# TIME OF FRUIT BUD FORMATION IN STRAWBERRY PLANTS AS INFLUENCED BY VARYING RATIOS OF NITROGEN

by

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# INTRODUCTION

The role of nitrogen in the fertilization of plants, and its relation to growth and fruit production have been the subjects of long and detailed research by experimental workers. Many of the results obtained from these experiments are in accord and are conclusive; some are vague and inconclusive while still others are actually at variance.

All research workers are apparently agreed upon one outstanding effect of nitrogen on plant growth and that is that nitrogen does promote vegetative extension. The amount and type of growth may depend upon other factors but in all instances where nitrogen was used there was a marked response in vegetative vigor.

The effect of nitrogen upon fruit bud formation and fruit production is not as well defined. Most experimental workers are again agreed that a certain balance must be attained between the nitrate and carbohydrate contents of the plant before fruit bud formation can take place but how to accurately ascertain the exact means of attaining this balance has not been determined.

It is also the consensus of opinion among research workers that nitrogen increases the size of fruit but whether or not it actually increases or decreases the number of fruits produced is a debatable question.

The successful and profitable production of strawberries is dependent upon the early production of strong runners in order that fruit buds may be formed early and store up sufficient nutrient material to produce vigorous flowers the following year.

This experiment was designed to determine what effect, if any, increased amounts of nitrogen over those normally used would have upon the time of fruit bud differentiation in the strawberry. The problem was based on the following premise: since research had proved beyond reasonable doubt that nitrogen did increase vegetative growth, then by increasing the amount of nitrogen over that normally used the following results might be obtained:

1. More rapidly grown runners would produce new plants in a shorter period of time;

2. These new runner plants, being more vigorous, would strike root quicker and be in a better position to obtain their own supply of nutrient material;

3. By developing more rapidly these plants would begin to differentiate their flower buds sooner and by so doing would

4. Produce stronger and more vigorous fruit buds capable of producing a larger crop of bigger berries.

The entire experiment was conducted to determine one point only: the time of fruit bud differentiation as affected by varying ratios of nitrate to the other elements commonly used for fertilizing strawberries. No attempt was made to ascertain what further effects the increase of nitrogen might have upon the number of flowers produced, or number and size of fruits produced.

## REVIEW OF LITERATURE

Exhaustive studies have been made by many investigators to determine the time of fruit bud differentiation in the strawberry and the factors that influence this differentiation.

Among the earliest investigators in this field of research was Goff (10) who found that the variety Clyde began to differentiate fruit buds on September 20 under Wisconsin conditions.

Macoun, et. al., (20), (21) using the Pokomoke variety, noted that the first differentiation of flower buds occurred on September 19. Up to this date runners 8 weeks from rooting differentiated no earlier than did those down to 4 weeks of age. After September 19 differentiation was observed in runners only 2 weeks from rooting.

Hill and Davis (15) state, "There is apparently a critical seasonal period before which the stimulus for flower bud formation is lacking, independent of the age of the runner."

Schilletter's work (29) is in accord with the foregoing statement. His investigation showed that an accumulation of carbohydrates was necessary for fruit

bud formation, that such accumulation is caused by a lessening of the amount of vegetative growth and that such retardation may be caused by lack of sufficient moisture at certain times and low temperatures. This agrees with the seasonal theory of Hill and Davis (15).

In other investigations on fruit bud formation in the strawberry Schilletter (30) and Richey (31) found evidence somewhat contradictory to the statement of Hill and Davis (15) regarding the age of the plant in relation to fruit bud formation. Schilletter and Richey (31) state, "The early set runners made the strongest plants and differentiated their buds first." Schilletter (29) later says, "It seemed feasible to expend extra effort in getting an early set of runners and thin out those plants formed late in the season.

Morrow and Beaumont (24) recommend that North Carolina growers secure as many new plants as possible during June, July, and August. They found that there was a marked decrease in flower and fruit production on plants rooting after August 15, thereby substantiating the theory that the early rooted plants differentiate their flower buds sooner than later rooted plants.

Shoemaker (32) also agrees with this theory

as he says, "When all factors are considered, the best advice that can be given strawberry growers who practise the matted row system is to encourage the formation, rooting and development of early runners of good size," and further states, "Two rows of plants which have received the same fertilizer treatment and are apparently equal in stand may vary greatly in their yield, if in one of these rows most of the runners are rooted early and in the other they are rooted late."

Another investigator who disagrees with the early runner formation theory is Morrow (25) who states that the age of the plant has no influence on time of fruit bud formation.

Ruef and Richey (28) found that the time of flower bud formation in the strawberry varied with the age of the individual plant. Their investigation disclosed that differentiation of flower buds on the first plant to form occurred about a week earlier than the differentiation of the buds on the second plant; and that there was a greater elapse of time in later plants.

Further confirmation is given to this theory by Moore (23). He says, "The plants should exert all their activity the first year in producing good vigorous crowns and strong runner plants. Runners should be

selected as quickly as possible and given conditions which will insure quick rooting."

Colby (4) observed that this theory also held true in Illinois and noted that it has been shown experimentally that the conditions under which the plant crowns were made during the growing period of the previous year determine to a considerable extent the total yield the first fruiting season.

The investigators are practically unanimous in their agreement that an accumulation of carbohydrates is necessary for fruit bud formation. Schilletter (29) states the general opinion of these workers quite clearly, "It is generally conceded that fruit bud formation is associated with an accumulation of carbohydrates. Evidently this accumulation occurs when the carbohydrates synthesized are more than are required for growth and other activities of the plant. Other things remaining the same, an accumulation of carbohydrates in the growing plant accompanies, or is caused by, a lessening in the amount or percentage of vegetative growth."

Hill and Davis (15) agree that nutritional conditions within the plant are the chief factors of fruit bud differentiation and that an excess of car-

bohydrates, together with the absence of any limiting factor that interferes with vegetative growth, constitutes favorable nutritional conditions.

Whitehouse (41) found that there was a correlation between fruitfulness and the carbohydrate-nitrate relation in the plant at time of fruit bud formation.

Contrary to the above results, Loree (19) determined from his investigations that variations in the nitrogen content of the plants at the time of fruit-bud formation affected the yield more than did variations in the carbohydrate content. His results show that a high nitrogen content is associated with high yield and that a low nitrogen content was associated with a low yield.

Ruef and Richey (28) conclude that if the carbohydrate-nitrogen ratio is one of the prime internal nutritional factors that influences the time of fruit bud formation, it is conceivable that the ratio might vary with the season, with the different periods of the season, with different varieties, and even with different aged plants of the same variety. They further state, "It is impossible to determine definitely the exact time of fruit bud differentiation since it is due

to chemical conditions rather than a pronouncedly visible morphological change."

Hill and Davis (15) state that the initiation of differentiation appears to occur as a gradual transition and is very difficult to determine.

Long (17) adds further testimony to the fact that nutritive conditions of the strawberry plant in summer and autumn determine its fruit production. He says, in part, - - - - "old plants are not as productive as new ones, and therefor the necessity for suitable growing conditions through the season preceding fruiting."

Loomis (18) also agrees to the theory of carbohydrate storage as a requirement for fruit bud formation. He states, "If the growth of a rapidly growing and apparently undifferentiated plant is checked in a manner which does not appreciably reduce the photosynthetic activity of the plant, for example by gradually reducing the moisture or nutrient supply available to the top, the carbohydrates formerly used in growth now accumulate and serve at once as the stimulus and as raw material for differentiation."

Gardner (18) also subscribes to the theory that carbohydrate accumulation is essential for fruit bud formation.

A voluminous amount of work has been done by investigators to determine the effect of fertilizers upon fruit bud formation, flowers and fruit production but among the many articles on this subject which were reviewed by the author only two made any reference to the effect of fertilizers on the time of fruit bud differentiation.

Hill and Davis (15) conclude that the correlation between the results obtained with the time of fertilizer applications in the field and the initial date of fruit bud differentiation is quite marked.

Ruef and Richey (28) reached the following conclusions:

1. Acid phosphate, alone or in combination, hastened fruit bud differentiation.

2. Nitrogenous fertilizers in general retarded development although at first heavy applications of nitrate seemed to stimulate differentiation.

3. Muriate of potash retarded differentiation.

Since fruit production is the ultimate goal of all strawberry growers, and since a knowledge of any practise which will either increase or decrease fruit bud formation and subsequent fruit production is of

vital importance to the grower, a review of the literature on this particular phase of strawberry culture was deemed important.

As early as 1900 Quaintance (27) recommended the use of a complete fertilizer, especially one quite rich in nitrogen and potassium. He also recommended that half the amount used be applied before planting to induce a vigorous growth.

According to Hill and Davis (15) the supply of available nitrogen is probably the most common limiting element; and a knowledge of the time of fruit bud differentiation is of great importance in connection with the possibility of increasing their number by fertilizer applications. They also state that while the majority of cases show, with reference to the strawberry, that fall applications of nitrogen produce rather marked beneficial results, instances are not wanting to indicate that late applications may result in reduced yield.

Loree (19) states that nitrogen is the limiting factor in growth and production, and that fruit bud differentiation is determined in the summer preceding fruiting.

Macoun and Davis (22) also found that beneficial results were frequently observed from nitrogen applications because nitrogen is more often deficient in the soil than other elements. Nitrogen was found to cause:

1. actual increase in the number of flowers
2. an increase in the size of individual fruits
3. an increase in the set of bloom.

They found that (1) was most important. Continuing their report they state, "The early formation of runners is dependent upon an available supply of plant food, including nitrogen, in the early part of the planting year. The presence of nitrogen therefor affects the number of fruits formed, by encouraging the early formation of runner-plants during the first year of the plantation."

Latimer and Wentworth (16) determined that the strawberry responds differently than other plants to fertilizer applications because the plants are shallow rooted and do not have many lateral roots.

Those investigators who recommend the application of complete fertilizers to strawberry plants are: Quaintance (27), Darrow (5), VanMeter (38), Talbert (36), Brooks, et. al. (1), Hartman et. al. (12), Brown (2), Fletcher (7), Szymoniak (33), and Shoemaker (32). These

investigators did not agree upon the proper time of application for best results although the majority concluded that application should be made just prior to the time of fruit bud differentiation.

Most of the investigators have confined their work to determine the effect of nitrogen alone on runner-plant, flower bud formation and fruit production. Their results vary considerably, however, and in several instances they are distinctly contradictory.

Peck (26) reports that nitrogen will ordinarily be found more useful and necessary in renewing the old bed than in securing a vigorous growth of newly set plants, and recommends that the fertilizer be broadcast and harrowed in prior to setting.

Taylor (34) and Macoun and Davis (22) agree with this report. On the other hand, several workers approve of the application of nitrogen the first year as a result of their experiments.

Hartman, et. al., (12) fertilized the plants the first year, after the plants had been set 4 to 6 weeks, and they report that where no treatment was applied the first year there was a significant difference in yield.

Loree (19) secured the best results from plants receiving fertilizer both in the spring and summer of the first year; Colby (4) recommends the use of nitrogen the first year when plants are set in poor soil or fail to make proper growth; Darrow (5) reports that strawberry plants need available nitrogen from early in September until the end of the next spring crop; Brooks, et. al., (1) recommend that higher percentage of nitrogen be applied for plant growth and that three applications be made; and Taylor (35) found that there was an increased number of flowers where nitrogen was applied.

Other investigators, however, have concluded from their experiments that the application of nitrogen is actually harmful. Hendrickson (13) states, "Caution is advised in the application of any commercial product which contains a high percentage of quickly available nitrogen because of the fact that this element often stimulates leaf production while fruit bearing is lessened." Macoun, et. al., (20) record that the stimlating effect of nitrogen is much more pronounced in younger plants and that nitrate applied to newly set plants frequently injures them.

Wentworth (40) found sodium nitrate to be rather injurious to strawberry beds when applied after considerable foliage growth had taken place.

Tucker (37) agrees and at the same time disagrees with Macoun, et. al., (20) as he states, "Commercial fertilizer increased the mortality of plants set out and apparently decreased vegetative growth."

Greve (11) reports that nitrogen had a depressing effect on the number of runner plants formed and a greater average number of blossoms per plant on the no nitrogen - no irrigation plots than on plots having any other combination.

Hendrickson (14) states that the experiences of strawberry growers in California indicate that fertilizers are unnecessary during the first year of planting, except possibly in some soils that are very deficient in plant food.

Shoemaker (32) concludes that where the soil is reasonably fertile other factors are usually of more importance than the application of commercial fertilizer. He then apparently contradicts himself as he states, "An increase in the number of fruit buds probably implies a larger plant. Fertilizer, particularly nitrogen, increases the size of the plant."

VanMeter (38) found that a slight increase in the number of fruits resulted from applications of ni-

trogen but it was not significant. Taylor (34) reports that few runners were formed on plots receiving no fertilizer and (35) that nitrogen applied in January increased the number of flowers.

## EXPERIMENTAL PROCEDURE

Object. The purpose of this investigation was to determine the effect of varying amounts of nitrogen in combination with fixed amounts of phosphorous and potash upon the time of fruit bud differentiation in the strawberry.

Material. Plants of the Majestic variety of strawberry were used because an adequate supply of runner plants of this variety was available.

The material used for potting consisted of two parts of garden soil of average fertility and one part of fine sand which were thoroughly mixed before placing in the pots.

Five-inch earthenware pots were used and one plant was placed in each pot.

The materials used for fertilizing were Chilean nitrate of soda, 16 per cent superphosphate and sulphate of potash.

Method of Procedure. Runner plants of Majestic variety of strawberry were dug from a planting in the author's garden and were graded so as to obtain plants of uniform size and having approximately the same degree of root development.

The five-inch earthenware pots were filled with the sand and soil mixture to within one and one-half inches of the top and the plants were set January 3, 1938. This particular soil mixture was used as it closely approximated the physical and chemical properties of the average soil used for strawberry production in Virginia. One plant was planted in each pot and was placed in the center as nearly as possible to insure even distribution of the root system and permit greater availability of the fertilizer to the plant. The plants were thoroughly watered immediately after setting.

One hundred plants were potted and were then divided into four lots of 25 plants each. A separate fertilizer treatment was used on each lot. The pots were then pressed into moist sand in a greenhouse bench to within one inch of the rim of the pot.

After a thorough study of the literature and discussing the problem with various members of the horticultural department a basic fertilizer having a formula of one part of nitrate of soda, two parts of superphosphate and one part of sulphate of potash, by weight, was decided upon.

One lot of 25 plants was left unfertilized to serve as a check and one lot received the basic

1-2-1 formula. The amounts of phosphorous and potash were kept constant in the other two lots but the amount of nitrate was increased so that one of the remaining two lots received an application of fertilizer having the formula 1.5-2-1 while the fourth lot received an application of a 2-2-1.

Again consulting the literature and horticultural specialists the author determined that the average application of a complete fertilizer recommended for strawberries was 500 pounds per acre. This was then used as a basis for the application of fertilizer to all lots. The area of the top of the potting mixture was calculated and each lot received the following application:

| Lot | | N. | P. | K. |
|---|---|---|---|---|
| I | (check) | 0 | 0 | 0 |
| II | (1-2-1) | .14g. | .28g. | .14g. |
| III | (1.5-2-1) | .21g. | .28g. | .14g. |
| IV | (2-2-1) | .28g. | .28g. | .14g. |

The fertilizer for each plant was weighed separately on precision balances, placed in individual envelopes, labeled and kept until time for application.

The plants were allowed to remain in the potting mixture for two weeks at which time it was assumed that the root system had become established, and the fertilizer was then applied. Application was made in a narrow, uniform band around the edge of the pot so that the young roots would not be injured by coming too quickly in contact with the nutrient material, particularly the nitrate.

The plants were watered at regular intervals so that no undue drying out took place. The temperature maintained in this greenhouse was approximately 78 degrees F.

The plants were examined at regular intervals and as the runner plants rooted they were pegged and tagged with a label noting the date on which they rooted. After the first runners rooted an examination was made at intervals of two weeks. The runners were rooted in the sand of the greenhouse bench so that practically all of the nutrient material which they received came from the mother plant.

After the first rooting had taken place collections of plants were taken at intervals of two weeks, these collections including runner plants that had rooted on all previous dates and had been pegged and dated.

The last collection was made on August 22, 1938. Space for this investigation was limited and subsequent to August 22, 1938, the runner plants had become so matted that it was impossible to accurately locate the pegged plants. The results show, however, that fruit bud differentiation had occurred prior to this date.

Killing the tissues, fixing, embedding, sectioning, staining and mounting followed closely the procedure recommended by Chamberlain*, but with sufficient modifications that a brief outline of procedure at this point may be of value.

The rooted runner plants were removed from the sand and all leaves and roots were removed so that only the crowns remained. Some difficulty was encountered in that it was impossible to remove most of the root area and this later was troublesome in sectioning. The crowns were placed immediately in a killing solution which was made up as follows:

| | | |
|---|---|---|
| Chromic acid crystals | - - - | 1g. |
| Glacial acetic acid | - - - | 1c.c. |
| Distilled water | - - - | 100c.c. |

The buds were allowed to remain in this solution for 30 hours after which they were dehydrated.

*Chamberlain, Charles J.
Methods in plant histology. Fifth revised edition.
The University of Chicago Press. 1935.

The buds were then dehydrated in the following series of alcohols for the length of time given:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | per | cent | - | - | - | - | -2 | hours |
| 35 | " | " | - | - | - | - | -2 | " |
| 50 | " | " | - | - | - | - | -2 | " |
| 60 | " | " | - | - | - | - | -2 | " |
| 70 | " | " | - | - | - | - | -2 | " |
| 85 | " | " | - | - | - | - | -2 | " |
| 95 | " | " | - | - | - | - | -6 | " |
| 100 | " | " | - | - | - | - | -6 | " |

The time allowed in each change of alcohol was much shorter than recommended but satisfactory results were obtained.

Clearing was done with xylol but before placing the buds in this material they were placed in the following series, and allowed to remain at least 24 hours in each series:

| | | | | | |
|---|---|---|---|---|---|
| Absolute | alcohol | 3 | parts; | xylol | 1 part |
| " | " | 1 | part ; | " | 1 part |
| " | " | 1 | part , | " | 3 parts |

After being placed in xylol the buds were allowed to remain several days.

Infiltration with paraffin was begun by pouring a small amount of melted paraffin (53 degrees - 55 degrees melting point) in each glass vial containing the buds immersed in xylol. At the end of 24 hours

another small amount was added until the contents of the vial became solid, with the exception of a small amount of xylol which was poured off.

The vials were placed in a paraffin oven and allowed to remain until such time as they could be embedded; it was found that the buds could be left in the paraffin oven a week or more without any injury, in fact, with sections as large as those worked with, such a procedure is recommended.

The buds were then embedded in the usual manner and the paraffin blocks were stored at room temperature until needed for sectioning.

Sectioning was done on a rotary microtome, the sections being 20 microns. Several trials, making sections at 10, 12 and 15 microns, proved that the material being sectioned was too coarse for the finer sections.

Considerable difficulty was encountered in making the sections owing to silicated hairs or other abrasive material in the buds. Some sections were quite badly damaged from this cause. It was found that suitable sections could be secured by setting the microtome to cut at 20 microns and then operating the machine at a rapid rate.

Sections were fixed to the slides in the usual manner, using albumen solution, and the slides were then kept at room temperature for at least 24 hours before removing the paraffin and staining.

The paraffin was removed from the slide by using the following series and treating for the time indicated.

| | |
|---|---|
| Xylol | 5 min. |
| Xylol, 1 part - - absolute alcohol, 1 part | 5 min. |
| Absolute alcohol | 5 " |
| 95 per cent alcohol | 5 " |
| 85 " " " | 5 " |
| 70 " " " | 5 " |
| 50 " " " | 5 " |
| 35 " " " | 5 " |
| Water | 5 " |

The sections were stained with a 1 per cent aqueous solution of erythrosin. Preliminary trials indicated that 20 minutes in this stain was necessary to secure satisfactory results.

The most outstanding departure from Chamberlain's recommendations was in dehydrating after staining. If an aqueous stain is used he recommends the use of the following series: water, 5, 10, 20, 35, 50, 70, 85, 95, and 100 per cent alcohol - - about 2 minutes each. This method was tried and it was found that the stain was completely removed.

Then the following procedure was adopted: after staining, the slides were taken directly from the staining solution and immersed in 95 and 100 per cent

alcohol - about 10 seconds each, then placed in Xylol until they were mounted.

The sections were mounted as soon as possible in the usual way using Canada balsam. Some difficulty was experienced with air bubbles on account of the thickness of the sections.

Each slide was labeled and later examined under the microscope to determine the stage of fruit bud differentiation.

Photomicrographs were made of such slides as showed outstanding development.

## RESULTS

At the beginning of this investigation an attempt was made to root the plants in sand and to supply the nutrient material in liquid form. This attempt resulted in failure because the runner plants did not have sufficient root system to absorb the moisture necessary for their maintenance.

Even the relatively small amount of fertilizer used was sufficient to cause nearly 100 per cent mortality of two sets of plants. The same soil was used each time but was thoroughly mixed and no additional fertilizer was added. It was assumed that the remaining amounts of fertilizer would be maintained in their original ratios. The plants in the check plots produced a perfect stand in each instance. Three lots of the last planting made satisfactory growth but one lot, that receiving the 1.5-2-1 application, had an exceedingly high mortality of plants the reason for which could not be ascertained or explained.

The work of those investigators, cited in Review of Literature, page 4, who found that nitrogen induced vegetative growth was verified by this experiment. The lot which was supplied with the basic fertilizer (1-2-1) formed runners first, followed by Lot IV (2-2-1), Lot I (check) and Lot III. As previously

stated the behavior of Lot III could not be explained. Measurements were taken of the length of the runner between each runner plant, after the plant was rooted, and the results are shown in Table I.

From this table it can be seen that the length of the runners was greater in the lots receiving nitrogen, Lot III excepted, than in the check plot, although the differences are not sufficient to justify any definite conclusion.

The behavior of Lot I (check) was especially interesting. The plants bloomed several times, the blossoms being removed each time, but runner formation was greatly delayed. When runners were produced they were extremely stocky and grew with great rapidity so that the rooting date of the first runner plants was not much later than that in the fertilized lots. This further confirms the results reported by other workers to the effect the nitrogen does encourage early production of runner plants.

The results obtained relative to the effect of fertilizer on the time of fruit bud differentiation coincide with the findings of Hill and Davis (15) concerning which they state that there is apparently a critical seasonal period before which the stimulus

for flower bud formation is lacking, independent of the age of the runner. Examination of the photomocrographs on pages 42 to 51 will clearly show that although rooting took place from June 5 through August 9 few of the runner plants showed signs of differentiation prior to August 22.

As stated by Hill and Davis (15), et. al. (28) it is very difficult to determine the exact date of fruit bud differentiation since it occurs as a gradual transition rather than a sharp and sudden change. Following the practise of these workers, in this investigation it has been considered that slight irregularities in the growing point or crown constitute evidence of the first differentiation of the flower stalk. Since a period of two weeks elapsed between the times that the runner plants were pegged and the same length of time intervened between samplings it is conceivable that there is some difference in the actual time that fruit bud differentiation took place which is not evident in the results obtained.

The results obtained in this investigation agree with the conclusion of other workers that the accumulation of carbohydrates is necessary for fruit bud formation. The following statement of Loomis (18) is particularly applicable to the conditions of this investigation:

"If the growth of a rapidly growing and apparently undifferentiated plant is checked in a manner which does not appreciably reduce the photosynthetic activity of the plant, for example by gradually reducing the moisture or nutrient supply available to the top, the carbohydrates formerly used in growth now accumulate and serve at once as the stimulus and as raw materials for differentiation."

The plants in this experiment were kept well watered throughout the time of the investigation and therefor lack of moisture was not a factor. But each plant was confined in a small area and the supply of nutrient material was limited. Observations showed that the plants receiving more nitrogen developed more runners and that these runners were somewhat longer and it is therefor logical to assume that the nitrogen supply in all lots was exhausted at approximately the same time. This assumption is further borne out by observations recorded in Table I. It will be noted that there was a decrease in vegetative extension during the last two weeks' recorded growth and this coincided very closely with the time of fruit bud differentiation as observed from a study of the microscopic sections. A particularly marked reduction in length of runners is noted in Lot IV

for the last period of measurement and it is of interest to note that ripe berries were picked from the mother plants on August 8, 1938.

The results obtained in this investigation do not coincide with the findings of Schilletter (29) and are at distinct variance with the results reported by Ruef and Richey (28). Schilletter states that carbohydrate accumulation is accompanied by a lessening of vegetative growth and this retardation is caused by lack of sufficient moisture at certain times and low temperatures. Since the plants were kept well-watered at all times and were kept in a warm greenhouse neither of these factors can be considered as being instrumental in retarding vegetative growth.

Ruef and Richey, (28) and Hill and Davis (15) are the only investigators, whose reports were examined, who noted the effect of fertilizer on the time of fruit bud differentiation. The latter simply states that there is a marked correlation between the time of fertilizer application in the field and the initial date of fruit bud differentiation. The former makes the following statements relative to the effect of fertilizer on the time of fruit bud differentiation:

"Acid phosphate, either singly or in combination, hastened fruit bud differentiation and development."

"Nitrogenous fertilizers in general retarded development although at first heavy applications of nitrate seemed to stimulate differentiation."

"Muriate of potash retarded differentiation."

It appears to the author that the above conclusions are contradictory. If their observations are true then the hastening effect of acid phosphate is sufficiently great to overbalance the inhibiting effects of either or both nitrate and potash, and would lead to the logical conclusion that acid phosphate and not nitrate, as reported by many investigators, is the most important nutrient element as affects flower bud formation.

The results secured in this investigation do not agree with those reported in the two experiments last mentioned. The author found that fertilizer did not affect the time of fruit bud formation in any way.

Following the high mortality of plants which resulted from the first application of fertilizer to potted plants in the greenhouse, the series was repli-

cated in the author's garden. Under outdoor growing conditions a 100 per cent stand of plants was secured. This experiment was conducted solely to determine the effects of the varying formulas of fertilizer under different conditions of soil, moisture and temperature. No attempt was made to record the effects of the fertilizers on growth or time of fruit bud differentiation.

Suggestions. As a result of difficulties encountered during the course of investigation, and the data secured, the author considers that suggestions for future procedure, should future work be done on this problem, are appropriate at this time.

1. If sand cultures are to be used the plants should be permitted to develop large root systems before transferring to the sand. Experience in this investigation showed that plants with root systems that were not fully developed were unable to continue root growth.

2. For data that may be of value to the commercial strawberry grower the experiments should be conducted under field conditions as this experiment proved beyond doubt that field conditions cannot be simulated in the greenhouse.

3. Soil tests should be made prior to planting to determine the nutrient content of the soil in order that any effects of the fertilizer may be more clearly defined.

4. The soil reaction should be determined so that its effect upon the action of the fertilizer may be determined.

5. Sufficient space should be allowed to permit spacing the runner plants. Crowded growing conditions during the latter part of this experiment seriously interfered with making growth measurements and securing samples for sectioning.

6. Plants should be pegged at shorter intervals and samples taken at periods closer together so that time of fruit bud differentiation may be more accurately determined.

Table I - Average length of runners (in inches).

| I | | II | III | IV |
|---|---|---|---|---|
| May 22 | 00.0 | 15.0 | 00.0 | 9.87 |
| May 22 to June 5 | 9.5 | 12.33 | 00.0 | 7.5 |
| June 5 to June 19 | 11.69 | 12.47 | 00.0 | 11.46 |
| June 19 to July 4 | 14.03 | 14.23 | 10.25 | 13.06 |
| July 4 to July 23 | 14.33 | 14.72 | 12.5 | 13.75 |
| July 23 to Aug. 9 | 12.43 | 12.82 | 12.62 | 12.55 |
| Aug. 9 to Aug. 22 | 11.04 | 8.20 | 6.0 | 8.41 |
| | | | | Ripe fruit on M.P.* 8/22/38 |

*M. P. - - Mother plant.

## SUMMARY AND CONCLUSIONS

As a result of this investigation the following conclusions were reached:

1. The application of nitrogen, in any amounts, made immediately following planting does not produce any noticeable effect on the time of fruit bud differentiation in the strawberry.

2. Nitrogen fertilizers applied to strawberry plants shortly after planting hasten the formation of runners and increase the number of runners produced.

3. The length of the runners between rooted runner plants is not materially increased by nitrogen fertilizers.

4. Although runner production is hastened by the use of nitrogen, the actual rooting of the runner plants takes place at approximately the same time in fertilized and unfertilized plants.

5. Fruit bud differentiation is associated with a decrease in the length of runners produced which probably results in an accumulation of carbohydrates.

6. Field conditions cannot be satisfactorily simulated under average greenhouse conditions and therefor results that are secured in greenhouse experiments cannot be deemed applicable to plants growing under field conditions.

## EXPLANATION OF ILLUSTRATIONS

Plate I.
Fig. 1. Lot I. No fertilizer
Fig. 2. Lot II. 1-2-1- fertilizer

Plate II.
Fig. 1 Lot III 1.5-2-1 fertilizer
Fig. 2 Lot IV 2-2-1 fertilizer

Plate III
Fig. 1 A. 1-2-1 B. Check

Plate IV
Fig. 1 Lot I. Rooted June 5, collected August 9. Note slight corrugation of crown indicating fruit bud differentiation.

Fig. 2 Lot I. Rooted June 5, collected August 22. Complete flower development with secondary bud showing.

Plate V.
Fig. 1. Lot I. Rooted June 26, collected July 23. Definite development of floral parts.

Fig. 2. Lot I. Rooted June 26, collected August 9. Shows about same stage of differentiation as preceding figure.

Plate VI.
Fig. 1. Lot I. Rooted July 4, collected August 22. Very definite differentiation noted.

Fig. 2. Lot I. Rooted July 4, collected August 22. Similar development to that in preceding figure.

Plate VII.
Fig. 1. Lot I. Rooted July 23, collected August 22. Complete differentiation is evident even though rooted later than in preceding figure.

Fig. 2. Lot II. Rooted June 5, collected August 9. Smooth, undifferentiated crown.

Plate VIII.

Fig. 1. Lot II. Rooted July 4, collected August 22. Although rooted later than figure 1, Plate VI, very definite differentiation is in evidence.

Fig. 2. Lot II. Rooted July 23, collected August 9. Development of fruit bud quite marked.

Plate IX.

Fig. 1. Lot II. Rooted July 23, collected August 22. Shows marked development of flower bud with secondary bud in evidence.

Fig. 2. Lot III. Rooted June 5, collected August 22. Differentiation of fruit bud is quite marked.

Plate X.

Fig. 1. Lot III. Rooted June 19, collected August 22. Note marked development of fruit bud.

Fig. 2. Lot III. Rooted July 4, collected August 22. Differentiation nearly as far advanced as in preceding figure.

Plate XI.

Fig. 1. Lot III. Rooted July 13, collected August 22- Indicates advanced development of floral parts. Runner primordium noticeable, left of flower bud.

Fig. 2. Lot IV. Rooted June 5, collected July 10. Note smooth crown, indicated that no differentiation has occurred.

Plate XII.

Fig. 1. Lot IV. Rooted June 5, collected August 22. Well developed primary fruit bud; secondary bud showing.

Fig. 2. Lot IV. Rooted July 4, collected August 9. Differentiation has progressed considerably.

Plate XIII.

Fig. 1. Lot IV. Rooted July 4, collected August 22. Fruit bud has developed further than in preceding figure.

Plate I

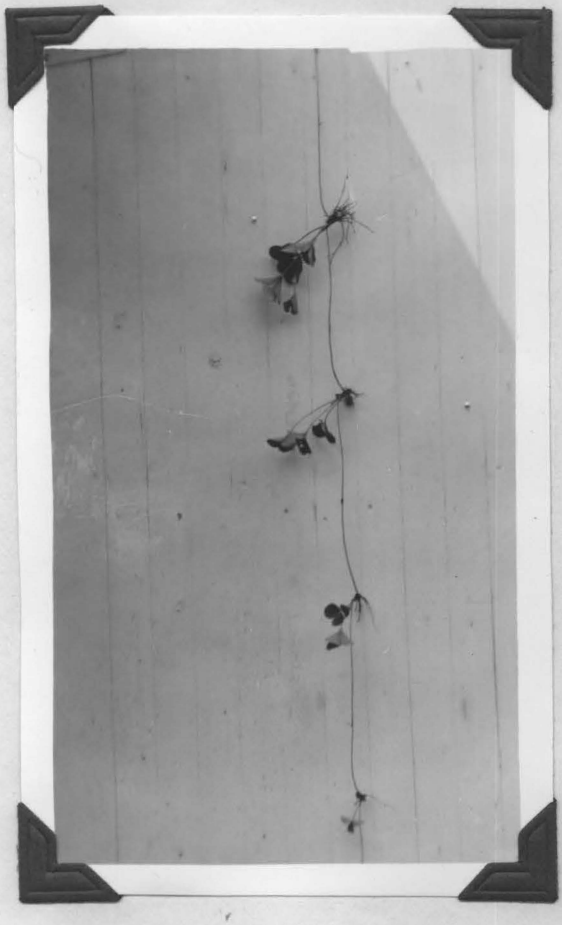


Fig. 1

Fig. 2

Plate II

Fig. 1

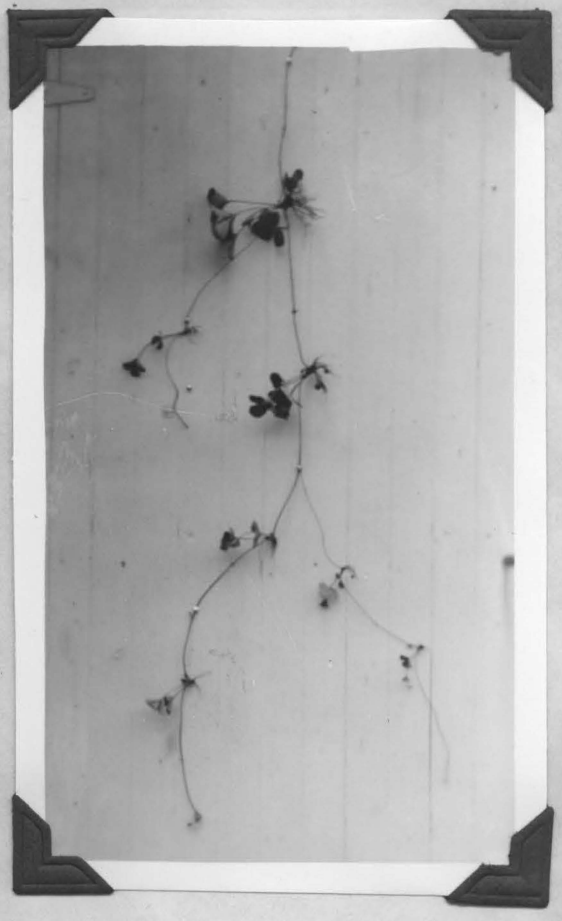


Fig. 2

Plate III

Fig. 1

A B

Plate IV

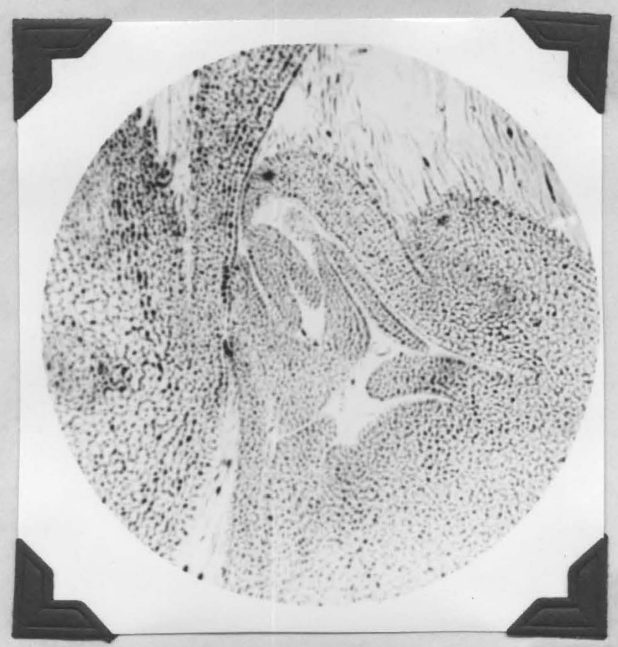


Fig. 1

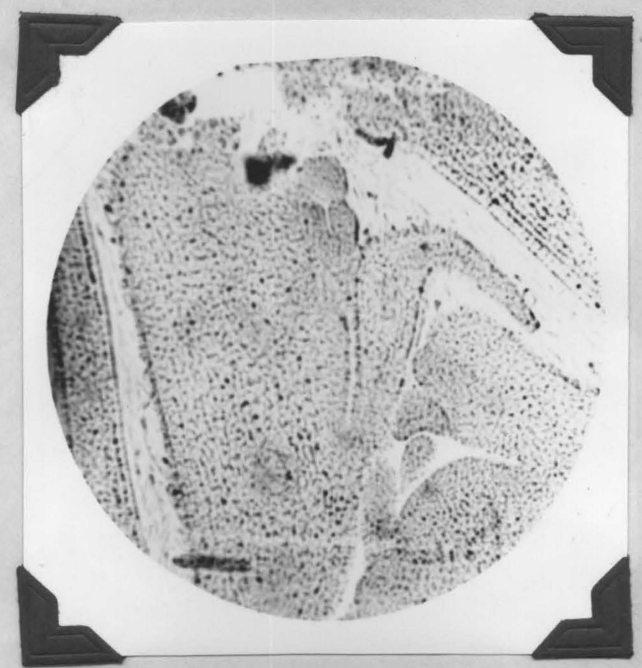
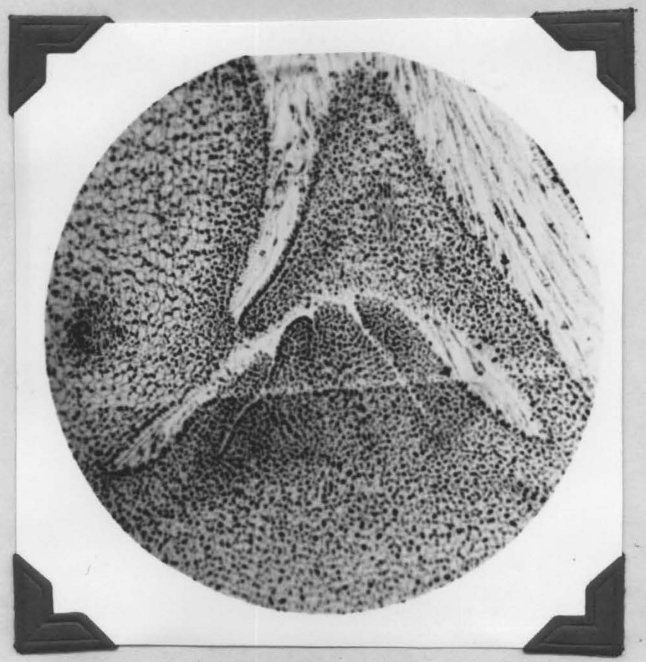


Fig. 2

Plate V



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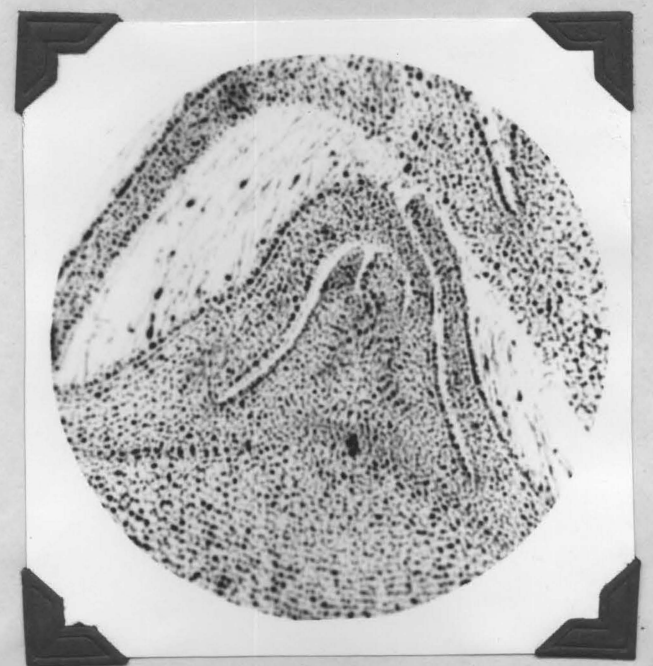

Fig. 2

Plate VI

Fig. 1

Fig. 2

Plate VII

Fig. 1

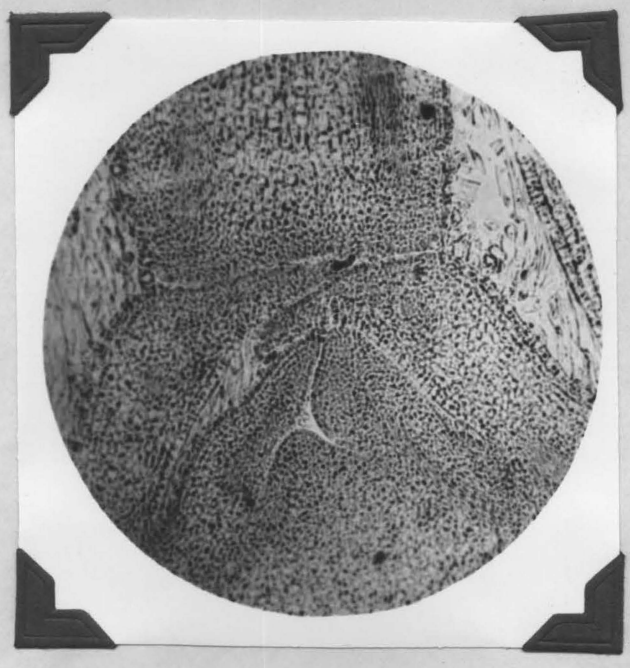

Fig. 2

Plate VIII

Fig. 1

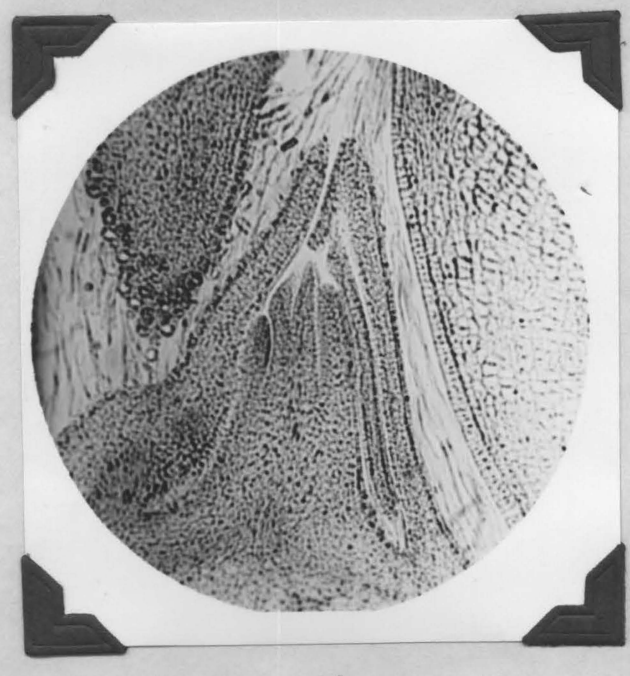

Fig. 2

Plate IX

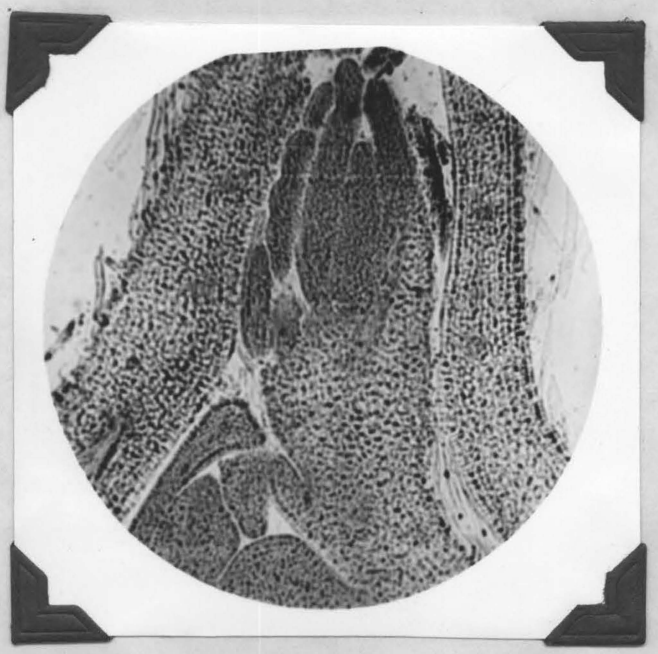

Fig. 1

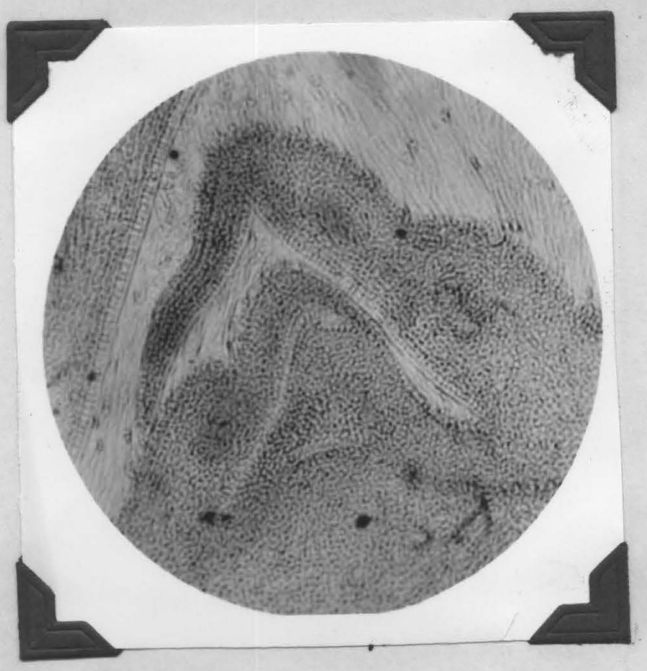

Fig. 2

Plate X

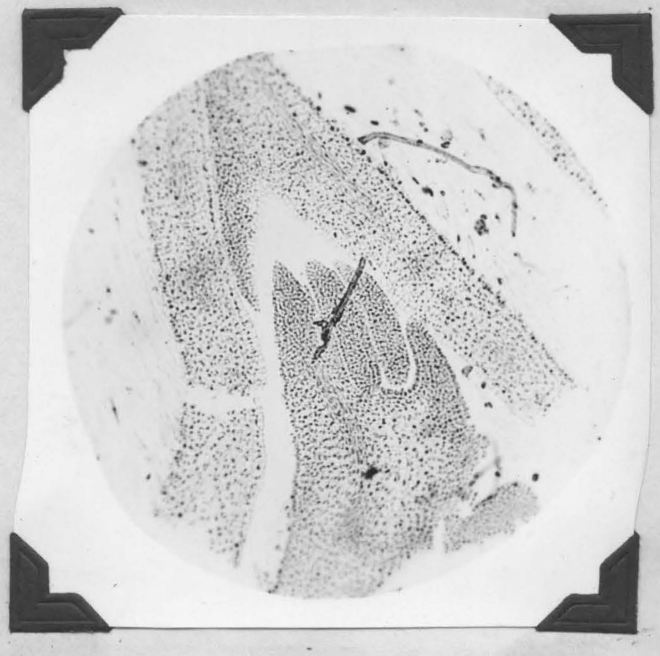

Fig. 1

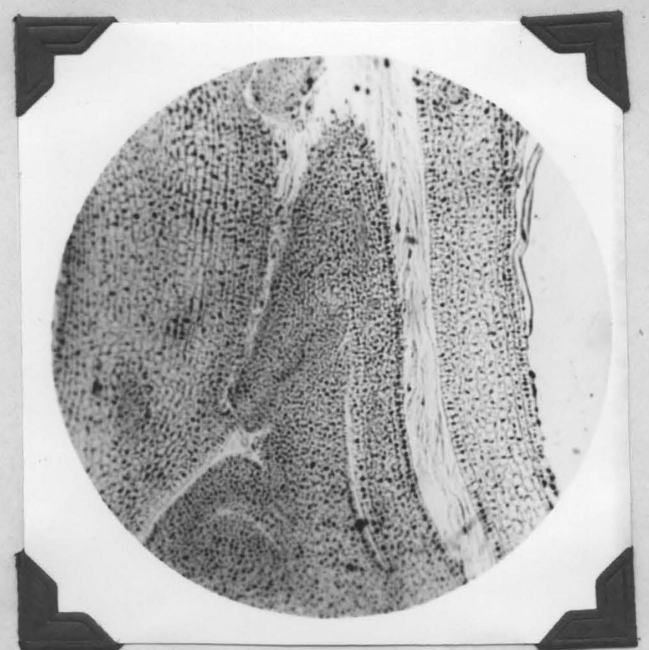

Fig. 2

Plate XI

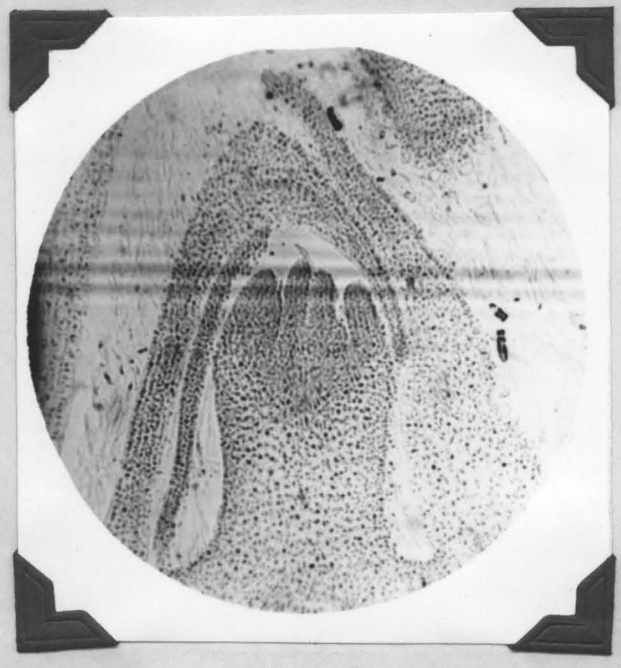

Fig. 1

Fig. 2

Plate XII

Fig. 1

Fig. 2

Plate XIII

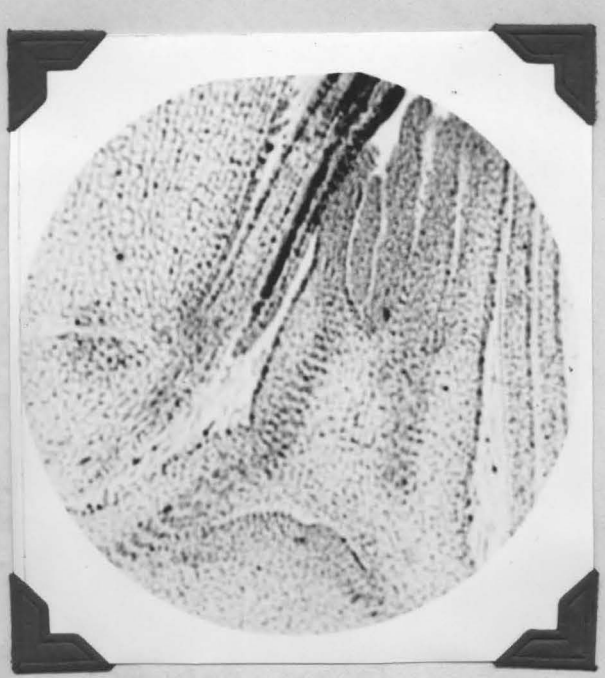

Fig. 1

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