GROWTH STUDIES OF THE PECAN

THESIS

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for the degree of Doctor of Philosophy

By
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TABLE OF CONTENTS

p14653

GROWTH STUDIES OF THE PECAN

By C. L. Isbell

INTRODUCTION AND STATEMENT OF PROBLEM

INTEREST IN the pecan producing industry of the South has grown very rapidly during the last quarter-century. In 1899 the number of bearing pecan trees, including seedling and budded or grafted, was given as 643,292. Figures indicating the number of trees of non-bearing age at that time are not available. These numbers increased to 1,619,521 for bearing and 1,685,066 for non-bearing trees by 1909; to 2,672,191 and 2,257,288 by 1919; and to 4,618,297 and 5,120,016 by 1924, respectively. The production of nuts in pounds increased from 3,206,850 in 1899 to 9,890,769 in 1909 and to 31,808,649 in 1919; and the value from $971,596.00 for 1909 to $7,792,866.00 for 1919 (2).

These great increases have created a demand among growers and prospective growers for information on all phases of pecan growing. The investigation herein reported was started to study the growth habits of the pecan. Three, more or less separate phases of growth, were studied,—namely, bud differentiation and development; growth and fruiting habits; and, influence of pruning, defoliating, ringing, and disbudding on the number of shoots and flowers produced.

HISTORICAL

WITHIN THE LAST fifty years many contributions have been made to our knowledge of the time and nature of bud formation in deciduous fruits and the growing habits associated with this function of trees. The literature on this subject indicates that in general for each kind of fruit there is a fairly definite period when fruit bud differentiation takes place, and that the initiation of the process depends on the existence of certain nutritive conditions within the tissues at or near the particular points and time in question.

Moderately vigorous vegetative growth in deciduous fruit trees is essential for maximum fruit-bud differentition and maximum fruitfulness. In some instances

P14653

pruning, defoliating, ringing, fertilizing and other treatments have exerted little or no influence on the number of fruit buds formed; in others they have resulted in increased numbers and in still others in deceased numbers.

Wellington (15) and Wiggans (16) have given rather complete summaries and bibliographies of experimental work bearing on fruit-bud formation. For that reason in this publication reference to other literature will be made only where it seems to have some definite bearing on the data being reported, and then only in connection with the specific topic under consideration. When this investigation was started in June, 1922, apparently no study of similar nature had been made on the pecan or any other nut bearing tree with similar growth and fruiting habits.

SOURCE OF MATERIALS

MOST OF the materials used in this investigation were obtained from a variety planting of pecans set in 1914 and from a seedling tree planted about 1900*. The trees of the variety planting were set 40 feet apart each way and peach trees were used as fillers until the first year the experiment started. The seedling tree is located on the college campus. The soil in which the trees are growing is sandy, underlaid with clay, and its natural fertility is below that required for best growth of the pecan. During the experiment the trees grew under lawn-sod mulch consisting of Bermuda and lespedeza during each summer and hairy vetch and bur clover during each fall and winter. From year to year the young trees received sufficient complete fertilizer to maintain vigorous growth. These applications were made in the spring just about the time the nuts were apparently set.

It was found early in the experiment that if the shoots of most varieties fail to produce pistillate blossoms they generally abscise the terminal bud and subsequent growth is made from lateral buds near the apical end of the shoot. It seemed advisable, therefore, to make a special study of these subterminal buds—that is, those axillary or extra-axillary buds just below nuts or below the point where a terminal bud or a terminal part of the shoot had abscised.**

* The seedling produces a good nut and would come in the early blooming group according to Stuckey's (13) classification. This tree has been given the variety name Earl, for Prof. Earl who planted it. It is referred to in this paper under that name.

** The lateral bud referred to here is usually the uppermost of the subterminal node remaining after the terminal bud or the terminal part of the shoot has abscised. On some varieties it is an axillary bud; on others it is an extra-axillary.

PART I.—BUD DIFFERENTIATION AND DEVELOPMENT

Methods.—Shoots from which buds were taken, as well as those labeled for study, were distributed over the entire tree.

The first samples of buds taken for microscopic examination were killed in Gilson's killing solution and infiltrated with paraffin, as outlined by Chamberlain (3). The nature of the bud scales and the close folding of the young leaves prevented thorough infiltration, except in buds that were in very active growth, and the material broke in sectioning. More satisfactory results were secured by removing the bud scales, aspirating for one hour and then infiltrating with celloidin. In subsequent collections the scales were removed immediately and chromeacetic acid was used for killing. Sections were cut to a thickness of about thirty microns, stained with Delafield's haematoxylin, destained with acid alcohol, washed, dehydrated with alcohol, cleared with xylol and mounted in balsam. Clove oil was used for clearing a few sections. Double staining with eosin and haematoxylin was used with a few sections.

Catkin Flower Bud Differentiation and Development

THE PECAN differs from many other monoecious plants in that the staminate catkin buds and the vegetative growing point which later may differentiate the pistillate flower buds are each enclosed in a separate bud scale or scales, within a common outer scale covering.

When the rudimentary bud formed in the axil of the leaf (either before or after the leaf unfolds) starts rapid development it forms a mixed bud consisting of three or more buds under a common bud scale with each bud enclosed in a separate scale. All of these except the middle bud are destined to give rise to catkin buds. Figures 1 to 13 inclusive are arranged to show the time at which the catkin differentiation occurs and the progressive stages in its development.

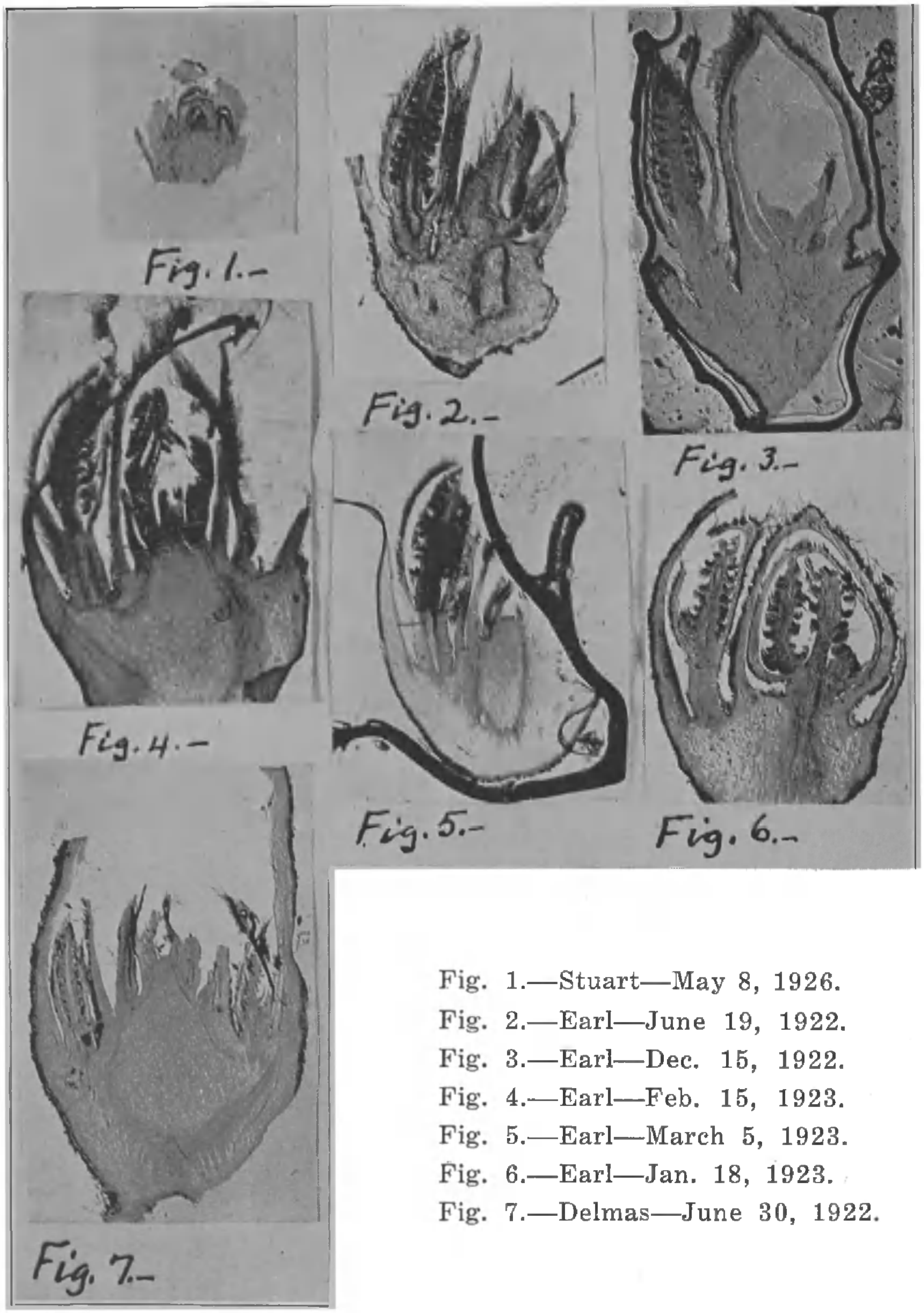

Fig. 1.—Stuart—May 8, 1926.
Fig. 2.—Earl—June 19, 1922.
Fig. 3.—Earl—Dec. 15, 1922.
Fig. 4.—Earl—Feb. 15, 1923.
Fig. 5.—Earl—March 5, 1923.
Fig. 6.—Earl—Jan. 18, 1923.
Fig. 7.—Delmas—June 30, 1922.

LEGENDS

Fig. 1.—Stuart bud taken May 8, 1926, from basal part of shoot just after pistillate flowers appeared at the top of the shoot. On the right and left catkin flower buds forming. In center vegetative bud.

Fig. 2.—Earl bud taken June 19, 1922, from a node near the developing nut. On the left is a catkin already well developed.

Fig. 3.—Earl bud taken December 15, 1922, from a node near the nut scar. Catkin on the left well developed.

Fig. 4.—Earl bud taken February 15, 1923, from a shoot that bore nuts in 1922. It shows on the left the extent of the development of the catkin and its hairy condition.

Fig. 5.—Earl bud taken March 5, 1923, from a shoot that fruited in 1922. It shows on the left a catkin rather well developed not long before the buds would have unfolded in the spring.

Fig. 6.—Earl bud taken January 18, 1923, from a shoot that fruited in 1922, showing one catkin bud with catkins enclosed and part of another. The vegetative part of the composite bud is not shown.

Fig. 7.—Delmas bud taken June 30, 1922, from a node near where terminal bud abscised between June 23 and June 30. Catkin on left and right not far advanced.

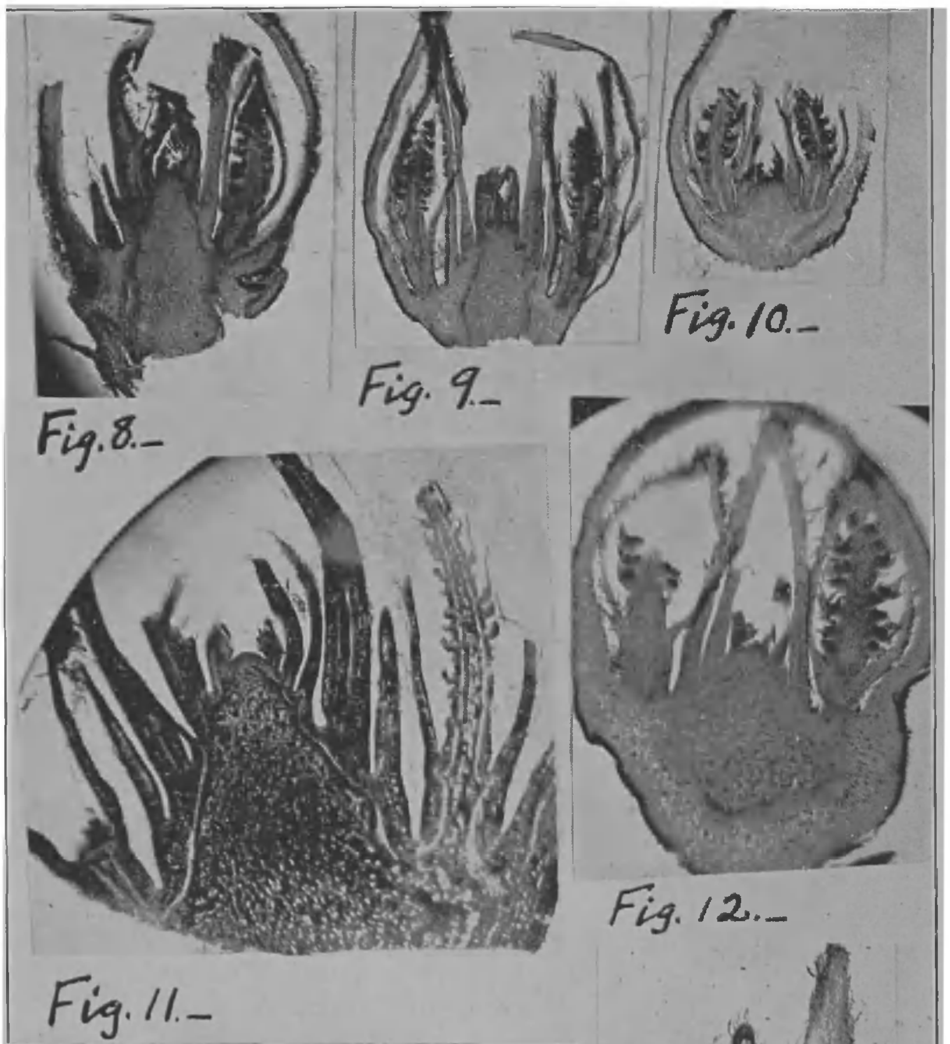

Fig. 8.—Earl—July 12, 1922.
Fig. 9.—Earl—July 4, 1922.
Fig. 10.—Earl—Feb. 1, 1923.
Fig. 11.—Stuart—April 3, 1926.
Fig. 12.—Earl—April 4, 1923.
Fig. 13.—Schley—June 23, 1922.

LEGENDS

Fig. 8.—Earl bud taken July 12, 1922, from a node near the developing nut. It shows a well developed catkin on the right and a vegetative bud in the center.

Fig. 9.—Earl bud taken July 4, 1922, from a node on the basal part of a fruiting shoot. It shows the development of the catkin buds on the right and left, and the vegetative bud in the center.

Fig. 10.—Earl bud taken Feburay 1, 1923, from the basal part of a shoot that fruited in 1922. It shows the relative development of catkins and vegetative parts of the composite bud.

Fig. 11.—Stuart bud taken April 3, 1926, from a shoot that fruited in 1925. Enlarged for comparison of catkin and vegetative parts of strong buds near the terminal part of the shoot, just as growth was starting and bud scales were being lost in the spring. Parts of some of the individual staminate flowers were broken off in sectioning.

Fig. 12.—Earl bud taken April 4, 1923, from a shoot that fruited in 1922. Enlarged for comparison of catkin and vegetative parts of buds near the basal parts of a shoot just as growth was starting in the spring.

Fig. 13.—Schley bud taken June 23, 1922, from the base of a second growth shoot, showing a catkin bud being abscised at A.

DISCUSSION

IT WILL BE SEEN from Figure 1 that catkin flower buds begin to form and staminate flowers to differentiate in the buds along the base of the new shoot soon after growth begins in the spring. The rapidity with which the catkins develop soon after they are differentiated and the continuation of their development until a short time before blossoming the following spring is shown in Figures 2 to 5 inclusive. Many of the well developed mixed buds contain three or four catkin buds by the end of the growing season. Figure 6 is an illustration of such a bud showing an entire catkin bud and a portion of another.

As the growing season advances buds formed at newly developed nodes on either first or secondary shoots differentiate catkin buds, as is shown in Figure 7. As might be expected, due to their differentiation very early in the growing season, the catkin buds on the basal portion of the shoot are more developed than those in buds toward the terminal part of the shoot. This difference, however, does not continue throughout the development of the catkin; in fact catkins in buds located near the terminal part of the shoot finally develop to a much greater size, as will be seen by contrasting Figure 8 with 9, 3 with 10, and 11 with 12 taken from buds toward the terminal and basal parts of the shoot respectively. These differences would appear greater were Figures 9, 10 and 12 not magnified more than 8, 3 and 11 with which they are contrasted.

When second growth takes place—that is, when lateral branches develop from mixed buds of the current season—the embryo catkins that were located in the buds are usually abscised, as shown in Figure 13. They may, however, remain on the base of the new shoot and produce catkins the following spring.

Although at the end of the growing season catkins in buds toward the base of the shoot are usually smaller than those in more terminal buds, they are larger in proportion to the vegetative bud with which they are associated. This is clearly shown by comparing the catkins with the vegetative parts in Figures 10 and 11.

When growth starts in the spring the vegetative part of well developed buds located near the terminal part of the shoot appears to develop more rapidly than the catkins with which it is associated. The more basal buds, however, either remain dormant or unfold and produce catkins and very weak vegetative growth, the vegetative parts usually abscising when catkins fall. Such a shoot is show at point A in Figure 31.

From the foregoing it is shown that the catkins are differentiated in the composite or mixed lateral buds of the pecan almost as soon as the buds themselves are formed and before the leaves subtending them have attained full size. This differentiation is more or less of a continuous process, taking place as new shoot growth is made and new lateral buds are formed. There is a second period of catkin differentiation corresponding with the laying down of new buds on the second growth. Considerable development of these catkins takes place as the growing season advances and is coincident with the increase in size of the buds*.

Pistillate Flower Bud Differentiation and Development

AS ALREADY STATED, the vegetative center of the composite or mixed lateral bud of the pecan remains vegetative from the time it is formed until the beginning of the growing period the following spring. With the appearance of conditions favorable for growth, both the vegetative center of the bud and the rudimentary catkins continue their development, the vegetative center developing more rapidly. The first stage of its growth appears in longitudinal section as an elongation of the central axis and a change in the shape of its crown from that of a broad to a rather narrow cone. Immediately, there appears at or just below and to the side of the growing point an enlargement which tends to give the growing point a shouldered or twisted appearance. Others appear as growth advances. These protuberances mark the initiation of individual pistillate flowers which develop rapidly. While pistillate flowers are being differentiated on the terminal parts of the rudimentary shoot, leaves, nodes and internodes are developing rapidly and rudimentary buds in the axils of the leaves are being differentiated and developed. Figures 14 to 22 inclusive are arranged to show the appearance of the terminal growing point at different stages before and during the process of pistillate flower differentiation.

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* This is in line with preliminary reports on this question made by the writer before the Horticultural Section of the Southern Agricultural Workers in February, 1923, and at the annual meetings of Georgia-Florida Pecan Growers' and the National Pecan Growers Associations, based on earlier studies. It is further corroborated by the investigation of Woodroof (17).

Fig. 14.—

Fig. 15.—

Fig. 16

Fig. 17

Fig. 14.—Stuart—Dec. 5, 1925.
Fig. 15.—Stuart—Jan. 11, 1926.
Fig. 16.—Stuart—Feb. 9, 1926.
Fig. 17.—Stuart—Feb. 20, 1926.

Fig. 18.–

Fig. 19.–

Fig. 20.–

Fig. 21.–

Fig. 22.–

Fig. 18.—Stuart—April 3, 1926.
Fig. 19.—Stuart—April 10, 1926.
Fig. 20.—Stuart—April 14, 1926.
Fig. 21.—Sawyer—April 12, 1925.
Fig. 22.—Sawyer—April 12, 1925.

LEGENDS

Fig. 14.—A mixed bud of the Stuart taken Dec. 5, 1925, from a node near the terminal part of a shoot that fruited in 1925. This bud shows the early winter stage of development of the vegetative part of the bud.

Fig. 15.—Stuart bud taken Jan. 11, 1926, from a node near the terminal on a shoot that fruited in 1925. This bud shows the midwinter development of the bud.

Fig. 16.—Stuart bud taken Feb. 9, 1926, from a node near the terminal on a shoot that fruited in 1925, showing catkin on the right and elongating crown of the vegetative bud on the left.

Fig. 17.—Stuart bud taken Feb. 20, 1926, from a node near the terminal on a shoot that fruited in 1925, showing the vegetative bud with internodes elongating and crown of the growing point also becoming elongated preceding pistillate flower differentiation. Catkin buds were broken off in sectioning.

Fig. 18.—Stuart bud taken April 3, 1926, from a node near the terminal on a shoot that fruited in 1925, showing an enlarged longitudinal view through the growing point just as it was starting rapid growth.

Fig. 19.—The terminal of a developing Stuart shoot taken April 10, 1926, showing a stage of pistillate flower differentiation further advanced. The bud scales had been lost and the young leaves were beginning to grow rapidly.

Fig. 20.—The terminal of a developing Stuart shoot taken April 14, 1926, showing the pistillate flowers further developed than in any previous figure. The vegetative shoot has made considerable growth; so have the leaves, but the young leaves were still folded over the cluster of pistillate flowers so that it could not have been seen without sectioning.

Fig. 21.—The terminal of a developing Sawyer shoot taken April 12, 1925, just before the pistillate flowers were large enough to be seen without magnification.

Fig. 22.—Terminal of a Sawyer shoot taken April 12, 1925, showing pistillate flower bud developed to the point where the ovule was formed.

DISCUSSION

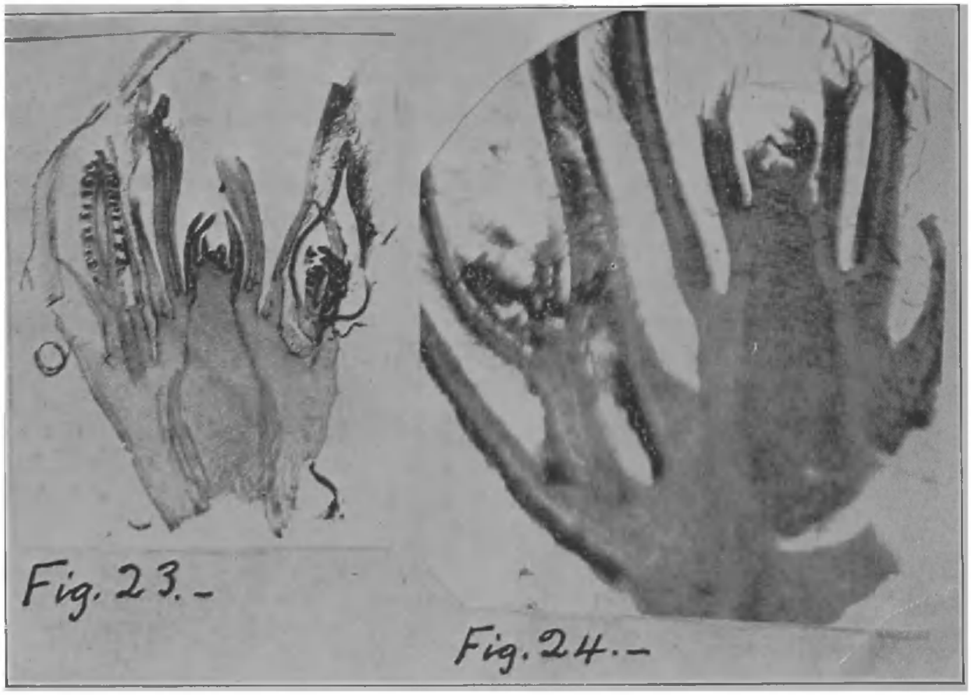
FIGURES 14 to 17 inclusive show the development of the vegetative parts of the bud during winter and early spring. It will be noted that there appears to be a slight change in the crown of the bud in that it becomes more pointed as the time for very active spring growth approaches. There is no evidence, however, in these figures that pistillate flower differentiation has begun.

Figure 18 shows rather clearly how the vegetative part of the mixed bud in the pecan appears as it changes from a vegetative to a pistillate flower structure. The crown of the bud first elongates then shows a slight protuberance which is a pistillate flower primodium. That the young pistillate flowers differentiate and develop rather rapidly once they have started is well shown by contrasting the extent of the differentiation and development of pistillate flowers in Figures 18, 19, and 20. Although Figures 21 and 22 are of a different variety and represent conditions existing in the spring of 1925 rather than 1926 they show that pistillate flowers are developed rather rapidly. A partly developed ovule is shown at "A" in Figure 22.

The above studies, which covered a period of five years and included different varieties, indicate that in east central Alabama pistillate flower bud differentiation in the pecan takes place in early spring just as bud scales are dropped and rapid growth is starting and then proceeds rather rapidly. Shuhart (14), and Woodroof and Woodroof (18) found pistillate flower bud differentiation taking place at about the same stage of spring development of the tree, as was also suggested by the writer (7).

Buds With Unknown Future Development

IN THE STUDY of the differentiation and development of staminate and pistillate flowers a number of miscellaneous observations were made which are of much interest. Photographs, some of which are shown in Figures 23 to 29 inclusive, were made to record these findings.



LEGENDS

Fig. 23.—Earl bud taken June 27, 1922, from a node near the nut, showing a vegetative bud in the center and a catkin bud on each side. The vegetative part was elongating, the scales were about to be lost and a lateral shoot would soon have arisen out of the vegetative end.

Fig. 24.—A mixed bud of the Earl taken Nov. 2, 1922, from near the terminal on a shoot that fruited in 1921. Outer bud scales had fallen. This is typical of buds that lose the outer scales during fall and winter.

Fig. 25.—A mixed bud of the Stuart taken Dec. 12, 1925, from a node near the terminal part of a shoot that fruited in 1925, showing the development of the leaves while yet in the bud. The crown of the vegetative bud is raised. However, it does not look exactly like the raised crown of a bud that will soon differentiate pistillate flowers.

Fig. 26.—Stuart bud taken Feb 6, 1925, from a node near the terminal of a shoot that fruited in 1924, showing the vegetative bud apparently starting spring growth with the internodes elongated and the terminal parts of the bud growing.

Fig. 27.—Stuart bud taken Feb. 6, 1926, from a node near the terminal of a shoot that fruited in 1925, showing the development of the rudimentary leaves and buds in their axils before the bud scales had been lost from the main vegetative bud. Such a bud does not appear as if it would differentiate pistillate flowers. Its growing point is very much like that in Fig. 29, which is known to be vegetative.

Fig. 28.—A true terminal bud of the Earl taken March 26, 1923, showing general development of the vegetative bud and on the right at C an undeveloped catkin. Such a terminal bud may or may not differentiate pistillate blossoms. On most varieties they abscise before growth starts the spring following their formation or just as rapid spring growth starts.

Fig. 29.—Longitudinal section through the growing end of a lateral shoot arising from an axillary bud during the summer.

Fig. 25.-

Fig. 26.-

Fig. 27.-

Fig. 28.-

Fig. 29.-

Fig. 25.—Stuart—Dec. 12, 1925.
Fig. 26.—Stuart—Feb. 6, 1925.
Fig. 27.—Stuart—Feb. 6, 1926.
Fig. 28.—Earl—March 26, 1923.
Fig. 29.—June 23, 1922.

DISCUSSION

SOME AXILLARY buds, usually just below nuts, produce lateral growth the summer immediately following their formation. Such buds would produce catkins and might differentiate pistillate flowers the following spring if they did not produce this vegetative growth. Figure 23 illustrates one of these buds coming into growth. It will be seen from the abscission layer at the base of the catkin flowers that they are about to abscise. The vegetative part of the bud is very different in appearance from an axillary bud that differentiates pistillate flowers when it comes into growth, as was illustrated in Figures 18 and 19. If the axillary buds are influenced to produce second or lateral growth due to defoliation by storms, caterpillars, drought or other causes, the catkins are not likely to be abscised, but appear in the form of blossoms along with the appearance of the second growth of the vegetative shoot.

During late summer, fall, winter, and early spring some of the largest and apparently best developed axillary buds located toward the terminal parts of the shoot may lose the bud scales. Just what will be the fate of such buds is uncertain; usually some of them drop; others may grow. Figure 24 is a good illustration of these buds.

There is another class of buds, probably not very numerous, that reach quite a development by early winter. These buds are interesting because of the apparent development of the crown of the bud as if pistillate flowers might differentiate. This class is represented in Figure 25.

Woodroof (17) believes such buds to be winter-resting buds, while Shuhart (14) classifies them as pistillate buds in winter stage.

There are also two other types of strong buds that are interesting in their winter stage, but their future is also uncertain. They are shown in Figures 26 and 27—the former with internodes apparently elongated and the growing point, judging from the dark stain it takes, somewhat active; the latter with axillary buds well formed and with a somewhat unusual type of growing point.

It would be interesting to know whether or not such rudimentary axillary buds contain primordia for catkin flowers fourteen months before they appear, but the histological technique used in this investigation did not make possible its determination.

As has been stated, most varieties of the pecan abscise the terminal bud. It will be shown later that terminal buds that do not abscise are not likely to develop catkin flowers. Figure 28 shows rudimentary catkins that will probably abscise and a terminal bud that may or may not differentiate pistillate flowers.

That the end of a growing shoot as seen in longitudinal section is in appearance much like that of a true terminal just before growth is resumed in the spring is evident from a comparison of Figures 28 and 29.

PART II.—GROWTH AND FRUITING HABITS

Varietal Variation in Number and Abscission of Buds

MOST VARIETIES tend to form several buds at a node, the number depending somewhat on the vigor of the shoot and the location of the node. The Stuart variety sometimes forms as many as six buds at a single node. The size of the buds at a node usually decreases from the uppermost to the basal one. In general the buds are successively larger from the basal to the distal end of the shoot, as shown in Fig 30 A and A', B and B'. When exceptions occur they are generally found where a vegetative shoot slowed down in growth, produced several short internodes, and grew more rapidly later that season. A temporary exception may occur at nodes located about the middle of rapidly-growing-vegetative shoots. In the former, buds located at nodes in short internode areas are small, as shown at D, E. and F in Fig 38. In the latter, buds at nodes near the middle of the shoot are largest.

Other varieties, of which the Success is an example, tend to form few buds at each node and appear to lose many of the uppermost buds of the nodal group by abscission. The distal bud at every node may drop from some shoots, the dropping taking place in late summer, fall, or winter. There seems to be a tendency, however, for the buds at the subterminal nodes to be retained for growth the following spring. When the uppermost bud at a node abscises, the second bud usually increased in size and functions in its place.

Characteristics of Pecan Shoot Growth

A FIELD STUDY was made of the growing habits of the pecan from the time growth started in spring until it started the following spring. These field observations showed that the pecan may—and usually does—have a great number of different kinds of shoots. Some of the most common and most important of these types are: long and short shoots that fruited the year of their formation; long and short shoots that remained vegetative but dropped the terminal bud before the winter following their formation; and long and short shoots that remained vegetative and retained their terminal buds the year of their formation. All of these types are of much interest because of their comparative fruitfulness the year following their formation, and because a careful study of these types and how to cause the formation of a large number of the most desirable should give the pecan grower better returns. These shoots are illustrated in Figure 30.

Very short weak shoots that arise out of buds located toward the middle or basal portion of shoots of the previous season's growth are of interest, because they usually abscise when catkins fall without making much vegetative growth or developing pistillate flowers. Such a shoot is illustrated at A in Figure 31.

Weak shoots that abscise the terminal or growing part of the shoot, including undeveloped leaves, just about the time catkins are falling, and more vigorous shoots showing pistillate flowers, are interesting because they usually go through the remainder of the current growing season without producing further leaves or linear growth. This type of shoot is illustrated at A in Figure 32.

Shoots that reach medium length or above and are vigorous but fail to produce pistillate flowers, as do other shoots of similar length and apparent vigor, attract the pecan grower's attention because of their failure to produce nuts. Such a shoot is shown in Figure 31 at B.

Shoots that reach medium length or above, produce pistillate flowers, and set nuts while short shoots and shoots of similar length and apparent vigor remain vegetative are also of special interest. Such a shoot is illustrated at B in Figure 32.

Weak shoots that differentiate pistillate flowers which abscise just before or just after reaching sufficient development to be seen without microscopic examination are of special interest to pecan growers because they represent one of the critical steps between large and small yields. It is reasonable to believe that orchard management practices could be modified so that such pistillate blossoms would set and produce nuts. Shoots that behave this way are illustrated in Figure 33.

As has been stated, most shoots of most varieties of pecans drop the terminal bud and make further development out of other buds; but, as many terminal buds are retained on some varieties and give rise to nut-producing shoots, such shoots are of importance. Figures 34 to 36 inclusive illustrate three ways in which a shoot may dispose of its terminal bud.

Shoots that develop a comparatively small number of strong buds near the terminal are usually light bearers. Even when nuts are produced, the number in the cluster is likely to be small. This type of shoot is illustrated at A in Figure 37.

Shoots that develop many strong buds toward the terminal are usually heavy bearers. Such a shoot is shown at A′ in Figure 37.

Shoots that produce a second growth while carrying nuts are of much interest because of the influence of this second growth on the location and number of flowers they produce the following spring. The first and second growth in shoots of this type are illustrated at B and C respectively in Figure 37.

Very long shoots are not likely to fruit the year following their development, especially if they make any form of second growth. There are several different types of these long shoots which make some form of second growth. They make long vegetative shoots, drop the terminal end, then make additional growth that season; or they make long vegetative growth which slows down due to unfavorable growing conditions then make additional vegetative growth, without dropping the terminal bud. These shoots are illustrated in Figure 38.

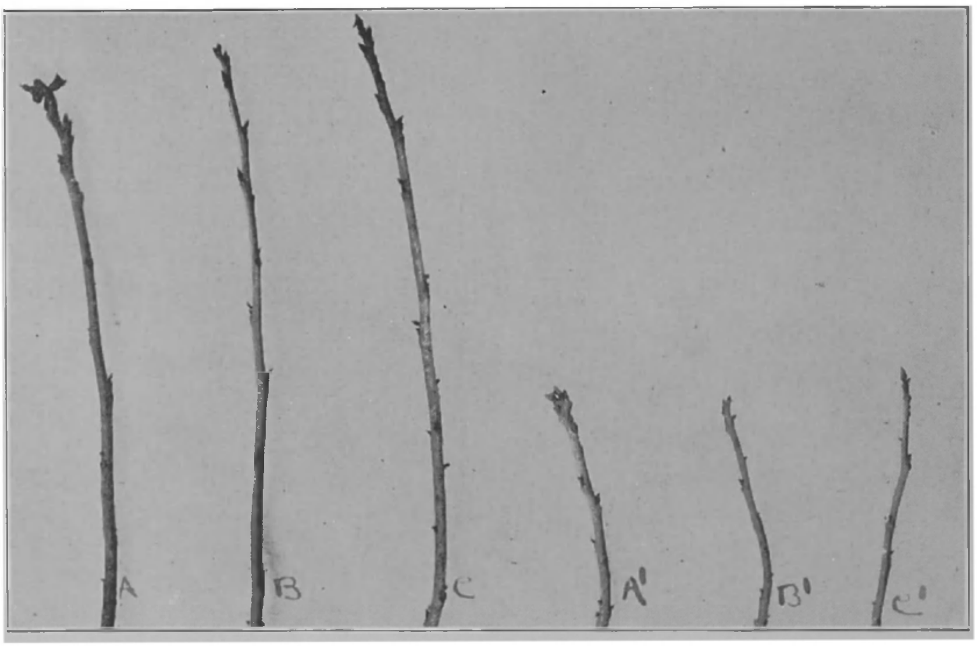


Fig. 30.

A and A'.—Long and short shoots that fruited and made no more linear growth until following spring.

B and B'.—Long and short shoots that were vegetative throughout the growing season and dropped the terminal bud some time before growth started the following spring.

C and C'.—Vegetative shoots that retained the terminal buds until the spring following their formation.

Fig. 31.

A.—Very weak shoot that produced very little vegetative growth. Such shoots abscise when the catkins fall.

B.—Vegetative shoot that was apparently vigorous enough to produce pistillate flowers, but failed to do so.

Fig. 32.—At A is shown a weak shoot that is abscising the terminal or growing point just about the time or a little after the pistillate flower cluster begins to appear on more vigorous shoots like B. Varieties that produce a large per cent of such shoots as A are not likely to be heavy bearers.

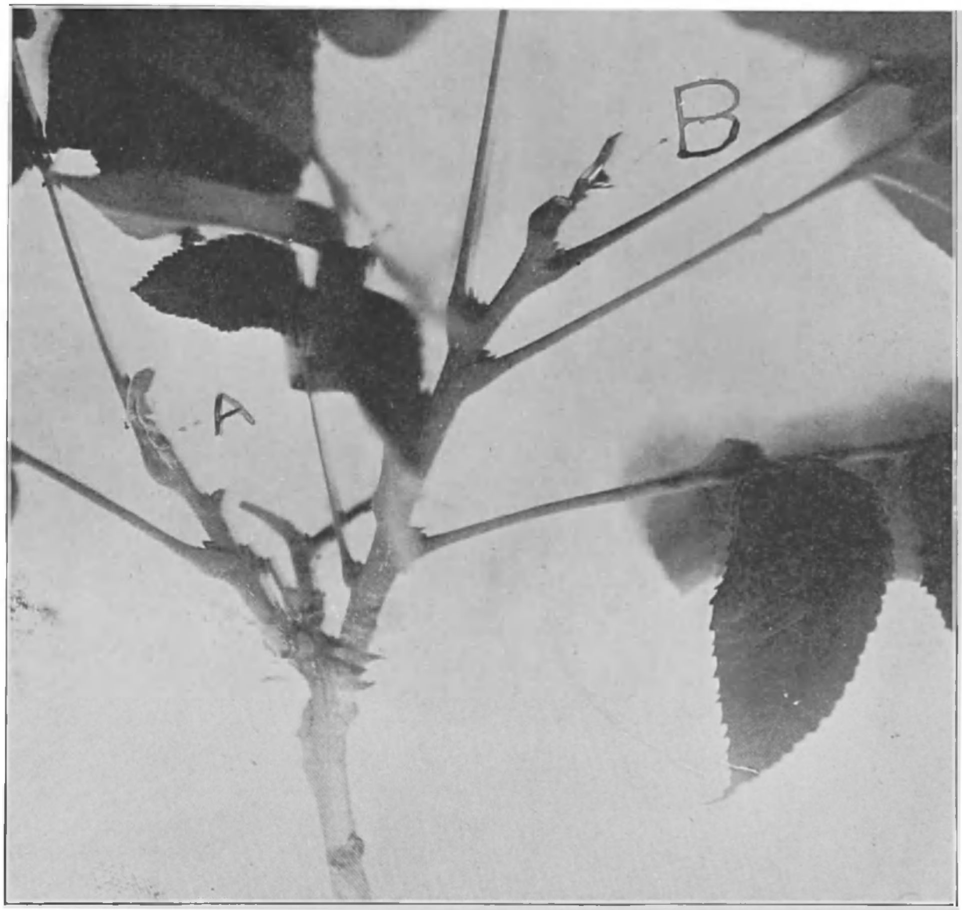


Fig. 33.

A.—A weak shoot that is abscising the pistillate flower cluster just before the flowers are large enough to be seen by careful examination without the aid of magnification.

B.—A shoot that produced a cluster of pistillate flowers which is abscising without setting any nuts.

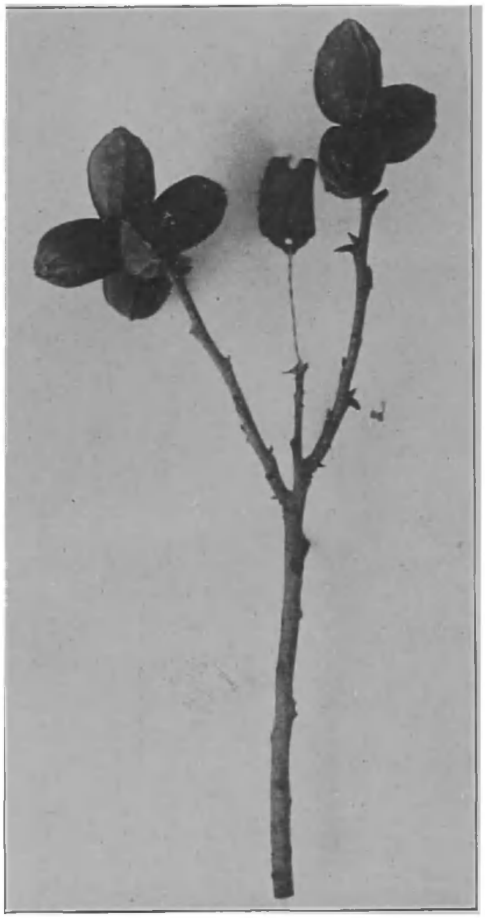


Fig. 34

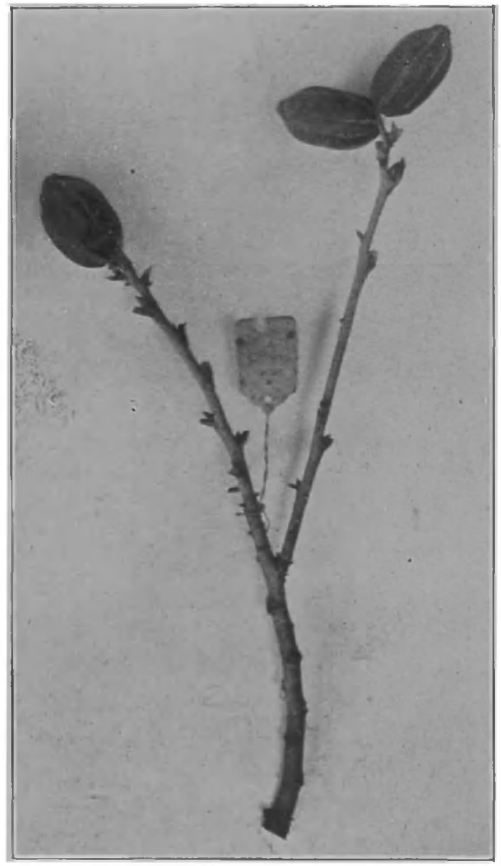


Fig. 35

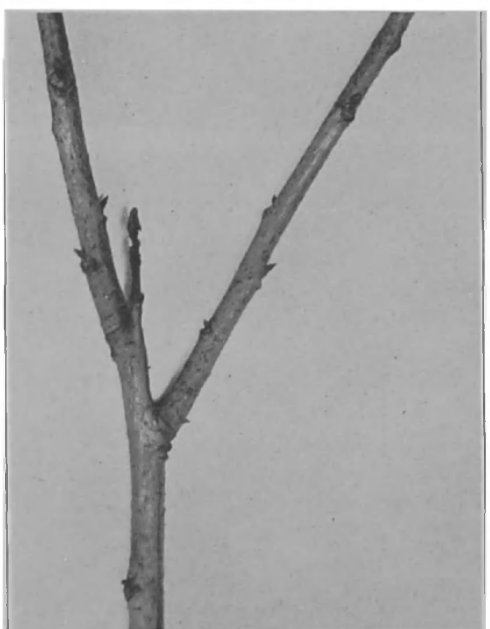


Fig. 36

Fig. 34.—Fruiting branches with tag attached at point where the terminal bud abscised. The shoots from subterminal buds fruited.

Fig. 35.—Fruiting branches with tag attached at the point where terminal bud fruited. The figure also shows a shoot from a subterminal bud that fruited.

Fig. 36.—The terminal bud from this 1925 VanDeman shoot did not abscise, but died and shoots were produced from subterminal buds in 1926.

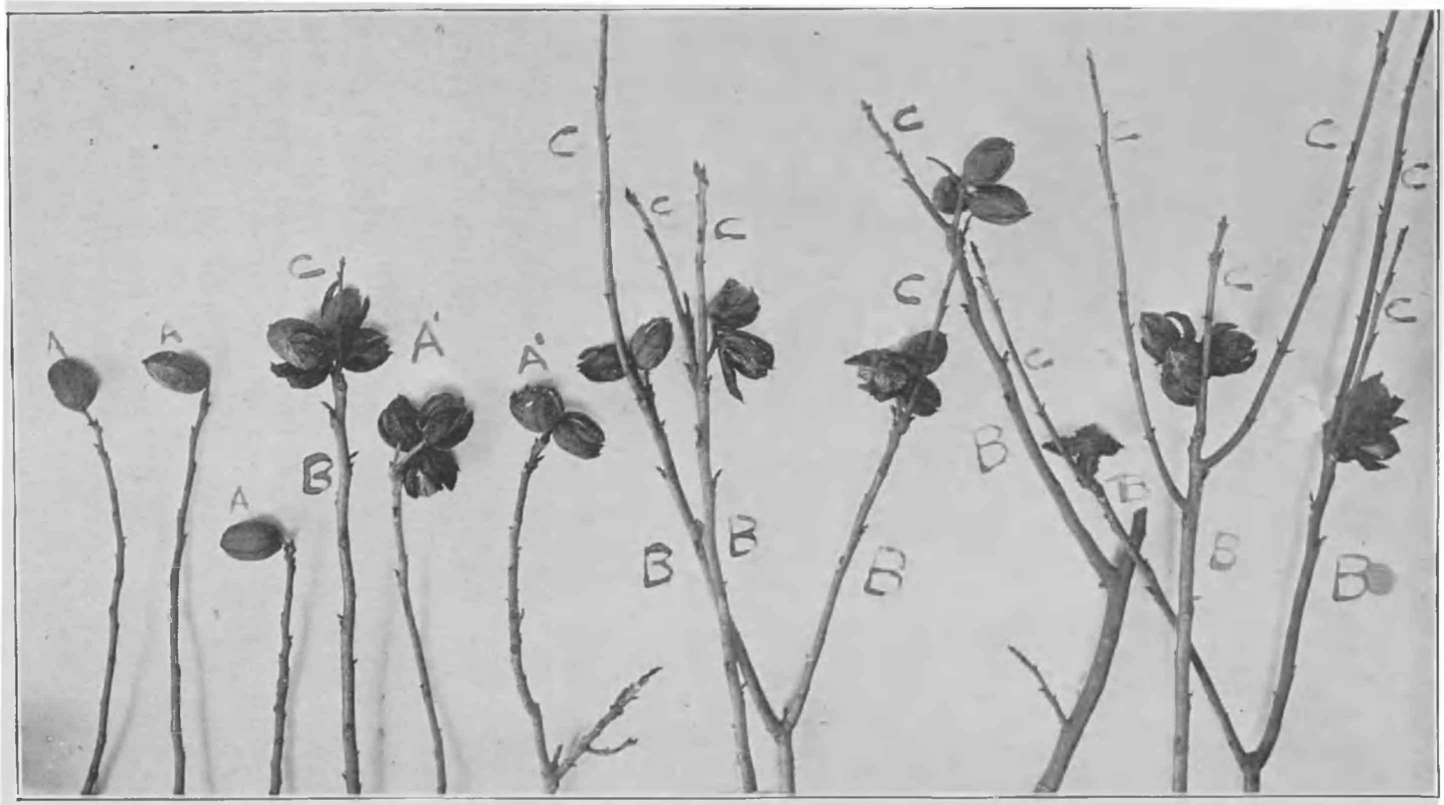


Fig. 37

A.—Columbian. A' Stuart. Shoots that set nuts and carried them to maturity, but made no more linear growth until the following spring. Contrast the development of the shoot and buds just below the nuts.

B.—Shoots of the Stuart that set nuts and later, from June to September, produced additional linear growth (C) out of one or more buds. This is a good illustration of how nut bearing shoots make a second growth.

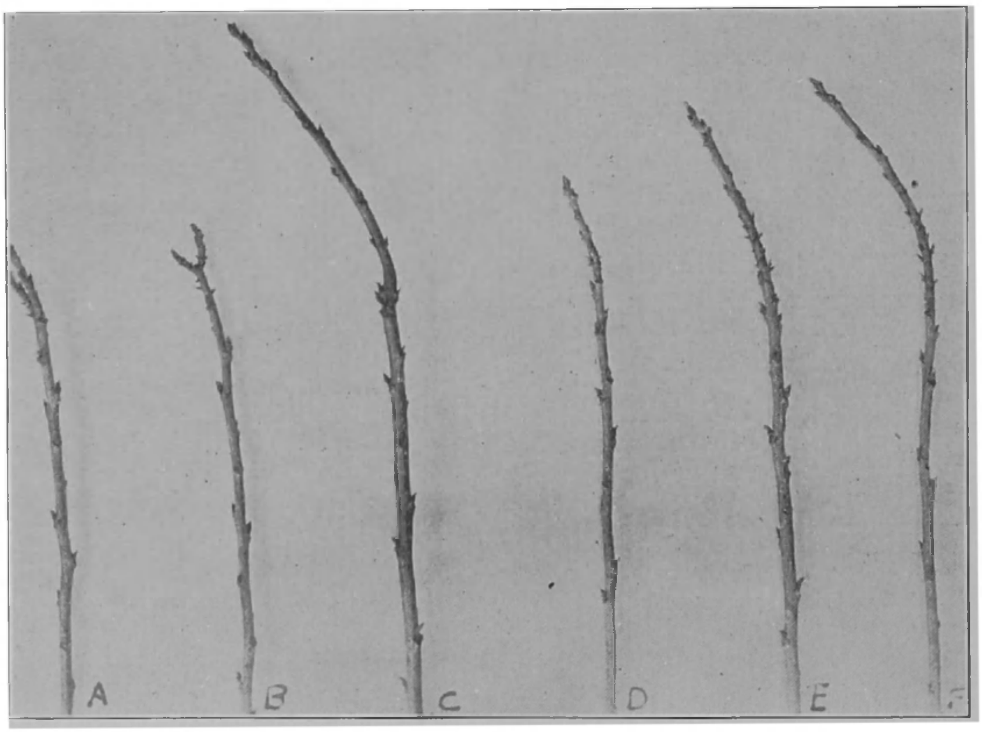


Fig. 38.

A B C.—Shoots that dropped their terminal buds and later made second growth out of buds near the terminal.

D E F.—Shoots that slowed down in growth, formed several short internodes with weak buds at these nodes, and later made further linear growth. These finally terminated with a terminal bud.

SINCE THE PECAN produces so many different kinds of shoots, as illustrated in Figure 30 to 38 inclusive, it was thought that a study of the relative number of each kind might throw some light on the bearing habits of the different varieties. Furthermore, information of this kind might also be valuable in suggesting modifications of some of the cultural practices to meet the special requirements of particular varieties. Three trees of each of several varieties were selected for this study, which was made just before nuts were harvested in the fall of 1922. Measurements were made of the length of the current year's growth of every shoot on each tree and at the same time records were made of the way each shoot terminated and as to whether or not a second growth had occurred. Table 1 presents these data in some detail and Table 2 summarizes them to show the number of shoots that fruited, the number of nuts carried, the number of shoots that dropped nuts, and the number of shoots that did not fruit.

DISCUSSION

THESE DATA SHOW in general that: (1) very short and very long shoots are not fruitful, though some varieties have the ability to fruit over a greater range of shoot length than others; (2) with each variety there seems to be an optimum shoot length for fruit production; (3) comparatively few nut clusters drop after they are actually set (a cluster of pistillate flowers that abscised before nuts were large enough to be pollinated would leave the shoot apparently as if it had abscised its terminal bud very early in the season and is included with such shoots); (4) the majority of shoots not fruiting, abscise their terminal bud before the nuts are ready to fall.

The well known high-productivity of the Delmas variety is probably due in part to its ability to fruit on comparatively short shoots, as well as over a wide range of shoot length, though its abundant foliage, vigorous growth, and good filling qualities are also factors of importance in this connection.

The figures for Pabst carry a suggestion as to why it is a little slow to come into bearing. It does not fruit either on very long shoots or very short shoots, as shown in Tables 1 and 2. Young trees, if vigorous, usually produce comparatively long shoots; if weak, very short

TABLE 1 THE NUMBER AND LENGTH OF SHOOTS PRODUCED BY DIFFERENT VARIETIES AND THE WAY THE SHOOTS TERMINATED GROWTH

Variety	Length of shoots in inches	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Variety Delmas average 3 trees	No. shoots that terminated with nuts	3.6	30.3	38.0	41.0	36.3	41.0	40.3	38.0	31.3	25.6	20.0	17.3	13.3	8.6	3.0	1.0	0.6	0.3									
	No. nuts carried by shoots that terminated with nuts	12.3	59.6	122.6	111.3	85.6	100.0	101.0	101.0	86.3	69.0	57.3	52.3	39.6	29.0	11.3	3.3	2.0	1.3									
	No. shoots that terminated by dropping nuts	0.6	3.0	3.6	2.6	3.0	1.6	1.3	0.3	1.6	0.6	0.6	0.3			0.3		0.3						0.3				
	No. shoots that terminated by dropping terminal buds	[illegible]	11.3	32.3	12.0	9.0	6.0	3.5	4.0	1.0	3.0	1.6	3.0	3.6	3.6	1.3	3.6	3.0	4.6	1.6	2.3	0.3	2.3	2.3	1.6	2.3	2.0	0.6
	No. shoots that terminated with terminal buds	32.0	3.6	5.3	4.3	3.3	4.3	2.6	1.6	2.6	4.0	2.6	3.0	4.3	4.3	1.6	4.3	0.8	2.6	1.3	2.0	2.0	2.6	1.0	1.6	1.6	0.8	0.6
	No. shoots that carried nuts and made second growth	1.0	3.0	3.3	4.3	4.0	3.3	1.6	1.3	2.6	3.0	1.0	0.6	0.3	0.3													
	No. nuts carried by shoots that made second growth	1.3	5.3	6.6	10.3	10.3	8.6	2.6	2.8	5.0	5.6	2.0	1.6	1.3	1.3													
Variety Pabst average 3 trees	No. shoots that terminated with nuts		5.3	32.6	55.3	50.0	40.0	[illegible]	34.3	33.0	24.3	14.6	15.0	5.3	4.6	0.6	1.0		0.6									
	No. nuts carried by shoots that terminated with nuts		7.6	67.3	126.6	123.0	[illegible]	116.6	86.3	85.6	60.3	42.3	38.0	10.0	8.0	2.8	2.0		2.3									
	No. shoots that terminated by dropping nuts	0.3	1.0	4.3	6.6	4.0	3.6	5.0	5.3	3.6	2.6	1.3	1.6	0.3	0.3	0.8	0.6											
	No. shoots that terminated by dropping terminal buds	72.0	61.3	39.0	22.6	11.0	10.3	5.0	8.6	5.6	5.0	4.6	8.3	5.0	4.6	4.6	6.6	3.0	4.6	2.6	2.6	2.6	4.3	3.0	7.0	4.6	3.6	3.6
	No. shoots that terminated with terminal buds	0.3	1.0	0.3			0.3																0.3					
	No. shoots that carried nuts and made second growth		0.3	0.3	0.3	1.0	2.0	2.3	1.6	1.6	2.8	2.3	1.3	2.0	1.6		0.3											
	No. nuts carried by shoots that made second growth		0.3	0.6	1.3	3.0	5.6	6.6	3.3	3.3	4.3	5.6	3.3	4.6	3.3		0.6											
Variety Frotcher average 3 trees	No. shoots that terminated with nuts	1.6	14.6	32.0	32.3	26.6	17.6	19.0	13.0	13.3	8.3	6.6	5.0	4.3	2.3	0.6	1.0	1.3										
	No. nuts carried by shoots that terminated with nuts	1.6	21.0	53.0	66.0	56.3	53.3	49.0	37.6	32.0	25.0	12.6	15.3	11.6	8.3	1.0	1.3	4.0										
	No. shoots that terminated by dropping nuts	1.6	8.3	4.6	2.3	3.0	1.6	0.3	1.0	1.3	0.3		0.6	0.3														
	No. shoots that terminated by dropping terminal buds	16.0	63.6	31.0	14.3	7.6	7.6	4.0	4.6	3.0	3.6	1.6	3.0	3.0	5.6	2.6	3.3	3.3	3.3	4.0	2.6	2.3	3.3	2.0	5.6	3.6	5.8	2.6
	No. shoots that terminated with terminal buds	11.0	3.3	3.6	3.6	0.3	1.0	0.3	0.3		0.6	0.3	0.3			0.3	0.3	1.6		0.3		0.3	1.0	1.0	1.0	0.6	1.0	
	No. shoots that carried nuts and made second growth		1.0	1.0	1.0	0.8	1.3	1.6	1.3	0.6	1.3	0.6	0.6	0.3	0.3	1.0	0.3		0.3									
	No. nuts carried by shoots that made second growth		2.0	1.6	3.3	1.3	4.0	4.8	3.0	1.3	3.0	1.6	1.0	0.6	0.3	4.3	1.3		0.6									
Variety Stuart average 2 trees	No. shoots that terminated with nuts		1.5	15.5	24.5	24.0	21.0	23.0	22.0	22.5	25.0	19.5	21.5	14.0	12.0	6.5	3.0				0.3		0.3					
	No. nuts carried by shoots that terminate with nuts		1.0	23.5	36.3	52.0	64.0	56.5	48.6	53.5	65.0	48.0	54.0	32.0	27.5	15.8	10.5				2.0		3.5					
	No. shoots that terminated by dropping nuts					1.5	0.3	0.6	1.0	0.3	1.3	1.0	0.6	0.6	1.0	0.3	0.3	1.0	1.0		0.5			0.5				
	No. shoots that terminated by dropping terminal buds	[illegible]	11.5	34.5	23.0	13.5	8.5	6.0	7.5	6.5	4.5	3.3	3.5	1.0	1.5		1.0	2.0	2.0	0.5	1.0	0.5	2.0	1.0	0.5		2.6	1.5
	No. shoots that terminated with terminal buds	14.0	24.0	16.0	6.5	3.0	2.5	2.0	2.5		0.5	1.0	1.0	2.0		0.5	1.0	0.5	2.0	0.5		0.5	0.5	0.8	1.0	2.0	0.6	
	No. shoots that carried nuts and made second growth		0.5	0.5	1.0		0.3		2.0	1.5	2.5	2.0	2.3	4.0	5.0	5.0	2.0	1.0	0.5	0.3	1.5				0.5			
	No. nuts carried by shoots that made second growth		1.6	1.0	2.0		0.3		3.0	2.0	8.5	3.3	6.0	3.0	14.5	14.5	7.0	2.3	2.5	2.0	4.3				0.8			
Variety Schley average 1 tree	No. shoots that terminated with nuts		1.0	1.0	11.0	11.0	18.0	13.0	13.0	19.0	17.0	12.0	14.0	4.0	3.0	1.0	2.0											
	No. nuts carried by shoots that terminated with nuts		1.0	1.0	19.0	17.0	45.0	32.0	28.0	41.0	48.0	31.0	42.0	12.0	6.0	2.0	8.0											
	No. shoots that terminated by dropping nuts						1.0	2.0	2.0	1.0			1.0															
	No. shoots that terminated by dropping terminal buds	27.0	12.0	34.0	13.0	16.0	3.0	2.0	4.0	2.0	2.0	3.0	4.0	1.0	3.0		1.0	1.0			2.0		2.0	2.0	1.0	1.0	1.0	3.0
	No. shoots that terminated with terminal buds	27.0	14.0	10.0	3.0	5.0	1.0	3.0	1.0			1.0	2.0		2.0	1.0	2.0		4.0			1.0	2.0			1.0		1.0
	No. shoots that carried nuts and made second growth							1.0	2.0	2.0	1.0	1.0	1.0															
	No. nuts carried by shoots that made second growth							2.0	4.0	3.0	2.0	3.0	3.0															
Variety Success representative part of 1 tree	No. shoots that terminated with nuts	2.0	17.0	44.0	63.0	44.0	21.0	13.0	3.0																			
	No. nuts carried by shoots that terminated with nuts	2.0	24.0	73.0	121.0	74.0	47.0	25.0	4.0																			
	No. shoots that terminated by dropping nuts	1.0	4.0	13.0	6.0	14.0	12.0	6.0	6.0	2.0		8.0		1.0		1.0		1.0	1.0	1.0								
	No. shoots that terminated by dropping terminal buds	47.0	24.0	21.0	12.0	3.0	3.0	1.0	[illegible]	10.0	2.0	2.0		1.0		1.0	1.0	1.0	2.0	3.0		1.0	3.0	2.0		1.0	1.0	2.0
	No. shoots that terminated with terminal buds									1.0													1.0					
	No. shoots that carried nuts and made second growth	1.0	3.0	9.0	12.0	14.0	14.0	3.0	7.0	1.0	1.0																	
	No. nuts carried by shoots that made second growth	1.0	4.0	14.0	23.0	27.0	18.0	17.0	14.0	2.3	1.0																	

Variety	Length of shoots in inches	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Variety Delmas average 3 trees	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminated with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	1.0	1.0	1.6	1.3	0.6	0.6	1.0		2.0	0.5	0.3																
	No. shoots that terminated with terminal buds	1.3			0.3			0.6	0.3	0.3		0.6																
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											
Variety Pabst average 3 trees	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminated with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	2.6	2.3	1.6	1.6	1.6	2.0	1.3		1.0		1.0	1.0	0.6	0.3	0.6		0.3	0.3		0.3							
	No. shoots that terminated with terminal buds				0.3																							
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											
Variety Frotcher average 3 trees	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminated with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	3.3	0.3	2.3	2.3	2.0	1.0	1.8	0.6	2.6	1.0	3.3	0.6	1.0		0.3	1.0			0.3		0.3						
	No. shoots that terminated with terminal buds		0.6	0.3	0.6	0.3		0.3				0.3		0.3		0.3	0.3											
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											
Variety Stuart average 2 trees	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminate with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	0.5	0.5	2.0	0.3	0.5	2.0	1.5		1.5	0.5	1.0				1.0						1.0						0.5
	No. shoots that terminated with terminal buds	1.0			0.5	0.5		0.5	0.5	3.0		1.5	0.5	2.5			0.8	0.5				0.5						
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											
Variety Schley average 1 tree	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminated with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	1.0	2.0	1.0		3.0	2.0	2.0		3.0		1.0		2.0		1.0						3.0						
	No. shoots that terminated with terminal buds	2.0	1.0	3.0		1.0																1.0				1.0		1.
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											
Variety Success representative part of 1 tree	No. shoots that terminated with nuts																											
	No. nuts carried by shoots that terminated with nuts																											
	No. shoots that terminated by dropping nuts																											
	No. shoots that terminated by dropping terminal buds	1.0	4.0	1.0	3.0	1.0	2.0	1.0	1.0	4.0	1.0	1.0	1.0	1.0	3.0	1.0	1.0	3.0	1.0					1.0				
	No. shoots that terminated with terminal buds	1.0	1.0			1.0	1.0																					
	No. shoots that carried nuts and made second growth																											
	No. nuts carried by shoots that made second growth																											

TABLE 2 — THE BEHAVIOR OF SHOOTS OF DIFFERENT LENGTHS ON DIFFERENT VARIETIES

LENGTH OF SHOOTS IN INCHES		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIETY DELMAS AVERAGE 3 TRESS	NO SHOOTS THAT FRUITED	106	53.3	61.5	51.3	40.3	44.3	42.8	59.3	34.0	28.6	21.0	18.0	12.3	5.0	3.0	1.0	0.6	0.3									
	NO NUTS CARRIED	15.3	92.0	128.6	128	96.0	109.6	85.6	83.3	51.9	74.9	59.3	54.0	41.0	30.5	11.5	5.5	2.0	1.5									
	NO. SHOOTS DROPPED NUTS	0.6	3.0	3.5	2.4	3.0	1.6	1.3	0.8	1.6	0.6	0.6	0.3			0.3		0.3						0.8				
	NO SHOOTS THAT DID NOT FRUIT	3316	80.0	42.6	21.5	12.6	10.5	6.4	5.6	3.3	7.0	4.3	6.0	8.0	8.0	3.0	8.0	8.3	7.3	3.0	4.8	2.8	3.0	3.0	5.5	4.0	2.6	1.3
VARIETY PABST AVERAGE 3 TREES	NO SHOOTS THAT FRUITED		5.6	31.0	55.6	51.0	42.0	51.3	36.0	34.3	26.6	17.0	18.3	2.3	6.3	0.6	1.3		0.6									
	NO NUTS CARRIED		8.0	48.0	133.0	116.3	89.3	125.3	90.0	83.0	64.3	48.0	41.6	14.0	16.3	2.3	2.6		2.3									
	NO SHOOTS DROPPED NUTS	0.3	1.0	4.3	6.6	4.0	3.6	6.0	5.3	3.0	2.6	1.3	1.6	0.3	0.3	0.3	0.6											
	NO SHOOTS THAT DID NOT FRUIT	72.3	64.6	59.3	22.6	11.0	10.6	5.0	8.6	5.6	5.0	4.6	8.3	5.0	4.6	4.6	6.6	3.0	4.6	2.6	2.6	2.6	4.6	3.0	7.0	4.6	3.6	5.6
VARIETY FROTCHER AVERAGE 3 TRESS	NO SHOOTS THAT FRUITED	1.6	15.6	33.0	32.3	27.3	19.0	20.6	14.3	14.0	9.6	7.3	5.6	4.6	2.6	1.6	1.3	1.3	0.3									
	NO NUTS CARRIED	1.6	23.0	54.6	65.0	57.6	42.3	51.3	40.6	19.3	26.6	14.3	16.5	12.5	8.6	5.3	2.6	4.0	0.6									
	NO SHOOTS DROPPED NUTS	1.6	8.3	4.6	2.3	2.0	1.6	0.3	1.0	1.3	0.8		0.6	0.3														
	NO SHOOTS THAT DID NOT FRUIT	17.0	72.0	34.6	18.0	8.0	8.6	4.3	6.0	4.0	4.5	2.0	5.3	3.0	4.6	3.0	3.6	3.0	3.5	4.3	2.6	2.8	4.3	5.0	4.6	4.0	6.3	2.6
VARIETY STUART AVERAGE 3 TREES	NO. SHOOTS THAT FRUITED		1.6	13.3	18.6	23.0	23.6	26.0	21.5	21.6	23.6	20.3	19.6	14.0	11.3	9.3	4.3	0.6	0.6	0.3	1.0		0.3		0.8			
	NO NUTS CARRIED		2.0	15.6	33.3	46.3	49.3	56.0	41.3	31.0	59.6	50.3	47.6	56.0	31.0	28.3	13.3	1.6	2.6	1.3	8.0		8.3		0.3			
	NO SHOOTS DROPPED NUTS					1.0	0.6	0.6	0.8	0.6	1.6	1.0	0.6	0.6	0.6	0.3	0.3	0.4	0.6		0.3		0.3	0.3	0.3		0.3	
	NO. SHOOTS THAT DID NOT FRUIT	3066	10.80	30.6	27.5	17.3	10.6	4.0	7.6	4.3	9.6	3.3	3.3	2.0	1.6	1.3	1.3	1.6	2.6	1.0	1.0	0.6	1.6	1.0	1.0	1.5	2.0	1.0
VARIETY SCHLEY AVERAGE 2 TREES	NO SHOOTS THAT FRUITED		4.3	11.5	19.0	17.3	28.0	20.0	21.3	23.5	16.0	12.0	10.0	5.0	4.6	0.6	1.5											
	NO NUTS CARRIED		16.0	23.0	35.5	54.0	43.0	33.5	31.0	33.5	41.3	40.0	28.5	12.5	11.5	1.0	3.5											
	NO SHOOTS DROPPED NUTS		1.0	2.0	1.5	0.5	1.3	1.0	1.0	1.0	1.3		1.0															
	NO SHOOTS THAT DID NOT FRUIT	178.0	13.5	51.0	20.0	14.0	4.0	3.5	4.3	3.0	3.0	4.0	3.5	2.0	4.3	0.5	3.5	1.5	4.0	1.0	1.0	1.0	3.0	1.0	2.5	2.0	2.0	4.0
VARIETY SUCCESS AVERAGE 2 TREES	NO SHOOTS THAT FRUITED	1.5	21.5	49.0	62.5	43.0	33.5	25.0	10.5	3.0	3.5	1.0	1.0															
	NO NUTS CARRIED	1.5	30.0	76.5	108.0	88.5	74.5	47.0	20.0	7.0	4.0	8.0	2.0															
	NO SHOOTS DROPPED NUTS	0.5	2.5	8.0	5.0	7.3	7.0	5.5	5.3	1.5	1.0	0.5	0.5		0.5		0.5	0.5	1.0									
	NO SHOOTS THAT DID NOT FRUIT	350	21.5	12.5	8.0	4.0	3.5	1.5	0.5	1.5	2.0	2.5		1.5		0.5	1.5	0.5	1.0	3.0	1.0	1.0	2.0	1.5	2.5	1.0	0.5	2.0

LENGTH OF SHOOTS IN INCHES		28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
VARIETY DELMAS AVERAGE 3 TRESS	NO SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO. SHOOTS DROPPED NUTS																											
	NO SHOOTS THAT DID NOT FRUIT	2.8	1.0	1.6	1.6	0.6	0.6	1.6	0.3	2.3	0.3	1.0																
VARIETY PABST AVERAGE 3 TREES	NO SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO SHOOTS DROPPED NUTS																											
	NO SHOOTS THAT DID NOT FRUIT	2.6	2.5	1.6	1.3	1.6	2.0	1.5		1.0		1.0	1.0	0.6	0.3	0.6		0.3	0.3		0.3							
VARIETY FROTCHER AVERAGE 3 TRESS	NO SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO SHOOTS DROPPED NUTS																											
	NO SHOOTS THAT DID NOT FRUIT	3.5	1.0	2.6	3.0	2.3	1.0	2.0	0.6	2.6	1.0	3.3	0.6	1.5		0.6	1.3			0.3		0.3						
VARIETY STUART AVERAGE 3 TREES	NO. SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO SHOOTS DROPPED NUTS																											
	NO. SHOOTS THAT DID NOT FRUIT	1.3	0.3	1.3	0.6	0.8	1.3	1.3	0.3	3.0	0.3	1.6	0.3	1.6		0.6	0.3	0.6				1.0						0.3
VARIETY SCHLEY AVERAGE 2 TREES	NO SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO SHOOTS DROPPED NUTS																											
	NO SHOOTS THAT DID NOT FRUIT	2.0	2.0	3.5	0.5	2.0	1.5	1.5		0.5	0.5	0.5		1.5		1.0						2.0	0.5					
VARIETY SUCCESS AVERAGE 2 TREES	NO SHOOTS THAT FRUITED																											
	NO NUTS CARRIED																											
	NO SHOOTS DROPPED NUTS																											
	NO SHOOTS THAT DID NOT FRUIT	1.5	3.0	1.5	2.0	1.0	1.5	0.5	2.0	3.5	1.5	0.5	1.0	1.5	1.5	0.5	1.5	1.0			0.5	0.5	1.0					

shoots. Heavy production must await the general appearance of shoots of medium length. The Frotscher is known to be a heavy producer where it receives an abundance of nutrients and moisture, for it fruits on shoots having a wide range in length. Possibly failure of the short shoots to retain the nuts is responsible for its low yields under unfavorable moisture and nutrient conditions. Petri. (11) showed this to be true with olives, as was also suggested by Lewis (9) and by Bradford (1) with apples.

The ability of the Stuart to fruit rather freely on shoots having a considerable range in length probably explains why it seems adapted to such an extended territory and such a wide range of soil types. It is one factor in accounting for its general popularity among pecan growers. The data suggest also why the Schley variety is not often a heavy bearer. Its maximum nut production is on shoots having a rather narrow range in length; no great percentage of the shoots ever reach the minimum fruiting length for that variety.

The fact that the Success variety fruits on comparatively short shoots, coupled with the fact that its foliage is not very luxuriant, probably explains why it requires an abundant nutrient and moisture supply to fill properly the heavy crop of nuts that the trees attempt to carry.

In general it may be said that the longer shoots carry more nuts than the shorter shoots, indicating that vigorous growth is necessary for maximum nut production. This suggests to the pecan grower the advisability of furnishing the trees with the best possible growing conditions. This is true especially of those varieties that fruit on short shoots and those varieties that have a tendency to produce a large percentage of shoots below minimum fruiting length, and which do not have naturally very vigorous growing habits.

Influence of the Kind of Shoot Growth Made One Year on the Number of Flowers Produced and Nuts Set the Following Spring

THE INFLUENCE of the kind of shoot growth made one year on the number of flowers produced and nuts set the following spring was determined by labeling, during the fall of 1922, long and short vegetative shoots that did not abscise the terminal bud, vegetative shoots of similar length and size that abscised the terminal bud and fruiting shoots of similar length and size and recording the behavior of the shoots arising from them in the spring of 1923.

These data are shown in Table 3. The different kinds of shoots are illustrated in Figure 30 A and A′, B and B′, C and C′.

Table 3.—Influence of Kind of Shoot Growth Made One Year on the Number of Flowers Produced and Nuts Set the Following Spring*.

	Shoot that did not abscise terminal bud in 1922		Shoot that abscised terminal bud in 1922		Shoot fruiting in 1922	
	Length of shoot under 6 in.	Length of shoot over 6 in.	Length of shoot under 6 in.	Length of shoot over 6 in.	Length of shoot under 6 in.	Length of shoot over 6. in
Delmas variety						
Catkins	9	32.9	9.9	32.8	13.4	15.6
Pistillate clusters formed	1.3	1.6	1.4	2.0	1.6	1.7
Pistillate clusters set	1.1	1.4	1.0	1.7	1.1	1.3
Nuts apparently set	3.6	6.5	3.0	7.8	4.2	5.9
Stuart variety						
Catkins	5.2	25.0	8.3	21.7	8.5	14.1
Pistillate clusters formed	1.3	1.9	1.2	1.8	1.8	1.7
Pistillate clusters set	0.6	1.6	0.9	1.6	1.0	1.5
Nuts apparently set	1.5	5.5	3.1	7.16	3.4	5.6

* For each group 21 to 28 shoots were recorded.

DISCUSSION

THE DATA IN this table show that in general buds out of long shoots produced more catkins and clusters of pistillate flowers and also set more nuts than did buds on short shoots of the same type. This is at variance with Woodroof's (17) statement that short shoots produce as many catkins as long shoots. Harvey and Murneek (5) found that in the apple the leaf area influenced the number of fruits per spur. This may also be true for the pecan and thus explains why the pecan grower who gives his pecan grove what it requires to make good vegetative growth produces more pecans per acre than the grower who does not, although each orchard may have the same number of shoots fruiting.

The fact that short shoots of the Stuart variety that did not abscise the terminal buds the previous year—as shown in Table 3—apparently set an average of 1.5 nuts, while shoots of similar length that fruited or dropped the terminal bud produced 3.4 and 3.1 respectively suggests that short shoots of this type are not as likely to fruit as short shoots of similar length that terminate differently. This may indicate that these shoots continue vegetative growth until rather late in the season and do not have enough stored food to initiate pistillate flower differentiation, or, if enough to initiate it, not enough to carry it to setting. If this is true and it could be applied to such varieties as the Schley, which often makes many short shoots that do not fruit, it may explain why the variety is not a regular bearer. The summer of 1925 was so dry that there was no second growth. The Schley variety fruited very well in 1926, which suggests further that this may be true. It is interesting to note in this connection that Roberts (12) found with the plum that blossom buds formed earlier on shoots that terminated growth earlier.

Influence of Kind of Terminal on Pistillate Flower Production the Following Spring

TO OBTAIN DATA on the influence of the kind of terminal formed by a shoot on the performance of the laterals growing out from it, a number of shoots were selected at random on trees of each of several varieties in the fall of 1925 and examined the spring 1926. The shoots were grouped to include (1) those that terminated with terminal buds, (2) those that abscised terminal buds, and (3) those that bore nuts. The data are summarized in Table 4 which follows:

Table 4.—Influence of Kind of Terminal Formed in the Season of 1925 on the Number of Shoots That Produced Pistillate Flowers the Spring of 1926.

Variety	Sawyer (2 trees)	Tesche (2 trees)	Centennial (1 tree)	Schley (2 trees)	VanDeman (2 trees)
No. shoots examined	188	116	105	192	203
Per cent shoots that terminated 1925 with terminal bud	33.51	20.68	83.80	40.11	9.35
Per cent terminal buds growing and producing pistillate flowers	77.77	91.66	68.18	74.02	*0.00
Per cent terminal buds not growing but pistillate flowers being produced on growth from lateral buds	17.46	8.33	1.13	9.09	100.00
Per cent shoots that terminated 1925 with nuts	16.48	20.68	0.00	43.75	25.61
Per cent shoots terminating with nuts 1925 and producing pistillate flowers 1926	92.90	100.00	0.00	84.52	100.00
Per cent shoots terminating 1925 with extra-axillary buds producing flowers 1926	50.00	58.62	16.19	16.14	65.02
Per cent shoots terminating 1925 in extra-axillary buds and not producing pistillate flowers 1926	6.38	0.00	5.88	12.90	0.00

* VanDeman shoots not included in this count were found that produced pistillate flowers out of terminal buds.

It is shown in Table 4 that it is possible for all varieties to fruit from true terminal buds, but the percentage of terminal buds that fruit is very low in some varieties. On the other hand, some varieties fruit from a large percentage of the terminal buds formed.

Flower Production from Terminal Buds

ON MOST VARIETIES a large percentage of the terminal buds are abscised before growth starts the spring following their formation. However, a study was made of several individual shoots that terminated with terminal buds that did not abscise to determine exactly how these buds behave the following spring. Table 5 presents these data.

Table 5.—Behavior During Spring of 1926 of Terminal Buds Formed in 1925

Variety	No. shoots with terminal buds	Per cent of terminal buds producing pistillate flowers	Per cent terminal buds growing but failing to produce pistillate flowers	Per cent terminal buds failing to grow	Per cent terminal buds producing catkins
Frotscher	116	18.10	0.00	81.90	0.25
Delmas	233	97.85	1.28	0.85	10.72
Stuart	42	97.64	0.00	2.38	0.00

These data show that the terminal bud is unlike most mixed or extra-axillary buds in the pecan in that it usually does not contain catkin flower buds that develop far enough to furnish pollen. On the other hand, they show that in some years true terminals in some varieties give rise to a high per cent of pistillate-flower-bearing shoots.

Figure 34 illustrates a shoot on which the terminal bud failed to grow, and fruiting shoots arose from buds where the terminal abscised. Figure 35 illustrates a shoot on which the terminal bud produced a fruiting shoot. In this illustration is shown also a fruiting shoot that arose below the terminal fruiting shoot.

Influence of Second Growth on Number of Flowers Produced and Nuts Set the Following Spring

A FIELD STUDY of the growing habits of the pecan, Table 1, showed that some varieties make a considerable amount of "second growth" after nuts are set. Table 6 presents data on how the following season's vegetative growth and flower production from these secondaries compare with that of shoots not making a second growth.

Table 6.—Influence of Second Growth on Number of Flowers Produced and Nuts Set the Following Spring*.

	Shoots that did not produce second growth		Shoots that produced second growth			
	Length of growth		Length of growth 6 inches		Length of growth 6 inches	
	Under 6 in.	Over 6 in.	Under 1st growth	2nd growth	Over 1st growth	2nd growth
No. catkins	4.3	6.0	3.1	10.0	1.6	11.0
No. pistillate clusters formed	2.3	2.1	1.2	2.4	1.2	2.3
No. pistillate clusters set	1.3	1.1	0.4	1.7	0.13	1.6
No. nuts apparently set	4.8	4.2	0.04	7.0	0.4	6.9

* For each group 27 to 32 shoots that fruited in 1922 were used.

DISCUSSION

These data show:

(1) That the production of laterals incident to "second growth" increases the number of both catkins and pistillate clusters; and (2) that the laterals of shoots that make a second growth produce more catkins and more pistillate clusters than the primary portions of the same shoots. Incidently they substantiate the statement made earlier to the effect that there is a long period of catkin bud differentiation. Gourley (4) has shown that in the Baldwin apple there is a second period of fruit bud formation the latter part of the summer and early fall, as evidenced by fruit bud formation on the terminus of the second growth. It appears that the catkin flowers that have already been differentiated when second growth occurs do not have an equal chance for development and flowering with those on the secondary shoots.

Field observations indicated that long shoots that made a "second growth" without dropping the terminal bud of the primary shoot, as shown in Figure 38D, E, F, are not very likely to fruit the following season. Heinicke (6) believed that after growth finally ceased on long apple twigs the time remaining for active assimilation was inadequate for abundant storage in the buds. This is probably true also of those pecan shoots shown in the figure to which reference has just been made. These shoots in the pecan are characterized by a group of very short internodes, at the nodes of which are located small weak buds that were subtended by poorly developed leaves.

Heinicke (6) says that the exact cause of variation in bud vigor in the apple is not known. In the pecan, on shoots as shown in Figure 38 E and F, the buds located at nodes not far back of the terminal are weak because the shoot was about to terminate growth by abscising the terminal parts when additional linear growth was made. However, the weak foliage and buds on the part that was about to abscise never recovered enough to become vigorous.

Influence of "Second Growth" on the Ultimate Weight of the Nut

FIELD OBSERVATIONS suggested that developing nuts on shoots that made second growth might be smaller than nuts on shoots making no second growth. Nuts were harvested from four varieties in the fall of 1923, three varieties in 1925, and from one variety in 1926, and weighed to determine whether these differences actually existed. Table 7 presents these data.

Table 7.—Number of Nuts per Cluster and the Comparison of the Weight per Nut on Shoots That Did and Did not Make Second Growth

			Shoots that did not make second growth			Shoots that made second growth		
Year	Variety	No. trees	Av. No. nuts per cluster	Av. wt. nuts per cluster	Av. wt. per nut	Av. No. nuts per cluster	Av. wt. nuts per cluster	Av. wt. per nut
				gms.	gms.		gms.	gms.
1923	Stuart	2	2.11	16.89	8.00	3.00	21.47	7.15
1923	Success	1	2.72	18.08	6.55	2.78	19.10	6.87
1923	Frotscher	2	2.11	20.34	9.65	2.36	21.08	8.94
1923	Tesche	2	2.30	14.31	6.22	2.76	15.39	5.54
1926	Tesche	2	3.04	17.63	5.80	3.71	21.02	6.16
1925	Stuart	5	2.25	20.20	9.05	No second growth occurred		
1925	Success	5	1.85	19.15	10.30	No second growth occurred		
1925	Frotscher	4	2.10	19.32	9.16	No second growth occurred		

DISCUSSION

IT IS EVIDENT that in 1923 the average weight of nuts per cluster and average number of nuts per cluster were greater in all varieties compared where the shoots carrying nuts made second growth, but the average weight per nut was smaller with three of the four varieties compared. The same was true of the Tesche in 1926, except the average weight per nut was greater on shoots making a second growth.

These facts indicate strongly that the shoots which for some reason are carrying the greatest number of nuts are also most likely to produce a second growth. It is also evident that the appearance of second growth influences the weight of the mature nut. A study of the rainfall at Auburn during these years indicates that the initiation of second growth is associated with heavy rainfall during the early growing period, and that the amount of rainfall during late summer and early fall influences the filling and, in turn, the weight of mature nuts.

PART III. INFLUENCE OF PRUNING, DEFOLIATION, RINGING, AND DISBUDDING ON NUMBER OF SHOOTS AND FLOWERS PRODUCED

Influence of Pruning on Shoot and Nut Production

PECAN GROWERS have generally believed that when a pecan shoot is pruned (i. e. headed back) it will not produce nut-bearing laterals the following season. Field observations in 1923 indicated that this notion does not accord with the facts (see Fig. 39) and raised the question as to whether or not certain types of pruning,—for example, that incident to cutting scion wood,—on some varieties might be practiced without injury and with the possibility of favorably influencing the quality and quantity of nuts. Following these observations an effort was made to determine how shoots on different varieties would respond to varying amounts of heading back at different dates.

Shoots that fruited in 1923 without producing a second growth and shoots that fruited and produced a second growth were pruned at different times and with various degrees of severity. Shoots that made a second growth were pruned to determine whether or not the secondaries would fruit after pruning and whether the first growth would fruit if all the second growth were cut away. The season of 1924 was not a heavy crop year

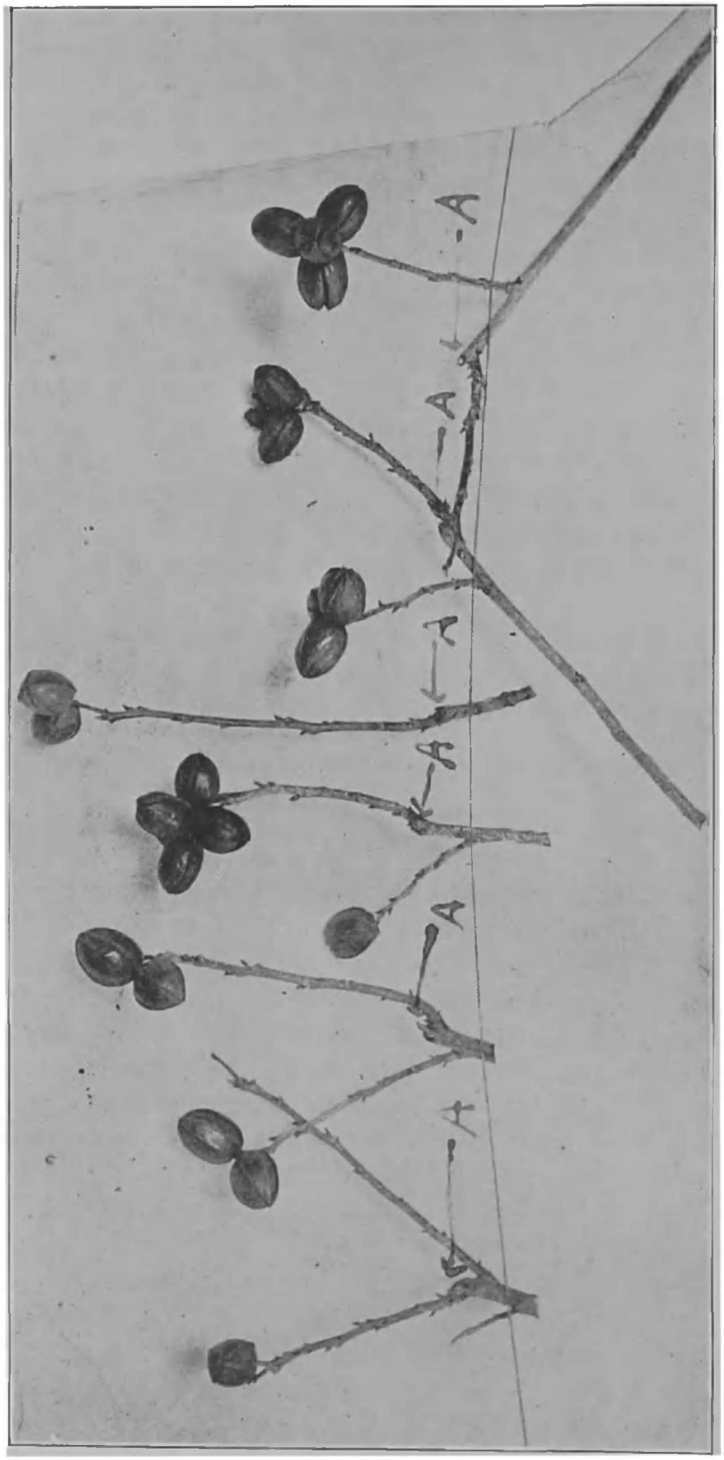


Fig. 39.—Fruiting shoots that grew from below pruning cut. Shoots were headed back at A.

and the data secured that season were not very extensive. They did, however, indicate that buds below cuts on all of the three classes of shoots mentioned could be made to yield fruit-bearing laterals if the shoot would have normally fruited out of buds near the terminal without pruning.

In another experiment, shoots that were vegetative throughout 1923 were pruned so that there would be four, eight, twelve, or sixteen nodes left after pruning. These were tagged and their growth compared with that from checks (i. e. unpruned shoots) in the spring of 1924. The resulting records are presented in Table 8.

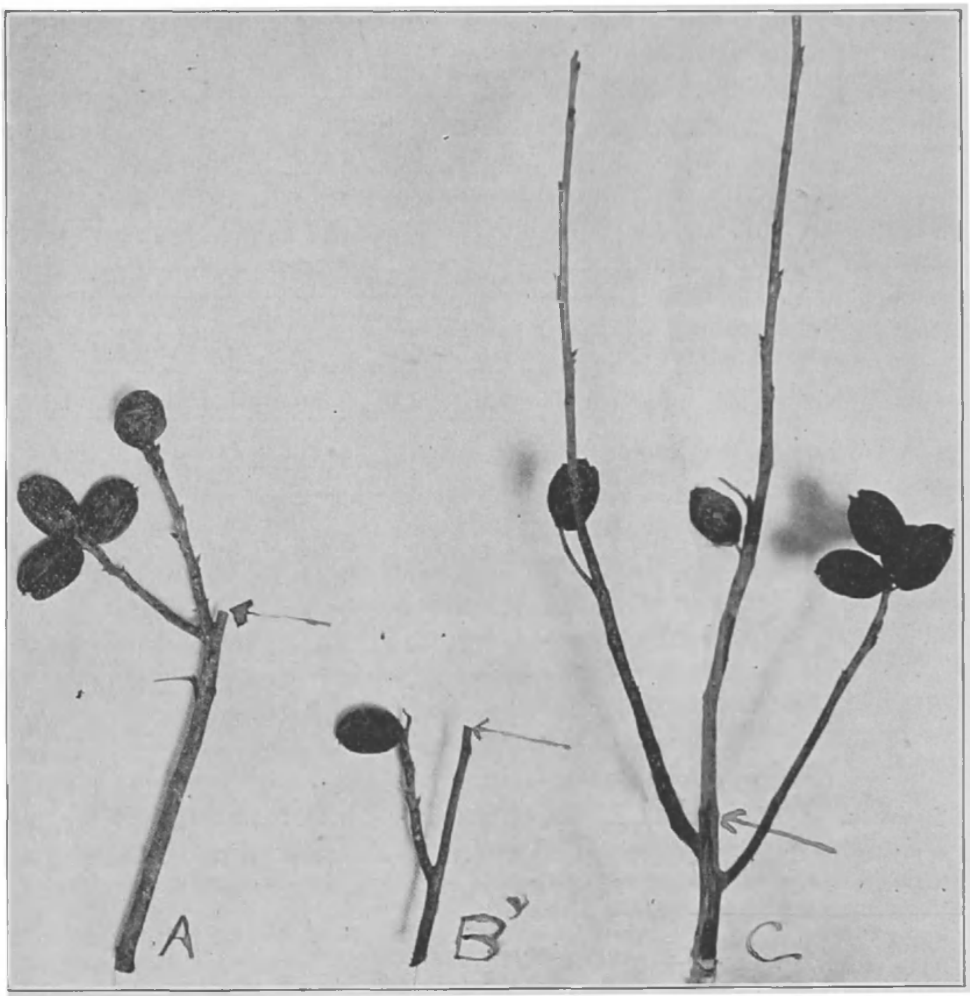


Fig. 40.—Nut-bearing clusters of the Success.

A.—Pruned shoot with two buds arising at the same node and fruiting.

B.—Pruned shoot fruiting out of a bud far below where shoot was headed back.

C.—Shoots arising below pruning cut, fruiting and making second growth. All cuts made at point indicated by arrow.

Table 8.—Influence of Different Degrees of Pruning on Production of Nuts the Following Year

No. nodes left after pruning		Varieties Delmas	Frotscher	Pabst	Schley	Stuart	Success
4	No. shoots pruned	13	9	5	10	2	12
	Shoots produced per pruned shoot	2.53	2.11	2	1.7	2.5	1.66
	Nuts produced per pruned shoot	0.0	0.0	0.0	0.0	0.0	1.58
8	No. shoots pruned	15	11	7	8	6	16.0
	Shoots produced per pruned shoot	3.2	2.81	2.28	2.5	2.5	2.25
	Nuts produced per pruned shoot	0.33	0.0	0.0	1.0	0.33	1.37
12	No. shoots pruned	21.0	9.0	7.0	8.0	8.0	10.0
	Shoots produced per pruned shoot	4.61	3.55	2.71	2.75	4.62	2.8
	Nuts produced per pruned shoot	1.61	0.0	0.32	0.87	2.62	1.7
16	No. shoots pruned	23.0	3.0	3.0	1.0	3.0	12.0
	Shoots produced per pruned shoot	5.65	4.66	3.0	3.0	5.0	2.66
	Nuts produced per pruned shoot	0.0	1.0	0.3	5.0	3.33	1.58
Check Not pruned	No. shoots not pruned	20.0	17.0	11.0	7.0	26.0	22.0
	Shoots produced per shoot	3.65	3.0	3.09	3.14	4.3	2.09
	Nuts produced per shoot	0.0	0.0	0.18	0.71	1.76	1.18

These data, though not extensive, indicate that some varieties may respond very satisfactorily to certain amounts of heading back. It was observed that, at least in the Success variety, it is possible for two of the buds at a single node to produce fruiting laterals and that, even though the buds near the cut on a pruned shoot may not grow, those lower down may grow and fruit, and that pruned shoots may produce laterals that fruit and make second growth. This is shown in Figure 40, A, B and C respectively.

DISCUSSION

RESULTS OBTAINED from heading back shoots as shown in Figure 40 A explain why shoots on some varieties may drop the extra-axillary bud at practically every node and then fruit freely on shoots developing from buds that are left.

Partridge (10) found that the fruiting capacities of grape buds vary with their position on the cane. There is a suggestion that the same may be true to a certain degree with reference to the position of the bud on the shoot of certain varieties of the pecan. Not only does the position of the bud on the shoot influence its ability to differentiate a pistillate flower cluster and its likelihood of fruiting, but the position likewise influences its fruiting capacity,—i. e., the number of flowers that the cluster produces.

Apparently the pecan shoot may be comparable in some degree with the raspberry and fig in that the buds at the most basal nodes are potentially fruit buds, though they are usually not utilized for fruit production unless the more terminal parts are removed by pruning, or otherwise.

Influence of Defoliation and Ringing on Shoot and Fruit Bud Formation

A YOUNG VanDeman pecan trees which had been killed back and sprouted out near the point of union of stock and scion was thought to be from the stock. In July 1921 an attempt was made to topwork this tree by means of ring budding one of its branches about eight inches from the main trunk. The ring or patch of bark carrying the bud lived but the bud which it carried did not grow and the branch was not cut back. Examination of the tree on October 16, 1922, led to the discovery that it carried five nuts of the VanDeman variety, showing that it had not been killed back to the stock and that the sprout had sprung from near the base of the scion. Three of the five nuts were on the branch that had been girdled incident to the budding operation, suggesting that ringing in this case might have promoted rather than interfered with fruit bud formation.

Following these observations experiments were planned to determine the influence of defoliation, ringing and certain combination treatments on fruitfulness in the pecan. Shoots on Delmas and Pabst trees were treated as follows during the weeks of July 13-26, 1924:

(1) Vegetative shoots 5 to 10 inches long were partly defoliated by severing the rachis (extension of the petiole) beyond the two basal leaflets. Any late summer growth produced by these shoots was left undefoliated.

(2) Vegetative shoots were defoliated as in (1) and the new growth that developed was promptly defoliated in a similar manner. As a matter of fact, such a small quantity appeared that the records of these shoots were grouped with those of (1) when final records were made.

(3) On vegetative shoots as in (1) a ring of bark one-fourth inch wide, located four nodes from the base, was removed and left unwrapped.

(4) From another group of shoots similar to those used in (1) the ringed portion was immediately wrapped with waxed cheesecloth, such as is used in budding the pecan.

(5) Other vegetative shoots similar to (1) were ringed as in (3) and partly defoliated as in (1).

(6) Still other vegetative shoots were ringed as in (3) and partially defoliated to the base of the 1924 growth.

(7) Vegetative shoots of medium vigor, 5 to 10 inches long and distributed throughout the tree were selected, left untreated and labeled as checks.

THESE SHOOTS were examined the latter part of August. On the Delmas where the wrap was wide enough to cover the ringed part and rest on the bark on either side, the ringed area had nearly or entirely healed. In many cases the callus or new bark formed at right angles to the branch was sufficient to force its way through two layers of wrapping cloth. There was a limited amount of new terminal growth, perhaps to an extent of about eight leaves. Where the shoots were defoliated and the wrappers were so narrow as to fit into the ringed spaces preventing the callus from bridging the wound, the bud just below the ring developed into a short shoot in a number of instances.

Pabst shoots had callused about the same as those on the Delmas. However, there was no additional growth from the terminal bud. In only a few instances did lateral buds even on the most vigorous shoots give rise to a second growth. In both varieties there was a tendency for partly defoliated shoots to drop even what foliage was left. This was most marked towards the base of the shoot and on the less vigorous trees.

By September 23, many of the treated shoots on Pabst variety were dropping the foliage. In some cases this condition extended only to the ring and in others to the base of the shoot. Similar shoots on Delmas had less tendency in this direction.

The treated shoots were examined the spring following treatment to determine the influence which different treatments and different degrees of healing of the ringed portion had on location and number of catkin flowers, pistillate flowers, and vegetative shoots that appeared.

A very few of the shoots with rings left unwrapped died before the spring following treatment. Figure 41 illustrates how this class of shoots appeared the following spring. It will be noted in this illustration that the majority of the vegetative response is out of the bud located just below the ringed area as indicated by the arrow. It will also be noted that there was a rather heavy production of catkin flowers at the first nodes below the ring.

Delmas shoots on which the ring failed to callus—due to interference of the wrap—produced vegetative growth and catkin flowers immediately below the ringed area and a rosette of several poorly developed leaves at the terminal the spring following treatment. Figure 42 illustrates this type of shoot.

Pabst shoots on which the ring failed to callus due to interference of the wrap responded the following spring in two more or less different ways. One was with vegetative growth and catkin development below the ring very similar to such shoots on Delmas. These varieties however showed great contrast in the response secured on the terminal portion of the treated shoot. The Pabst produced many catkins that died before reaching more than half normal development. This response is well illustrated in Figure 43.

Other Pabst shoots on which the callus failed to cover the ring gave vegetative growth, pistillate and catkin flower response below the ringed area and a terminal catkin response that was so weak as to almost fail to throw off the bud scales before dying. Figure 44 illustrates a shoot that gave these responses.

The differences pointed out above between the two varieties may be at least partly due to difference in relative maturity of Delmas and Pabst shoots at time of ringing. With shoots of both Delmas and Pabst varieties on which the ringed area partly callused, the vegetative response and catkin flower develpoment tended to be distribtued over the entire shoot with the greatest response occurring just below the ring and at the terminal part, while the weakest vegetative and catkin response seemed to appear not far above the ringed area.

These responses for Delmas and Pabst shoots are illustrated by Figures 45 and 46 respectively. With shoots of Delmas and Pabst on which the ringed area almost or entirely callused the catkin flowers appeared just below the ring and toward the terminal, with catkins absent just above the ring. The flower and vegetative response of this class of Delmas shoots is illustrated in Figure 47, while that of the Pabst is illustrated in Figures 48 and 49. In connection with these observations on the influence of ringing, Figure 50 is included to illustrate a fruiting shoot arising out of an adventitious or reserve bud two years after being ringed by a wire. The influence of defoliation on the production of flowers is illustrated in Figure 51.

In vigorous apple and pear trees, girdling and ringing have frequently induced fruitfulness in the portion above the girdle; in the pecan like results have not been secured. However, it must be recognized that in the apple the time the operation is performed makes a great difference in the results, as has been found to be true in case of the pecan (8). Furthermore, girdling the apple is generally practiced on wood distinctly older than that used in this work on the pecan. With all these allowances made, however, the effects actually appearing are certainly quite different from any that could be expected in the apple, and suggest the possibility of a different chemical basis for blossom differentiation. This would not be surprising in view of the different periods of differentiation in the apple and the pecan.

Fig. 41.—A Delmas shoot where the ring was not wrapped. The part of the ringed shoot above the ring died before growth started the following spring.

Fig. 42.—A Delmas shoot on which the ring did not callus. Vegetative growth and catkins were produced immediately below the ring, and a whorl of small leaves on the terminal part of the ringed shoot the spring following ringing in summer.

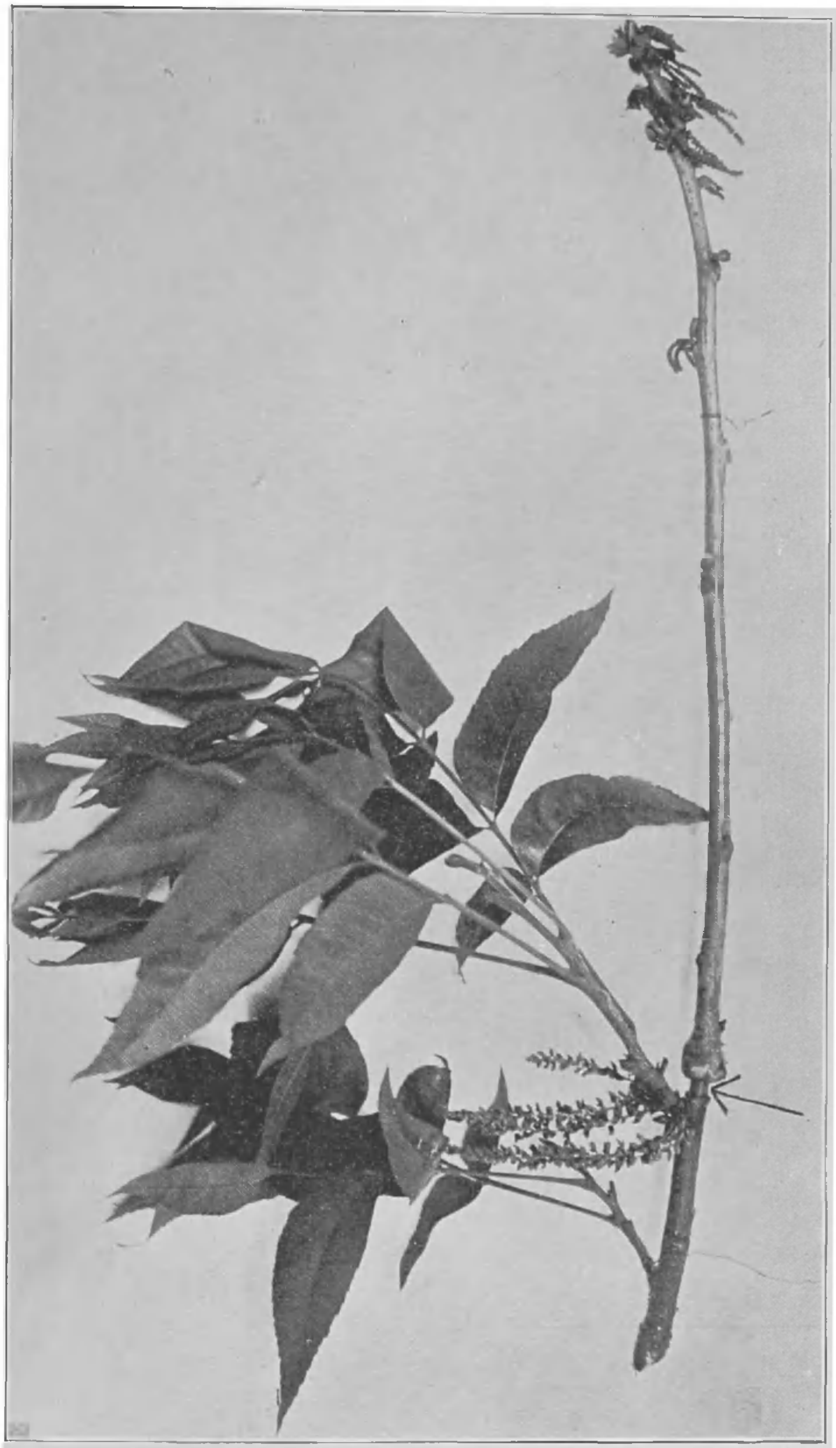


Fig. 43.—A Pabst shoot on which the ring did not callus. It produced vegetative growth and catkins below the ring, and a few weak catkins toward the terminal part of the ringed shoot the spring following ringing.

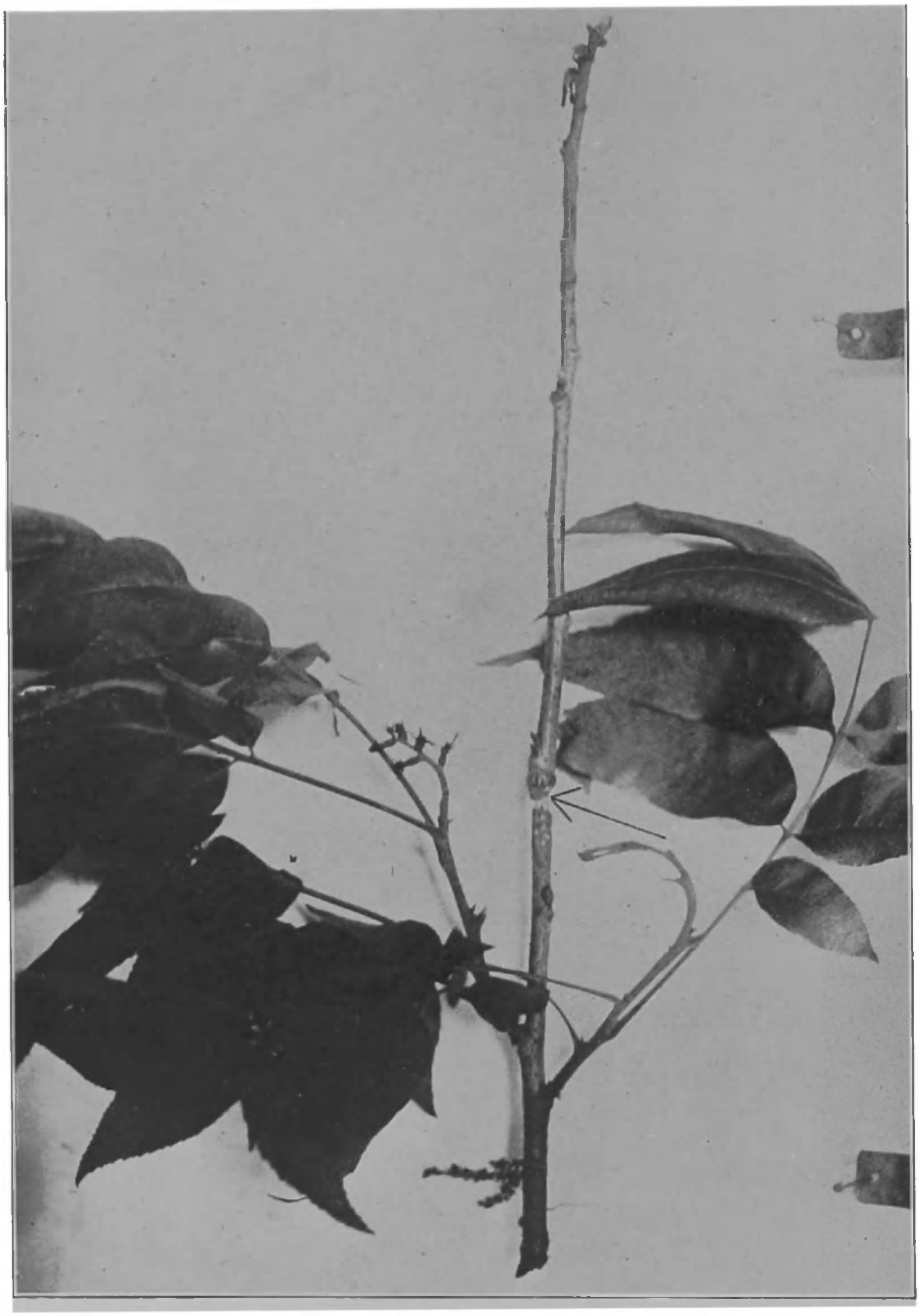


Fig. 44.—A Pabst shoot on which the ring did not callus. It produced vegetative growth, catkin flowers and a cluster of pistillate flowers below the ring, and weak catkin flowers near the terminal part of the ringed shoot the spring following ringing.

Fig. 45.—A Delmas shoot on which the ring healed partly. The vegetative growth and catkins appeared above and below the ring the spring following ringing, and both were vigorous.

Fig. 46.—A Pabst shoot on which the ring healed slightly. The vegetative growth and catkins appeared the spring following ringing above and below ring.

Fig. 47.—A Delmas shoot on which the wound caused by ringing almost healed. The vegetative growth and catkin flowers appeared above and below the ring and pistillate flowers only above the ring.

Fig. 48.—A Pabst shoot on which the ring healed entirely. The catkin flowers appeared below and above the ring while the vegetative growth and pistillate clusters appeared only above the ring. Foliage removed to show pistillate flowers on young shoots.

Fig. 49.—A Pabst shoot where the ring partly healed. Nuts set both above and below the ring. Those below the ring matured, while those above dropped before maturity.

Fig. 50.—A shoot arising and fruiting out of an adventitious or reserve bud two years after being ringed by a wire. The variety is Sawyer and the tree is about eight years old.

Fig. 51.—Shoots that were (A) and were not (B) defoliated. Otherwise these shoots were apparently alike. They were on the same branch. Note that B produced more catkins than A and it also produced a cluster of pistillate flowers while A did not.

BETWEEN MAY 1 and May 15, 1925, the treated shoots were examined further to determine the number of branches that had arisen both above and below the ring; also the vigor of these new shoots and the number of pistillate clusters and staminate flowers produced. A young shoot that made little growth and carried small, light colored leaves was termed very weak; one that made a long, well developed growth and carried large, deep green leaves similar to the best arising from buds on the untreated shoots was termed very vigorous. The terms weak, medium, and vigorous represent gradations between these two extremes.

Figures indicating relative vigor of the treated shoots as reflected by vigor of young shoots arising from them were obtained by assigning to very vigorous, vigorous, medium vigorous, weak and very weak shoots values of 10, 8, 6, 4 and 2 respectively and multiplying the number of shoots occurring in each group by the assigned value and adding to secure total vigor, then dividing by number of shoots treated to get averages. By this method of estimating vigor of the treated shoots may be as low as zero or greater than ten.

The records that were obtained are shown in Table 9.

Table 9.—Influence of Defoliation, Ringing, Ringing and Defoliation during summer of 1924 on Shoot Growth and Fruit-Bud Formation—4 to 6 trees were used in all cases and from 5 to 77 shoots were treated

Treatment	Variety	Average No. of shoots produced per treated shoot spring following treatment		Av. vigor per treated shoot as indicated by vigor of shoots produced spring following treatment		Av. no. of blossoms produced per treated shoot spring following treatment			
						Catkins*		Pistillate clusters	
		Above girdle	Below girdle	Above girdle	Below girdle	Above girdle	Below girdle	Above girdle	Below girdle
Ringed and defoliated to base. Ring partly or entirely healed	Delmas	1.4	1.0	8.93	6.8	13.4	4.33	0.0	0.0
	Pabst	1.66	0.55	11.77	3.22	17.22	4.55	0.66	0.11
Ringed and defoliated to base; no part of ring healed	Delmas	0.43	1.26	2.08	10.52	0.00	4.56	0.00	0.00
	Pabst	0.14	1.96	0.42	13.57	0.25	5.43	0.07	0.03
Ringed and defoliated to ring. Ring partly or entirely healed	Delmas	1.63	1.09	10.18	7.81	12.54	2.72	0.0	0.0
	Pabst	1.60	0.60	9.60	3.60	12.00	3.00	0.60	0.0
Ringed and defoliated to ring; no part of ring healed	Delmas	0.78	1.46	4.07	13.85	0.0	4.82	0.0	0.03
	Pabst	0.12	1.78	0.36	12.72	0.15	12.72	0.0	0.18
Ringed, ring partly or entirely healed	Delmas	1.72	1.50	17.44	19.44	16.88	3.11	0.14	0.05
	Pabst	1.55	1.44	9.11	7.77	16.00	5.0	0.33	0.33
Ringed, no part of ring healed	Delmas	0.58	2.00	2.34	12.00	0.0	5.30	0.0	0.03
	Pabst	0.08	1.66	0.33	12.16	1.12	5.79	0.04	0.33
Defoliated	Delmas	1.80		11.74		18.37		0.06	
	Pabst	2.20		14.61		32.18		0.40	
Check	Delmas	1.72		13.08		21.77		0.50	
	Pabst	2.17		19.79		14.34		0.75	

* In case of Pabst a storm removed some of catkins before count was made.

IT IS OBVIOUS that data in Table 9 were obtained from a comparatively small number of shoots but there seems to be sufficient evidence to show that:

(1) The number of young shoots produced above the ring, where it was partly or entirely healed, was in all cases greater than the number below the ring.

(2) The number of young shoots produced above the ring, when no part of the ring healed, was less in all cases than the number produced below the ring.

(3) The vigor of the shoots produced above and below the ring depended on the extent to which the ring had healed. Where it had healed the vigor of shoots was greater above the ring than where it did not heal.

(4) Defoliation tended to increase the number of shoots produced and lower the vigor of shoots produced in both varieties.

(5) Defoliation materially cut down the number of clusters of pistillate flowers in both varieties.

(6) Defoliation cut down catkin flower production in the Delmas and apparently increased it in the Pabst variety. The increase in case of the Pabst may have been due to possible error in estimating and figuring catkins, since it is possible that only the weak shoots of the check held catkins after the storm.

(7) Ringing and preventing the ring from healing reduced catkin and pistillate cluster formation in both varieties more than did defoliation.

(8) Ringing and allowing the ring partly or entirely to heal resulted in a slight increase in the number of catkins in Pabst and Delmas and decreased the number of pistillate clusters in both varieties. The decrease was considerable in case of Delmas.

(9) Ringing and defoliating to the base of the shoot and then not allowing the ring to heal resulted in reduction of catkins and in the complete prevention of nut cluster formation in Delmas and in reduction in case of Pabst.

(10) Ringing and defoliating to the base of the shoot and then allowing the ring to partly or entirely heal resulted in an increase in number of catkins and pistillate clusters in Pabst, and to a considerable reduction in catkins and prevention of pistillate cluster formation in case of Delmas.

(11) In general preventing the healing of the ring reduces flower production.

Influence of Disbudding on Shoot and Fruit-Bud Formation

TO OBTAIN definite data on the degree of uniformity or similarity between the several buds at a single node, as measured by the kind of shoots to which they give rise, a series of disbudding experiments was started on Stuart and Pabst trees.

Shoots that carried nuts in 1925 were labeled and the first, first and second; first, second and third buds at the first six nodes below the nut scar were removed on different trees at weekly intervals from March 24 to April 14, 1926, and their subsequent records checked against those of similar shoots from which no buds were removed. The response to disbudding for the two varieties was very similar. Data for Stuart are given in summarized form in Table 10 and illustrated in Figure 52.

Table 10.—Influence of Disbudding on Production of Shoots and Flowers (variety Stuart)

Position (1)	No. of shoots produced				No. of catkins produced				No. of pistillate clusters			
On node Below terminal	Check	1 bud re-moved	2 buds re-moved	3 buds re-moved	Check	1 bud re-moved	2 buds re-moved	3 buds re-moved	Check	1 bud re-moved	2 buds re-moved	3 buds re-moved
1	76*	23		3	77	20	1		71	11		
2	74	19	2	3	77	20	1		41	11		
3	46	23	2		76	23	1		9	8		
4	12	15	5		71	26	1		1	3		
5	5	13	2		73	24	2		1	3		
6	3	10	2		68	24	1		1	3		
7	1	53	61	67	60	56	61	67	1	34	54	46
8	1	41	59	58	53	61	61	65	1	16	39	52
9		19	34	46	43	55	55	66		4	8	15
10		6	15	19	28	33	49	57		1	1	2
11		3	15	15	18	28	36	47			1	3
12		2	5	8	9	17	26	28				1
13		1		2	4	10	19	17				
14		1		1		5	5	10				
Total	218	228	202	222	657	402	319	357	126	94	103	137
*No. shoots used	77	64	65	69	77	64	65	69	77	64	65	69
Av. per shoot	2.8	3.6	3.1	3.0	8.5	6.3	4.8	5.2	1.6	1.5	1.6	1.9

(1) Disbudding was practiced on nodes 1-6 inclusive.

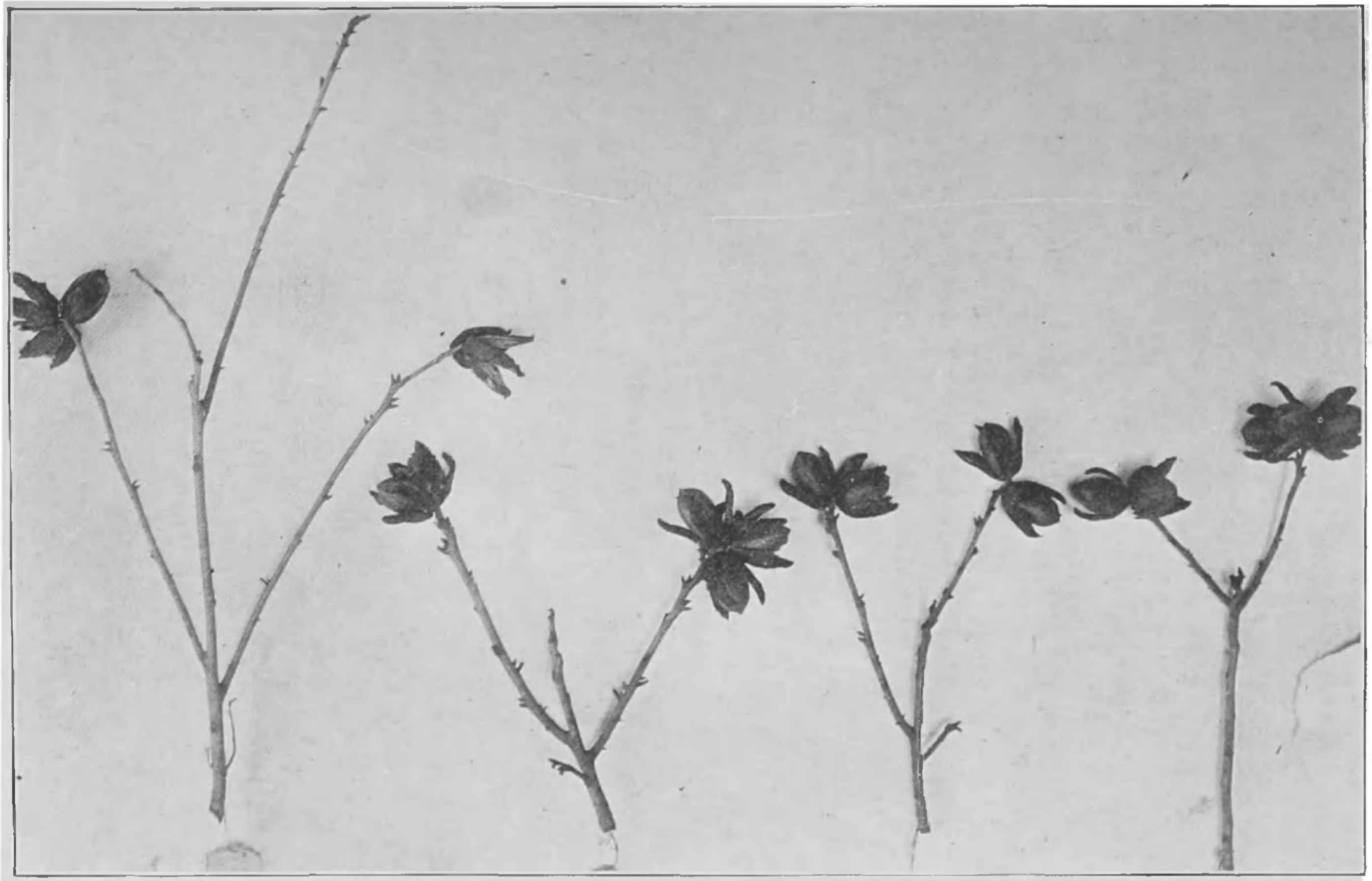


Fig. 52.—This figure shows the 1926 shoot growth arising from 1925 shoots that were disbudded to different extents. The shoot on the right was not disbudded and serves as a check. From the second, third and fourth shoots from the right, one, two and three buds respectively were removed at each of the first six nodes below the nut scar.

DISCUSSION

IT WILL BE seen from Table 10 that normally most of the vegetative growth and pistillate-flower-producing shoots arise from buds located at nodes near the terminal part of the shoot. Similarly the majority of the catkins are normally developed from buds located at nodes near the terminal part of the shoot. However, some of the catkins are normally produced from buds extending almost to the base of the shoot.

The second bud, as well as the first, at a given node may produce either pistillate or staminate flowers, or vegetative growth, or all three, while the third bud arising at a given node apparently does not differentiate flowers and produces very few catkins when the buds above it are removed as late as March 24.

The removal of more than one bud at nodes near the terminal shifts fruiting possibilities to more basal buds with a tendency to increase yields and lower catkin production, but where only one bud is removed from nodes near the terminal it tends to scatter fruiting and vegetative growth over the entire shoot. It also has the effect of lowering production from 1.6 to 1.5 nuts per shoot, as shown in Table 10, while the number of catkins is reduced from 8.5 to 6.3 per treated shoot.

Disbudding as late as April 14 caused buds to fruit that otherwise would have remained latent or produced only catkins and short vegetative shoots that would have abscised when the catkins fell.

THESE DISBUDDING experiments indicate that the condition existing in the pecan is more closely comparable to that existing in the grape, raspberry, and probably other bramble fruits than to that found in the apple, peach, and most other tree fruits whose fruiting characteristics have been carefully studied.

In other words, a comparatively large percentage of the over-wintering buds may be potentially pistillate flower buds. Under normal circumstances only a few of these will produce pistillate flowering shoots. The rest remain dormant or are abscised or perhaps give rise to weak vegetative parts that abscise along with the falling of the catkins. They function only when those that normally give rise to pistillate flowers are removed by pruning or other means. This is in marked contrast to the condition existing in the peach, pear, etc., where the flower parts are differentiated in the bud during the growing season of the year before which they open.

GENERAL DISCUSSION

THE DIFFERENTIATION of the staminate flower cluster in the bud is a process that extends over a comparatively long period, beginning in early spring in the first formed buds of the season and occurring in mid or late summer in those buds laid down in the axils of late formed leaves on secondary shoots. The extreme earliness with which these first catkins are differentiated (associated as it is in time with very slight leaf development) leads to the surmise that it is probably more closely related to and dependent on food storage conditions in the parent twig or branch, in the old wood: and, therefore, on late summer and fall activities in the tree than on spring growing conditions. However, catkin differentiation in the bud is so abundant and takes place under such a wide range of environmental, nutritive, and growth conditions that obviously it seldom, if ever, becomes a limiting factor; and, therefore, for all practical purposes may be ignored.

Pistillate-flower cluster differentiation, on the other hand, is not all-summer in duration but occurs within a relatively short period as growth is starting in the spring. The time of its occurrence is probably in itself sufficient evidence that—to the extent that it is a response to nutritive conditions within the plant—it is due to or associated with winter storage of food materials. This means that it is determined by what goes on in the tree during the summer and fall before.

In other words, the pistillate flower crop of the following year is apparently being determined while the nuts of the current year are filling and maturing, and it is then that cultural and fertilizing practices are very important if they are to function in increasing yields. Further evidence on this point is supplied by the data from the defoliation and ringing experiments.

THE DISBUDDING and pruning (heading back) experiments indicate a rather marked degree of flexibility in the pecan. It obviously has the ability to adapt itself to circumstances, in regard to fruiting, by developing a fruit crop from buds that would never have opened had the buds that normally open been uninjured or unremoved. This probably means that some types of pruning could be employed without materially interfering with crop production. However, it is doubtful if the evidence available warrants the interference that pecan yields may be increased practically or profitably by pruning.

There is a marked correlation between type and amount of new shoot growth made and the tendency to form pistillate-flower producing shoots. With some varieties this correlation is close (i. e. the range in growth associated with pistillate bud production is narrow); with others it is not so close.

The real problem of the grower is to handle his trees in such a manner that each year a comparatively large percentage of their shoot growth will be as nearly the optimum as possible for the variety in question. This means that control over production is possible largely through the soil and, incidentally, particularly important is it that cultural operations and fertilization practices be sufficient to assure good vegetative growth.

SUMMARY

1. Buds located at the more basal nodes of the new shoots rapidly differentiate into three, sometimes four, and occasionally five growing points under a common bud scale. Each of these growing points is surrounded by a separate bud scale.

2. The growing point occupying the central part of the compound bud retains its vegetative nature throughout the growing season, while the others rapidly differentiate catkins.

3. As the growing season continues buds formed at other nodes undergo similar changes. However, toward the end of the season buds on the terminal part of the shoot develop more rapidly than those near its base. Ultimately the more terminal buds come to have more and larger catkins than those at more basal nodes.

4. Catkin flower clusters develop more rapidly in the buds of those varieties that are heavy catkin producers and that put out catkin flowers early in the spring than in the case of varieties that are light catkin producers.

5. Shoots that terminate spring growth with a cluster of nuts or by dropping the terminal bud and that later make a second growth, differentiate catkin flowers on the "second growth" part of the shoot (that is, on its laterals or secondaries) very much as they did on first growth. These constitute the majority of the catkins appearing as blossoms on such shoots the following spring. The basal catkin buds on second growth shoots are the apical catkin buds of the first shoot growth. Such buds may drop when the second growth shoot pushes out, or remain on the new shoot until the following spring, at which time they may abort or produce flowers.

6. The true terminal bud in most varieties does not usually differentiate and develop catkin flowers.

7. If a tree is prematurely defoliated because of insect attack,

drought, storms, or other causes, and the tree makes a second growth, catkin flowers may appear along with the new growth.

8. The part of the compound bud that remains vegetative while catkin flower buds are differentiating continues its development by forming nodes, internodes, leaves and rudimentary buds in the axils of the leaves. Buds toward the terminal part of the shoot become very much larger than those toward the basal part of the shoot. In general the apical bud at each node becomes larger than the one immediately subtending it at the same node and the second bud at a node larger than the one just below it, and so on with all buds occurring at any given node.

9. Just about the time buds begin to swell in the spring following their formation some of the hitherto vegetative buds begin to differentiate pistillate primordia. These continue their development as the internodes of the vegetative shoot elongate until about ten or more leaves have unfolded, at which time the pistillate flowers become visible on the terminal part of the young shoot.

10. When second growth occurs on any shoot the buds formed toward its terminal are the ones that produce the majority of the nuts on that shoot the following year.

11. Normally the terminal bud of most varieties of the pecan abscises and the pistillate flowers are differentiated in larger apical buds at the nodes near the terminal. However, all varieties studied may hold at least a few terminal buds and differentiate pistillate flowers in them, and some varieties may form and hold many terminal buds that differentiate pistillate flowers.

12. The shoots of some varieties, Success for example, may lose almost all buds formed at all nodes at some time of the year. There is a tendency in such cases for the strong buds at nodes near the terminal part of the shoot to be retained for flower and fruit production.

13. The pecan produces a number of different kinds and lengths of shoots which behave somewhat differently in the several varieties. Such variations suggest that orchard practices should be adapted to the variety in order that maximum production may be obtained.

14. In general very short and very long shoots carry very few nuts.

15. Each variety produces the maximum number of nuts on shoots of rather definite length.

16. Long shoots that fruit produce more nuts than similar short shoots on a given variety.

17. Many shoots, especially those that are weak, abscise their cluster of pistillate flowers. With some this abscission occurs before the cluster of flowers is visible, with other it occurs after it is visible, but before being receptive to pollen.

18. Pruning shifts vegetative growth, catkin flower development and pistillate flower differentiation to buds at more basal nodes.

19. Defoliation reduces catkin flower development and pistillate flower bud differentiation.

20. Ringing and allowing the ring partly or entirely to heal scatters catkin flower development and pistillate flower bud differentiation over the treated shoot.

21. Ringing and preventing the healing of the ring stops catkin flower development and prevents pistillate flower bud differentiation above the ring.

22. Removing first and second apical buds at nodes near the terminal parts of a shoot in general shifts catkin flower development and pistillate flower differentiation to buds at more basal nodes, showing that the third apical bud at a node does not usually have pistillate flower producing possibilities.

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