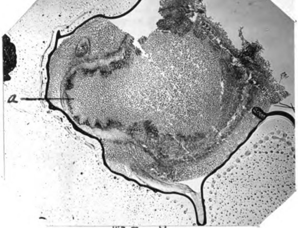

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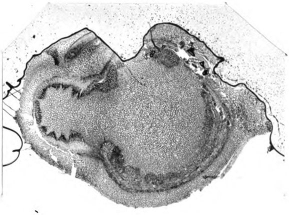

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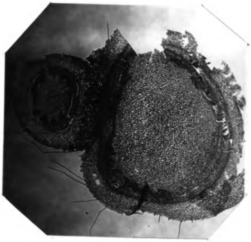

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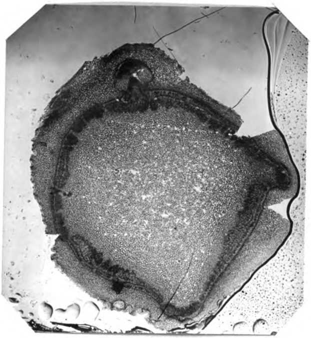

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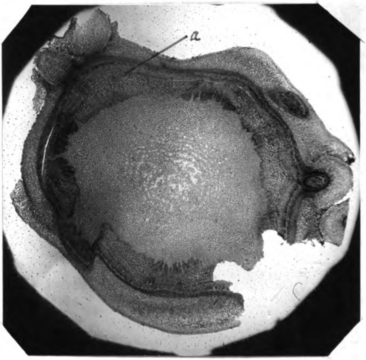

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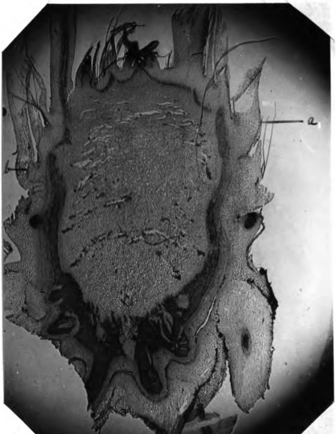

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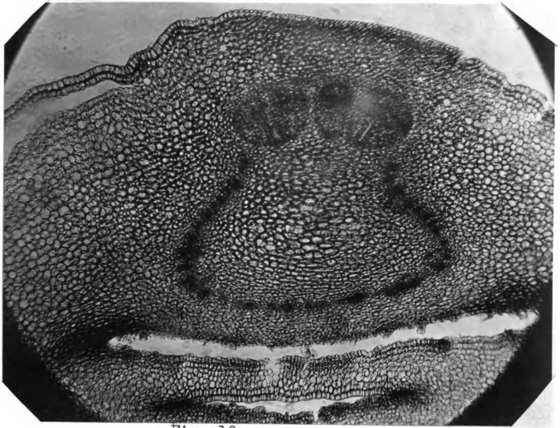

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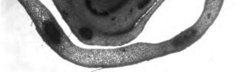

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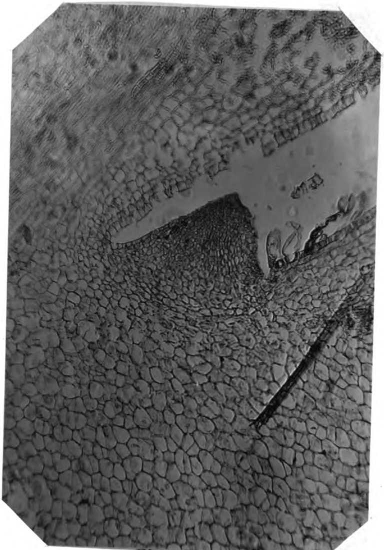

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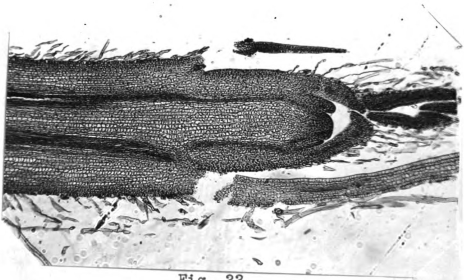

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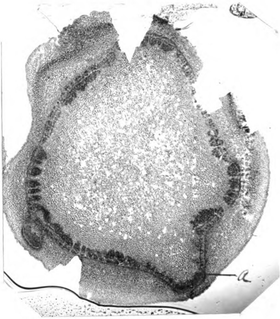

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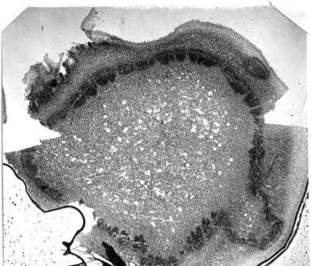
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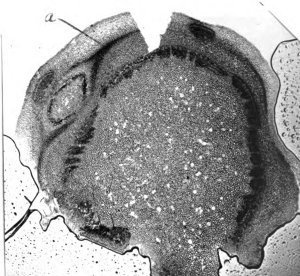

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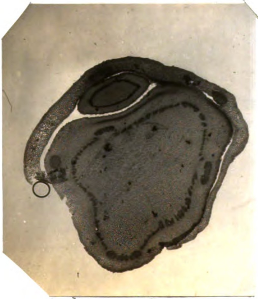

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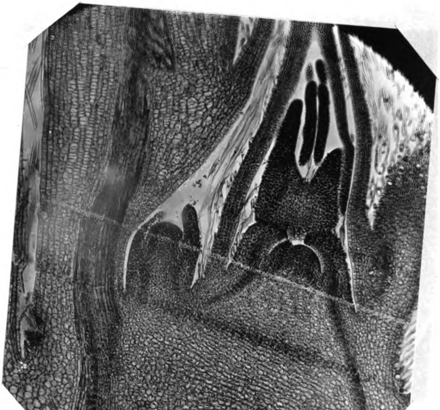

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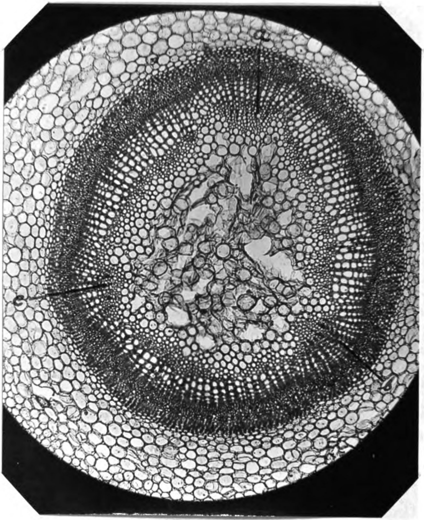

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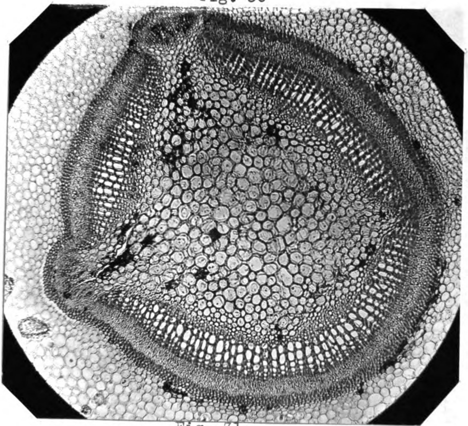

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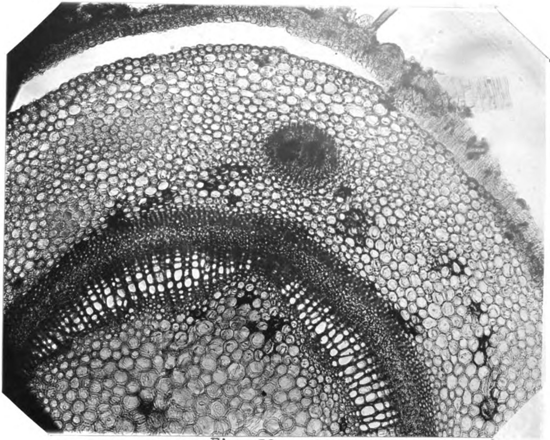

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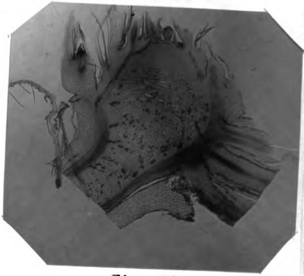

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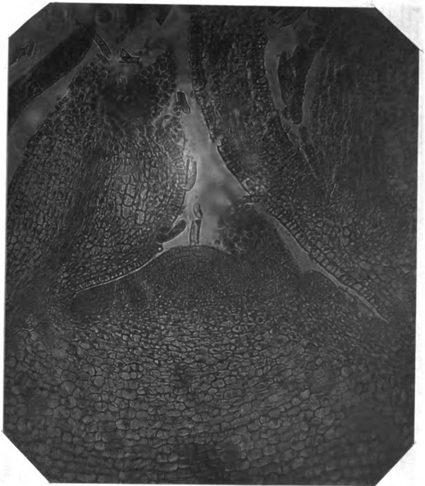
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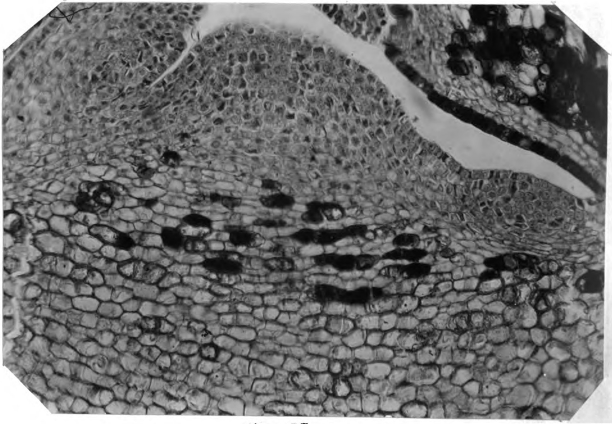

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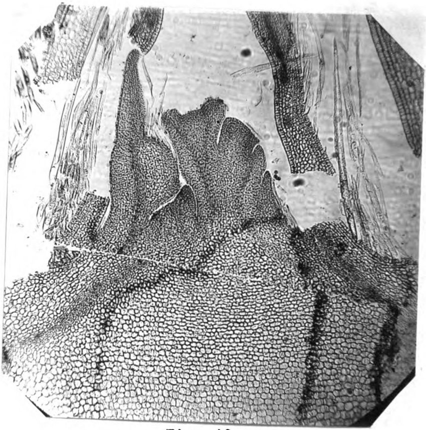

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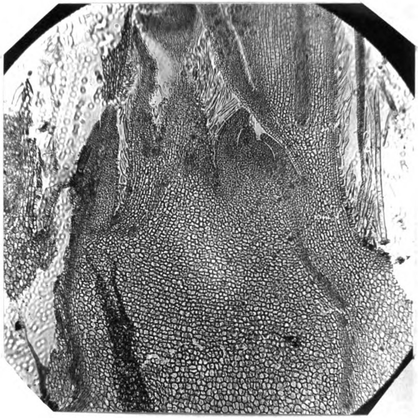

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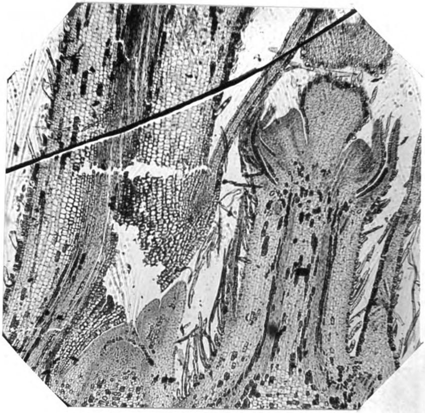

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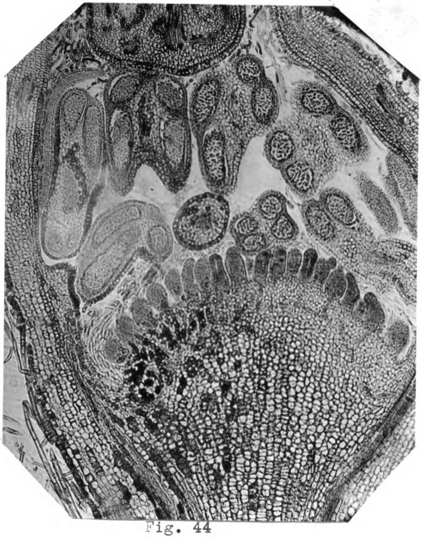

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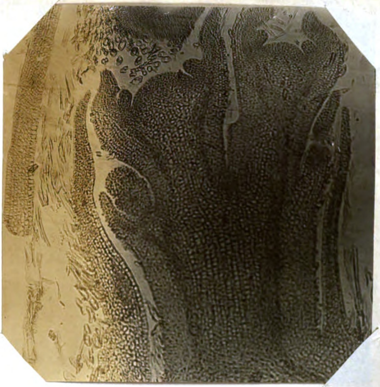

Fig. 45

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