FLOWER BUD DEVELOPMENT IN THE TUNG OIL TREE

Thesis for the Degree of M. S.

Charles E. Abbott

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THESIS

Submitted to the Faculty of the Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

by

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Introduction and Statement of Problem

The Chinese wood oil or tung oil tree, Aleurites fordi, Hemsl., was introduced into this country from China in 1905 by the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. Of the genus Aleurites five species have been described, namely: A. fordi, A. montana, A. cordata, A. moluccana and A. trispermia.

The investigations reported herein deal only with the species A. fordi, which is known in its native country as "tung-shu" or "tung-yu-shu", literally, tung oil tree. Commercially this is by far the most important species of the group since it furnishes approximately ninety per cent of the tung oil of commerce.

The tung oil industry of this country which is limited to the southern states, particularly to Florida, is of recent origin. The tree has not been long enough in cultivation in America for experience to demonstrate what cultural practices are best suited to insure high productivity. The various practices may be considered to affect the crop in three rather distinct ways; the growth of a large and healthy tree, the differentiation of blossom buds and the development of nuts from the blossoms. Consequently the outlining of a rational cultural program should be based on knowledge of the time and conditions of differentiation of blossom buds.

Work of this type on other orchard trees, such as the apple, the plum, and the peach has yielded valuable results in that it has shown the possibility of adjusting methods of culture in such ways as to modify materially both the quantity and possibly the quality of the crop of fruit. It is believed that the data presented in this report will afford the basis for similar adjustments in cultural practices with the tung oil tree.

Review of Literature

Goff (5) working with apples, cherries, cranberries, currants, gooseberries, peaches, plums and strawberries, determined the time when differentiation of fruit buds occurs and traced the successive stages of development until the unfolding of the blossoms in the spring. He found that the time of differentiation, in the several fruits mentioned as grown in Wisconsin, ranged from June 30 to September 20. In a comparison of apple varieties there was a variation of as much as five weeks in the initial time of fruit-bud differentiation.

The time of fruit bud formation in the cherry and plum was also found to vary several days in different years.

Drinkard (2) studied the fruit-bud formation of the apple, peach, pear and plum in Virginia and found results similar to those reported by Goff (5).

Bradford (1) found that the blossom buds of some varieties of apples differed not only in the date of differentiation but also in the rapidity of subsequent stages of summer and fall development. Comparatively wide differences were also found in the time of differentiation, depending upon the position of the buds on the trees.

Waldo (10) made a study of fruit-bud development in the Dunlap strawberry and found that differentiation of floral parts was clearly evident by September 22.

Shuhart (9) says "Observable differentiation in the pistillate flowers of the pecan does not take place until after growth has started in the spring---Some differences have been noted between varieties, but this difference is not as great as that which results from different latitudinal locations of the same variety." Isbell (6) also working with the pecan says, "Just about the time buds begin to swell in the spring following their formation, the hitherto vegetative bud that is to produce pistillate flowers begins to differentiate inflorescence primordia and continues their development as the internodes elongate and as the leaves unfold and develop."

The above citations are by no means a complete resumé of the literature on the problem of fruit-bud differentiation and development in horticultural plants. Furthermore, they do not bear directly on the question as related to the

tung oil tree and are given merely to afford a general perspective of the field. Apparently no data are available on flower bud differentiation in the tung oil tree nor its related species.

Source of Materials

The materials used in this study were collected from two groups of trees at Gainesville, Florida, one on the grounds of the Experiment Station, the other belonging to a private grower, Mr.B.F.Williamson.

The trees at the Experiment Station were grown from seed in 1914 and transplanted to the present location in 1917. The site has a very sandy soil and slopes gently to the south. Cultivation has consisted of one plowing during the late fall, followed in the spring by discing. During the remainder of the year the land is hoed frequently to keep down weeds. The trees have received annually an application of five pounds of fertilizer (6-8-4 mixture) per tree, applied about the middle of March. The terminal growth made during 1926 was comparatively short, ranging from two to twenty inches with an average of possibly eight or nine inches.

The soil in the Williamson orchard is a light sandy loam. The trees are four years old and in 1926 each received two applications of Peruvian guano, one

in February and the second in July. A cover-crop of Crotalaria was grown during the summer. This crop was cut and disced in in early December. A second discing was given in March of the following year, and at this time the trees were mulched with mattress factory refuse. These trees were very vigorous, making terminal growths ranging from fifteen inches to seven feet.

Each sampling consisted of sixty terminal buds taken at random. The first samples were collected on April 19, 1926, from the Experiment Station grounds. Thereafter they were taken each week until September 3, and at two-week intervals from that date until December. During December, January and February only three collections were made; these came at intervals of four weeks. Beginning on May 3, 1927 and continuing through June, collections were again made one week apart.

The first collection from the Williamson orchard was made on July 31, 1926; thereafter and until March 1927 on the same dates as those taken from the Experiment Station trees.

Methods

Standard histological methods were used in the preparation of the buds for sectioning and photographing. Killing and fixing were accomplished with picric acid and alcohol solution (1 gram of picric acid per 100 cc.

of 50 per cent alcohol). Alcohol was employed in the dehydration, xylol in clearing, paraffin for embedding, and Delafield's haematoxylin in staining. A rotary microtome was used in sectioning and sections were cut at 12 microns. The magnifications used for the photomicrographs are indicated in the legends for the figures presented later.

Presentation of Data

In this investigation fruit bud differentiation was considered to have begun when longitutinal sections of the terminal bud showed an elongating growing point with concurrently developing lobes, (see Figure 5-B). The first evidence of inflorescence differentiation in 1926 appeared in material collected from the trees on the Experiment Station grounds, June 14. Figures 5-A and B represent two stages of buds collected on that date. The broadening or flattening of the growing point is shown in A, a stage that might be termed the pre-differentiation stage. This stage is very similar to that observed by Waldo (10) in his study of the strawberry. Figure 5-B shows the first inflorescence differentiation with potential branches of the flower cluster on either side of the central axis. Figures 9-A, and B, of materials collected July 10, show an early stage in the development of individual female and male flowers. Figure 9-A shows an early stage of the pistillate flower with sepals, petals, staminodia and pistil primordia in the center, while B shows early

stage in the development of the male flower with sepals, petals, two sets of stamens and a flattened central portion indicating that the stamens are not all differentiated. The difference in the length of the central axis of the male and female flower cluster, which continues throughout the development of the bud, is clearly evident at this stage.

By July 17, considerable development had taken place as is shown by Figures 10-A and B. The crown or central growing axis had divided showing advancement in the growth of male and female flower parts. In the male flower, 10-B, the sepals are well advanced, the stamens are individually distinct, while the petals, yet in a very embryonic state, appear as pointed projections. In the female flower, Figure 10-A, the pistil primordia, with a small cavity representing early locule development is clearly evident. Between the base of the pistil primordia and the rudimentary petals can be seen staminodia, which rarely develop beyond this stage, as is evident upon comparison with Figure 17-A.

Collections made between July 17 and October 2, show in general a progressive increase in size of bud and a general filling out of flower parts already formed. However, little change took place in the individual pistillate flower, other than a slight increase in size of parts already laid down, the pistil remaining in an

undeveloped condition and the petals only slightly larger than they were on July 16. The pistillate flower is in this condition when development practically ceases and the flower parts pass through the winter inclosed by bud scales the outer of which are cemented by an exudation of yellowish brown, resinous material that fills the spaces between the individual flower-buds of the cluster.

No great amount of development took place between October and February 5. Shortly before the flower buds begin to unfold, growth is resumed and changes take place very rapidly in all parts of the individual flower. This is shown by comparison of Figure 16 with Figure 17-A and B which illustrate the state of development reached by individual male and female flowers on March 2.

The first material from the Williamson orchard to show fruit bud differentiation was collected October 2. At this time, (as is evident in Figure 20) the central axis is well extended and distinct branching of the flower cluster is evident. The calyx of the central or terminal flower is very conspicuous. On the inner side near the base of the calyx are small rounded protuberances, indicating the initial petals and stamens or staminodia in case of pistillate flowers. The stage of development at this time (Oct. 2) indicates that differentiation started late in September. The development of the buds, for the first eight weeks after differentiation, was far more rapid

than the development of those from the Experiment Station grounds that were differentiated in mid-June. Although, as shown by Figure 22, the buds continued to grow and develop until late in December, the rate of growth after November 13 was very much slower than during the earlier stages of development. The changes in development can be seen by comparison of Figure 21 with Figure 22. Figure 23 shows no evidence of growth during the month of January.

Some signs of immaturity were noticed in the Williamson orchard, when material was collected on December 10 and January 8. On December 10, 1926, the orchard retained almost full foliage. But, approximately 60 per cent of the leaves, (those toward the base of the current wood) showed yellowing preparatory to falling. On January 10, 1927, many leaves which had been killed by frost in late December were still clinging to the terminal portion of the branches and wherever this condition existed the buds as well as the terminal portion of the wood were in a slightly soft or wilted condition, indicative of immaturity, though no particular injury from cold could be noted when growth was resumed in the spring.

In sectioning it was found that a much higher percentage of pistillate flowers had been produced in the Williamson orchard than was found in the material from the Experiment Station. This observation is in line with results reported by Gardner (3) concerning sex development in strawberries.

The first indication of fruit-bud differentiation in 1927 was found in material collected at the Experiment Station, May 10. Figure 25 shows differentiation well under way on May 17, and Figure 26 shows that the stage of development on May 30, was as far advanced as that of material collected July 17 (see Figure 10,) of the previous year. Furthermore, the rate of development was much more rapid than it was in the first buds to differentiate during 1926.

The date of differentiation seems to differ considerably from year to year, probably as a result of variations in the time of slowing down of shoot growth. A checking of vegetative growth may be brought about by a number of factors such as a shortage in the amount of available soil moisture, the lack of a continuous nutrient supply, method of cultivation whether sod or clean, the tax of a developing crop of nuts, etc.

Table 1 shows conditions strikingly similar immediately preceding the period of fruit bud formation in each case and indicates that the difference in time of differentiation in the two seasons is due primarily to the early drought in the spring of 1927.

Table 1.-Rainfall in inches in the Gainesville area for the first six months of 1926 and for corresponding months in 1927

	1926	1927
January	5.59 inches	0.19 inches
February	1.42 "	5.78 "
March	4.93 "	2.33 "
April	4.51 "	0.46 "
May	1.60 "	0.46 "
June	8.84 "	10.53 "

DISCUSSION

Although a large part of the fruit buds differentiate in late June and in July, the data herein presented show that differentiation may occur at any time between May 10 and October 1, depending upon weather, cultivation and varying nutritive conditions. The variation in time of floral differentiation in the two lots of trees, was clearly due to differences in vegetative vigor and prolongation of vegetative growth. As previously stated the Williamson trees were decidedly vegetative, delaying differentiation until late in the summer.

The relation between soil moisture supply and time of fruit-bud differentiation observed here in the tung oil is in line with the findings of other investigators with various fruit crops. Thus Kirby (7) in his work with apples grown under varying conditions, says, "The amount of soil moisture is a very important, if not the chief external factor in determining the time at which flower buds form." Wiggans (11) working with pear and apricot found that irrigation had a retarding influence on fruit-bud differentiation and development, while Kraus and Kraybill (8) in their work on tomatoes say, "Withholding moisture from plants grown under conditions of relative abundance of available nitrogen results in much the same condition of fruitfulness and carbohydrate storage as the limiting of the supply of available

nitrogen itself."

Perhaps the most serious objection to prolonged summer growth and late differentiation is the lack of time the tree has properly to develop fruit-buds and to mature the terminal portions of the wood sufficiently to pass the winter without frost injury.

The large percentage of female flowers found in the Williamson orchard as compared with the number produced on trees at the Experiment Station is probably due largely to nutritive conditions. Gardner (3) in his work with strawberries found "-----in most cases femaleness was associated with vigorous growth and good growing conditions generally while maleness or hemaphroditism was associated with less rapid growth and more unfavorable growing conditions." The data that were obtained incident to this study are not conclusive in this respect but they at least suggest the desirability of keeping the trees in a relatively vigorous condition and this delaying the period of inflorescence differentiation with the object of promoting the formation of pistillate flowers and preventing irregular bearing due to an alternation of unisexual and bisexual flowering years.

SUMMARY

1. Fruit-bud differentiation in the tung oil may occur at any time between May 10 and October 1.
2. Inflorescence differentiation in 1926 was clearly evident June 14, and as early as May 10 in 1927.
3. The time of differentiation is hastened materially by a shortage in the amount of available soil moisture.
4. The time of differentiation varies with the vigor of the trees; those that are growing vigorously differentiate floral parts later in the season than trees of less vigor.
5. The percentage of pistillate flowers formed depends upon the vigor of the tree, more female flowers being produced on trees making vigorous growth than are formed on trees showing signs of less vigor.

Acknowledgements

The writer wishes to express his appreciation to Mr.L.P.Moore, President of the Alachua Tung Oil Corporation for financial aid which has made it possible to carry on this work; also to Professors V.R.Gardner, J.W.Crist and F.C.Bradford of the Michigan State College for suggestions in planning and conducting the investigations and for the helpful assistance in preparation of the manuscript, to Professor W.C.Dutton, of the same Institution, for assistance in making the photographs. To Dean Wilmon Newell, of the University of Florida, the writer is indebted for assistance in securing aid to carry on this work. The writer is also indebted to Messrs. Harold Mowry and B.F.Williamson for suggestions and the privilege of collecting materials from their orchards, and to Major W.L.Floyd, of the Univeristy of Florida, the writer is indebted for laboratory materials and equipment.

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Explanation of Figures

Figures 1 to 17 inclusive were collected from Experiment Station trees.

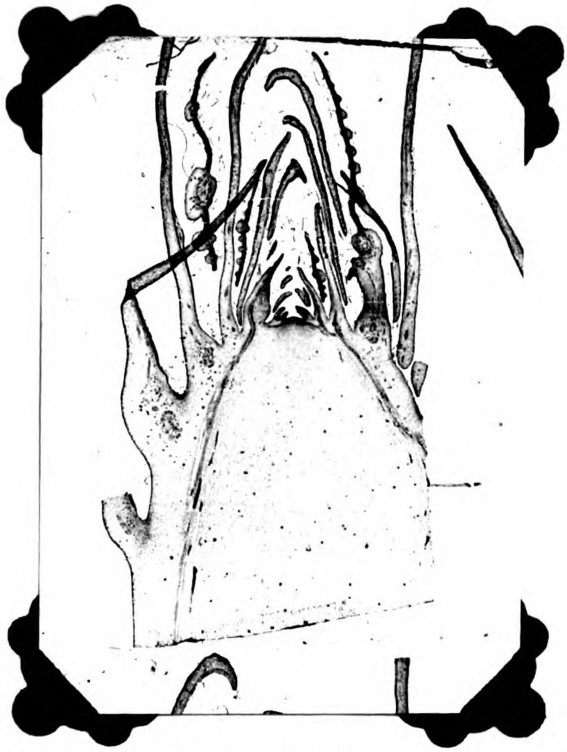

Fig.1.-Vegetative bud from on-bearing tree 18 months old, for comparison with Figures 2, 3, and 4, which are buds in vegetative stage but collected from trees of bearing age.

Fig.2.-April 17, very early vegetative stage of a bud which presumably would later have become a fruit bud.

Fig.3.-May 28, shows progressive development of bud still in vegetative stage.

Fig.4.-June 5, shows development of vegetative parts with a slight broadening of the growing point.

Fig.5-A.-June 14, broad flat growing point considered the pre-differentiation stage.

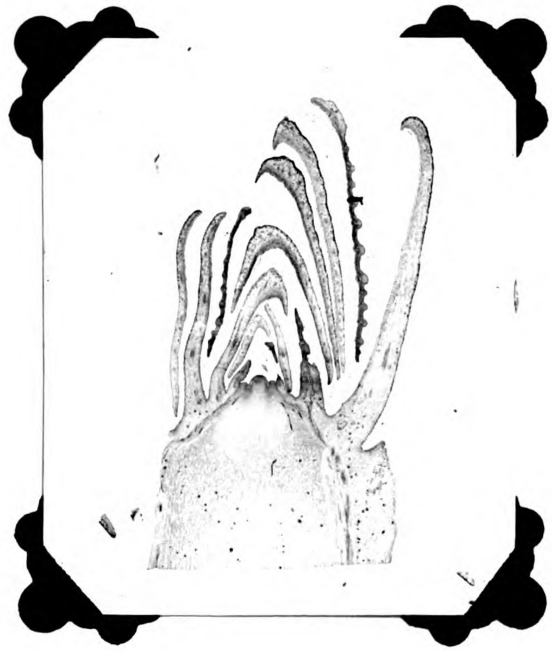

Fig.5-B.-June 14, very early stage of fruit-bud differentiation evidenced by the growing point becoming elongated and lobes developing on the crown.

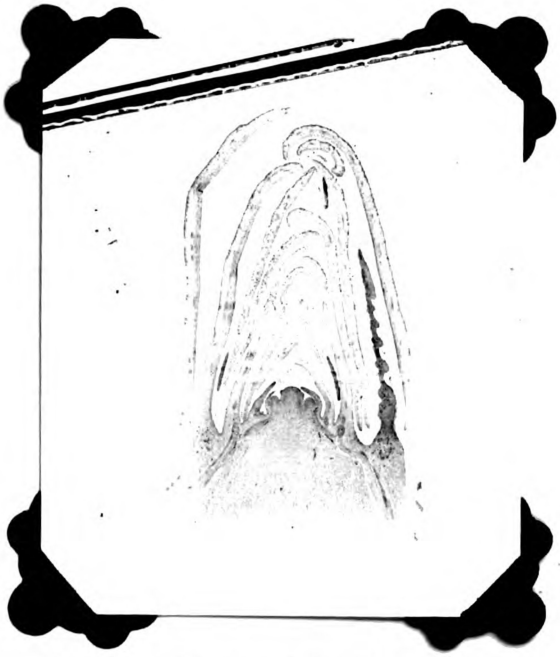

Fig.6.-Second week after differentiation.

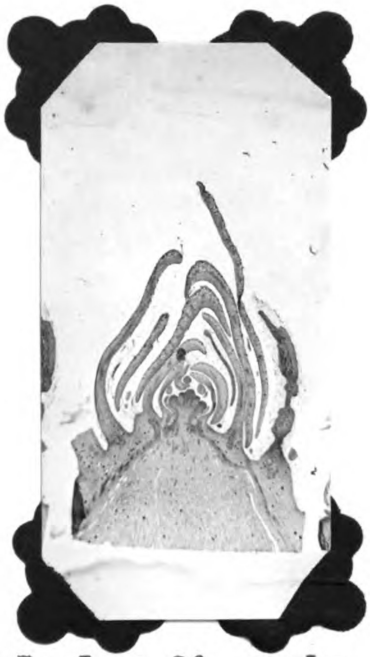

Fig.7.-June 26, early stage in branching of flower cluster.

Fig.8.-July 3, first differentiation of individual flower parts. Rudimentary sepals appear on either side of tip of central axis.

Fig.9-A.-July 10, early stage in the development of a pistillate flower. Sepals, petals, staminodia and pistil primordia are evident.

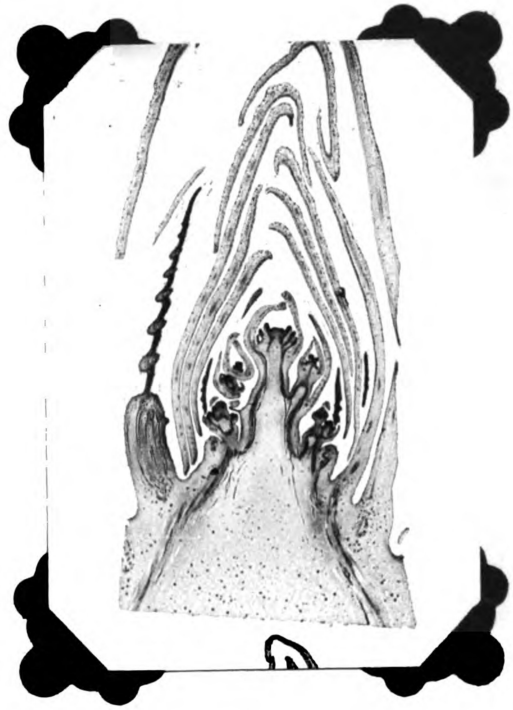

Fig.9-B.-July 10, early stage in the development of a staminate flower. Sepals, petals and two sets of stamens are evident. Not all stamens are differentiated as is evidenced by the blunt central portion of growing point.

The above figures show a difference in the elongation of the central axis of the male and female flower clusters.

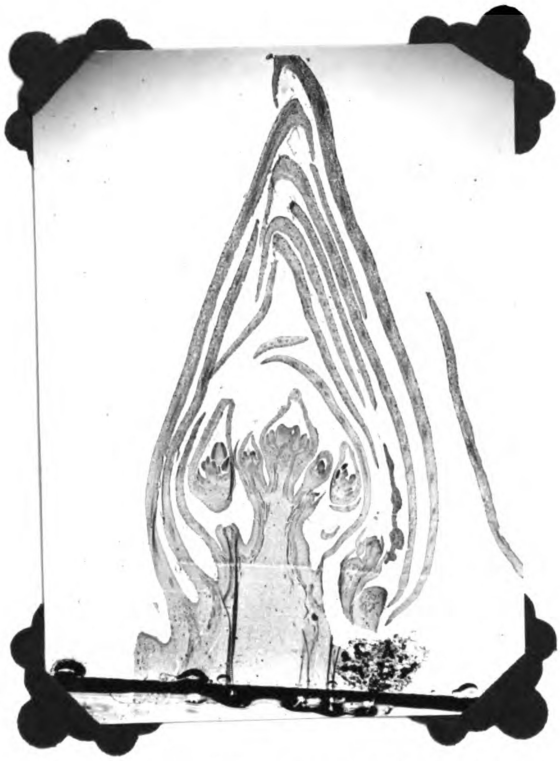

Fig.10-A.-July 17, pistillate flower showing early stage of locule development near upper portion of pistil primordia.

Fig.10-B.-July 17, staminate flower with stamens well advanced. Continued differance in elongation of central axis of the two flower clusters is evident.

Fig.11-A.-July 31, pistillate and staminate flowers developing in same bud.

Fig.11-B.-July 31, staminate flower showing a greater difference in elongation of the central axis of male and female flower clusters.

Fig.11-C.-July 31, cross section through ovary of pistillate flower.

Fig.12.-Aug.14, female flower with several branches in same plane showing male flower development.

Fig.13.-Aug.28, male flower showing advanced stage of development and extreme elongation of central axis.

Fig. 14.-Oct. 2, male flower showing little advancement in development after August 28.

Fig.15-A.-Nov.13, a female flower showing stage of development reached before winter.

Fig.15-B.-Nov.13, cross section of pistil near base of ovary.

Fig.15-C.-Nov.13, cross section of same pistil as (15-B) near upper portion of undeveloped ovary.

Fig.16-A.-Feb.5, pistillate flower indicates little change having taken place through the winter.

Fig.16-B.-Feb.5, staminate flower shows little change through the winter.

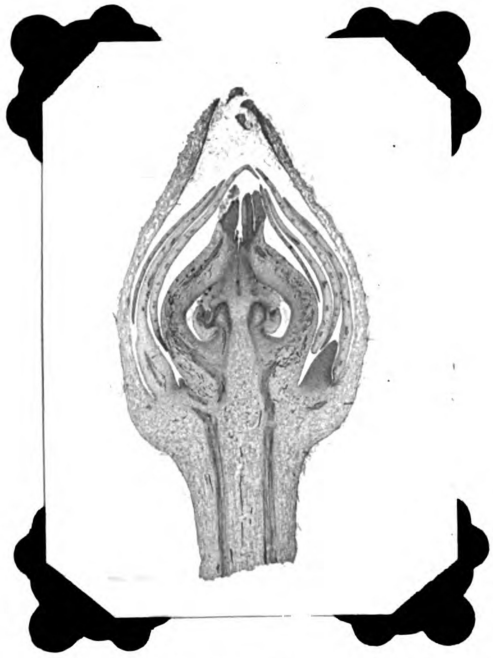

Fig.17-A.-March 2, pistillate flower shortly before unfolding, showing ovule development.

Fig.17-B.-March 2, staminate flower shortly before unfolding, showing anthers and pollen grains.

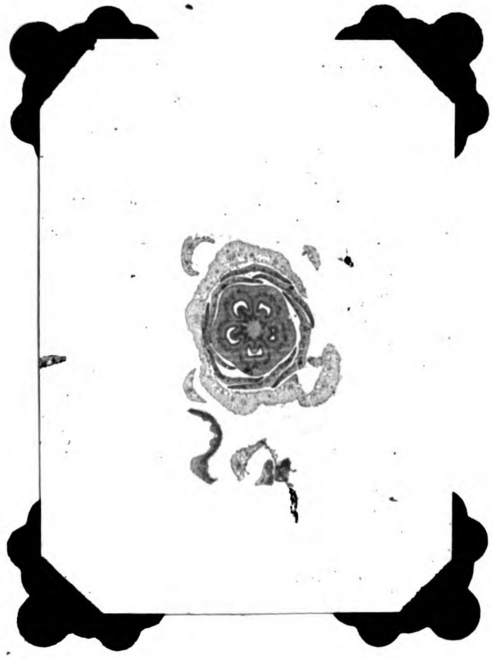

Fig.17-C.-March 2, cross section of ovary showing ovule development.

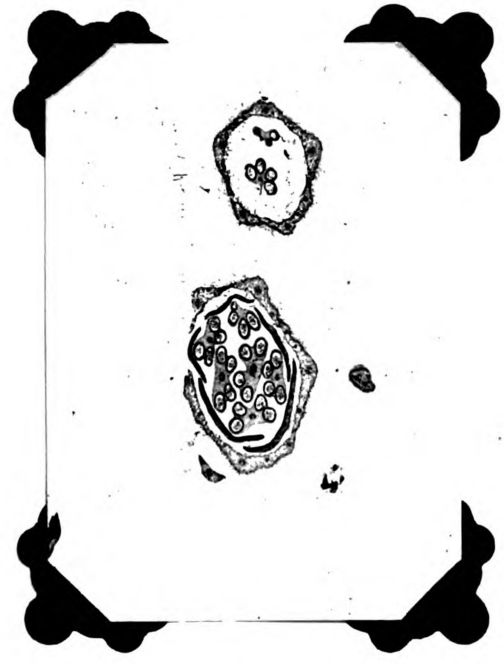

Fig.17-D.-March 2, cross section of staminate flower showing anthers with pollen grains.

Figures 18 to 23 inclusive were collected from the Williamson orchard.

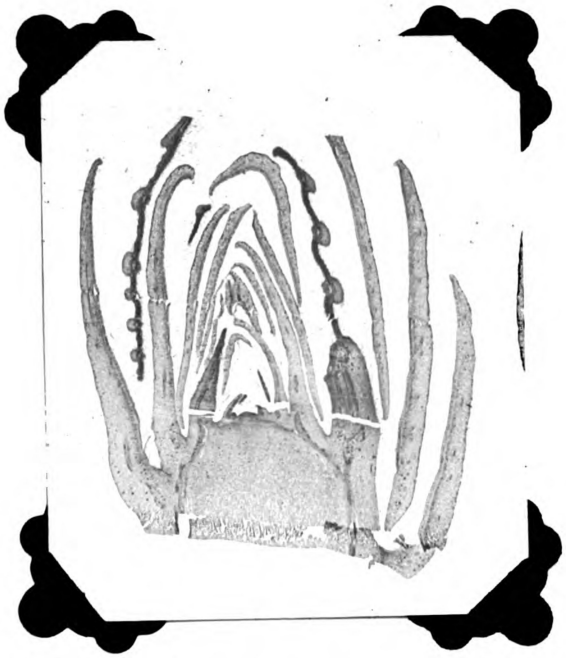

Fig.18.-Aug.14, shows no signs of fruit-bud differentiation.

Fig.19.-Aug.28, a slight flattening of the growing point, which occurs shortly before differentiation takes place, is evident.

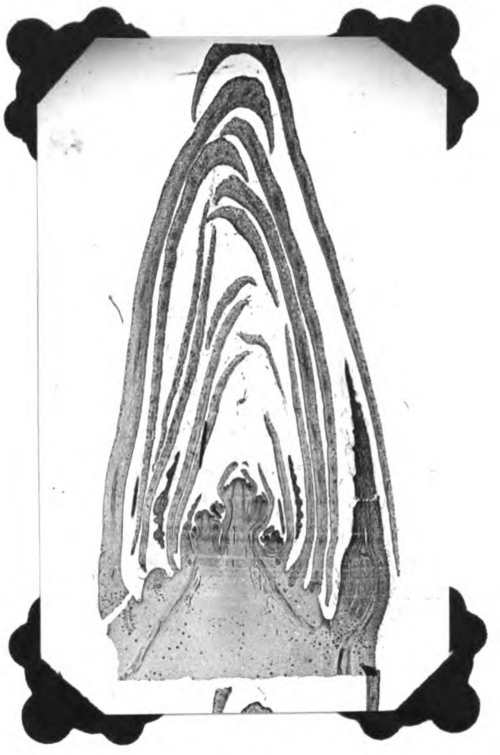

Fig.20.-Oct. 2, fruit-bud differentiation well advanced, showing early stages of individual flowersand flower parts.

Fig.21.-Nov. 13, pistillate flower showing rapid development after October 2.

Fig.22-A.-Dec. 10, pistillate flower showing a continuation of development until late in December.

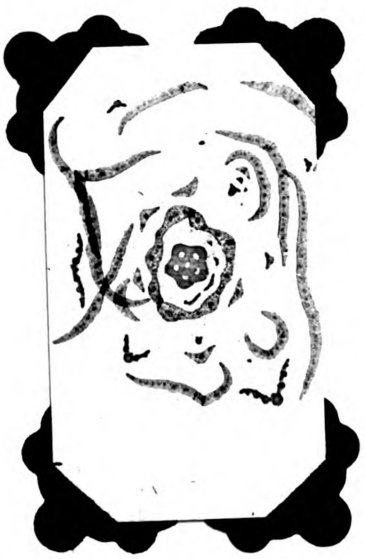

Fig.22-B.-Dec. 10, cross section of pistillate flower showing locules.

Fig.23.-Feb. 5, pistillate flower shows that little change in size of flower parts took place during December and January.

Figures 24 and 25 show buds that were collected during the 1927 period of flower bud differentiation.

Fig.24.-May 17, differentiation well under way, showing signs of flower cluster branches.

Fig. 25.-May 30, pistillate flowers as far advanced as those collected July 17, 1926.

The following photographs are placed here to give a more vivid idea as to the tree's growth and blossoming habits and an idea as to the appearance of the fruit, both green and mature, and to show the arrangement of the nuts within the individual fruit.

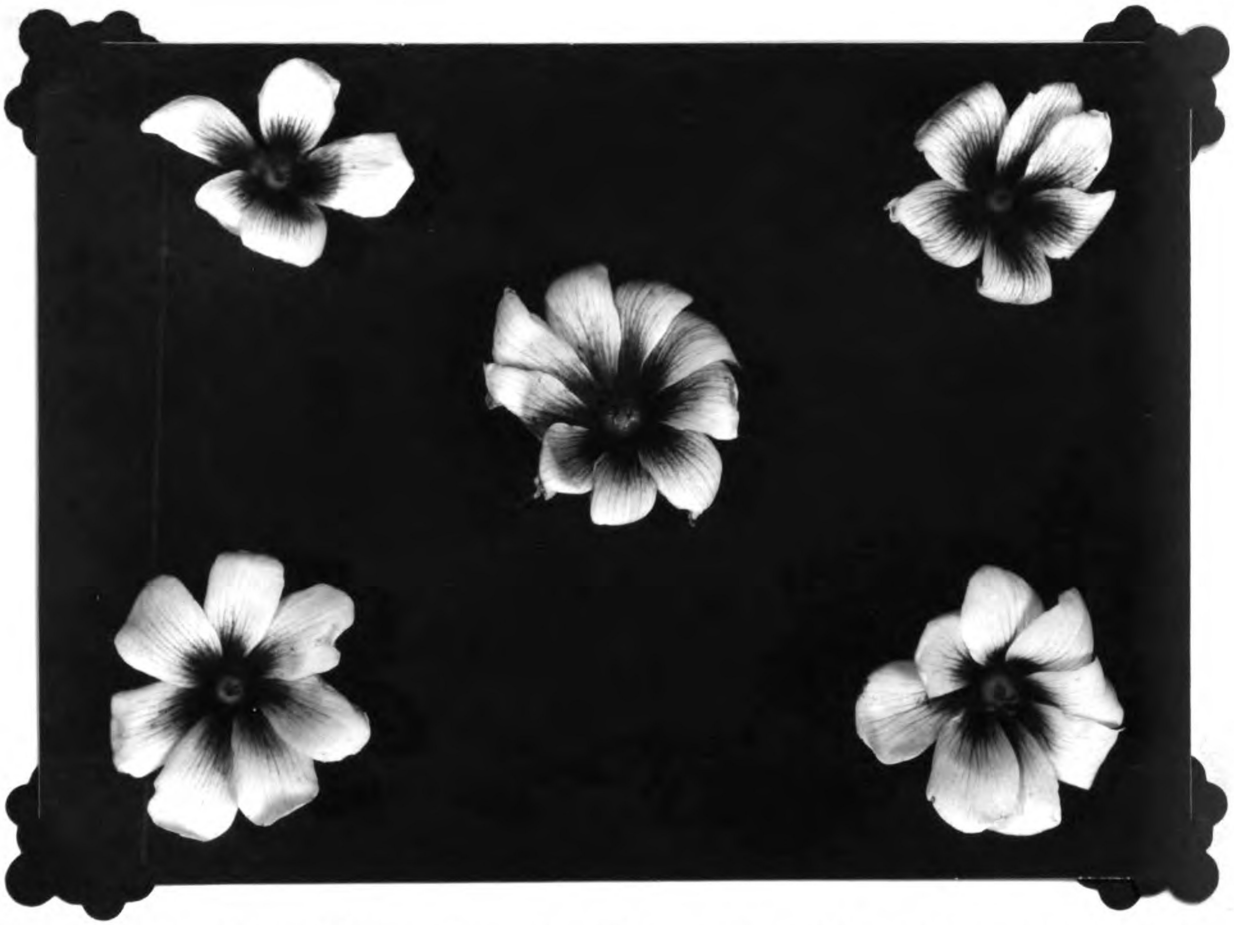

Fig.26.-Pistillate flowers. The number of petals vary from five to nine but eight is by far the most common in the female flower.

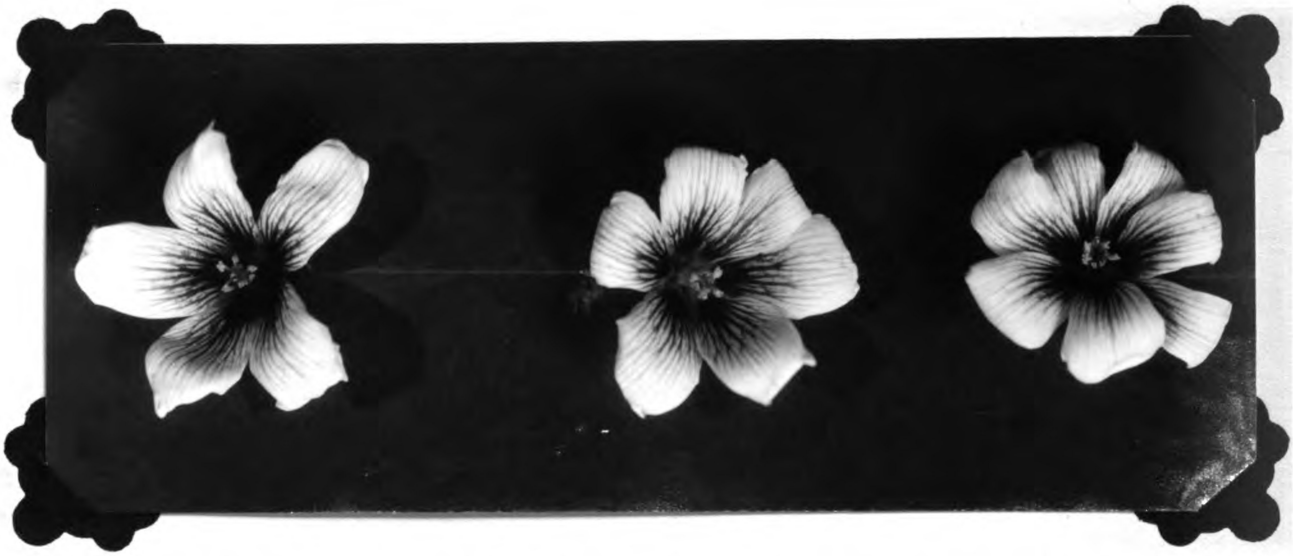

Fig.27.-Staminate flowers. The number of petals vary from five to eight but five is by far the most common in the male flower.

Fig.28.-A four year old tree in full bloom.

Fig.29.-A nine year old tree in full foliage.

Fig.30.-A cluster of green fruit showing foliage and fruit cluster method of bearing.

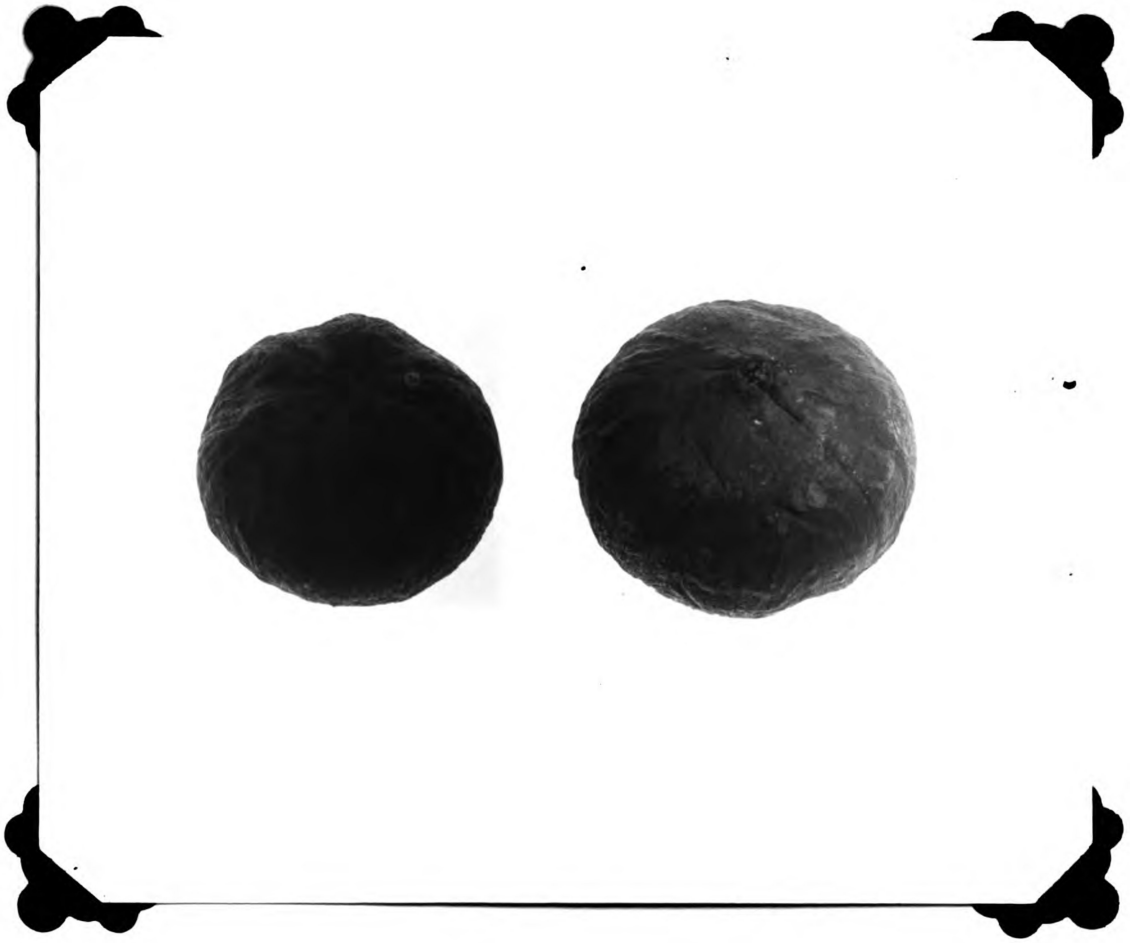

Fig. 31.-Apical and basal view of mature fruits.

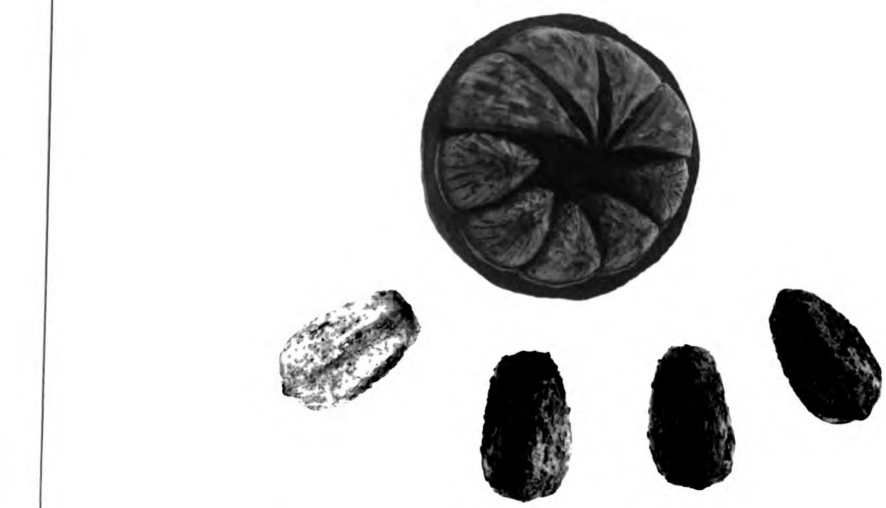

Fig. 32.-Mature fruit showing arrangement of nuts within the individual fruit and nuts after removed from husk.