A STUDY OF SELF-STERILITY IN PECANS

A Thesis

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in

Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture

by

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Acknowledgment

The author is deeply indebted to Dean E. J. Kyle and Mr. Guy W. Adriance, of the Horticultural Department of the Agricultural and Mechanical College of Texas, for their keen criticism and practical advice. The untiring efforts and expert assistance rendered by Mr. D. J. Pratt, of the Biology Department, in preparing the camera lucida drawings, have been invaluable.

To others who have made possible the completion of this work, I wish to extend my thanks and appreciation.

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Importance of the Project

Within the last few years the pecan has begun to assume considerable importance on the market as an article of food. Its cultivation in orchards has been developed very rapidly. Various problems in connection with the culture of this fruit have arisen. One of the chief problems is to secure a maximum yield.

It has been observed that certain varieties of pecans when planted in solid blocks, do not set fruit to any considerable extent. Up to the present time, very few investigations have been made to determine the cause of this behavior. Although several men have sought to discover the factors which caused sterility in pecan varieties, no work along this line has been done in Texas.

The work of investigators in other states is of value in Texas only so far as it gives a method of investigation which can be carried out under local conditions and with Texas varieties. It is well known that the same variety of pecan may range from self-fertility to self-sterility under environmental conditions which may or may not be favorable to pollination, and it is equally well established that different varieties vary in regard to the degree of self-fertility which each may possess.

In consideration of the above facts, it was thought desirable to test the varieties of pecans growing at this place to determine; (1) to what extent they are self-fertile; and (2) what varieties will pollinate those not completely self-fertile. Pollination must be abundant to insure a good yield.

The importance of such an investigation is shown in the following review of literature on the subject of pollination.

In many cases the deciduous fruit growers of the Pacific Coast have been able to turn complete failure of an orchard into success, as a result of discoveries of effective methods of insuring pollination and fruit setting. Many difficulties formerly attributed to other conditions, such as temperature, moisture relations, and soil fertility, have been overcome through the intelligent use of pollinators.

Review of Literature on Pollination

Joseph Gottlieb Koelreuter's most important and best known work was published in four portions in 1761, 1763, 1764 and 1766 under the title, 'Vorläufige Nachricht von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen.' This article gives an account of cross-pollination to produce hybrids. He showed that the process of pollination is carried on by insects. They are attracted to the flowers by some agreeable substance.

Konrad Sprengel in his famous work, Das entdeckte Geheimnis der Natur im Bau und in der Befruchtung der Blumen, 1793, discussed cross-pollination of the flowers by the insects that are attracted to the floral parts by their bright colors.

Very little attention, however, had been given to the subject of pollination until Darwin published his work in 1862 showing that plants were cross-pollinated not only by insects but by wind and water. Since then, few horticultural plants of any consequence have escaped notice in the investigations on cross-pollination, and cross-pollination has led to large yields of better fruits having a greater economic value. The first systematic research work on sterility of horticultural plants was carried on by Beach, Bailey, Waite, and Waugh. Numerous other research men have added to this knowledge within recent years.

When the growing of various nuts in commercial orchards was begun, the question of their self-sterility or self-fertility became an important problem, and has led to numerous investigations on such nuts as the almond, Persian walnuts, and hickories.

Warren P. Tufts and Guy L. Philip of California state that in their work on the almond, the Languedoc variety always bore more fruit when planted near seedlings than when planted in solid blocks. Though the Languedoc trees were replaced by varieties of greater bearing qualities which the growers thought would prove profitable under all conditions, it was soon discovered that all varieties of the almond when planted in solid blocks would give poor results.

C. T. Lewis of Oregon states that Persian walnut trees from four to six years old often started crops of nuts, only to have them drop from the trees before maturity. "This", he says, "is due to the fact that young walnut trees do not produce sufficient catkins and, therefore, do not have a sufficient quantity of pollen. After the trees become older there seems to be less trouble from this source. With the young Franquette , it is especially noticeable that the c tkins are scarce the first few years, but by the time the trees reach the period of heavy bearing, at seven years, there are generally sufficient catkins to insure a good crop. With the Mayette, the female blossoms sometime appear before the male, while with the Gladys, they are both apt to appear together."

Ramsey in his works on other varieties of Persian walnuts found similar conditions.

In Berkman's work on self-sterility in pecans, in which he states that sometime staminate flowers of the pecan appear before the pistillate flowers, causing poor crops of nuts, there are no data included to prove this statement.

The most complete work along this line has been done by H. P. Stuckey of the Georgia Agricultural Experiment Station. The conclusions reached by Mr. Stuckey in his report on "The Two Groups of Varieties of the Hicoria Pecan and Their Relation to Self-Sterility" are:

1. Varieties of pecans can be divided into two distinct groups based on

floral characters.

2. Varieties of Group I shed their pollen at about the same time the majority of pistillate flowers become receptive.

3. Varieties of Group II shed their pollen after most of the pistillate flowers have passed the receptive stage.

4. On the whole, the varieties of Group I are apt to be self-fertile, while those of Group II are apt to be self-sterile.

5. Varieties of both groups produce viable pollen.

6. Phenological data from varieties grown in South Georgia agree fairly closely as regards the two groups with that from the varieties at the Experiment Station.

7. Native hickory trees in the vicinity of Experiment, Georgia, could be divided into early and late staminate flowering groups.

8. It is probable that the hickory will serve as a pollinator for the pecan.

9. Self-sterility of a variety may be expected in proportion to the interval between the receptive stage of the pistillate flowers and the shedding of the pollen

10. Mechanical injury to catkins before the date of normal shedding of pollen may partially prevent self-sterility among varieties of Group II.

11. Parthenogenesis in pecans is indicated.

12. Varieties from Group II should be planted in close proximity to varieties from Group I to insure successful pollination.

The knowledge that certain varieties of pecans are self-sterile naturally brings up the question, what causes sterility in the plant bearing abundant pollen in the staminate flowers, and normal pistillate flowers. Factors causing sterility in other orchard fruits might be expected to have a direct relation to those affecting the pecan, especially those plants having dichogamous flowers.

Dorsey in his work gives a good discussion of factors causing self-sterility in plants.

"While there seems to be an 'inherent tendency' in some genera towards such a differentiation and specialization of the floral parts as tend to favor cross-pollination, in others this differentiation is not found and close pollination habitually occurs. This specialization or lack of specialization, as the case may be, results in a complete series of conditions with respect to a differentiation of floral structures when both flowers are taken into consideration. If the stamens and pistils are borne in the same flower, it is perfect, bisexual, hermaphroditic or monoclinous; if in separate flowers, the flower is imperfect, unisexual or diclinous. Diclinous species may be monoecious, i. e., the two kinds of flowers are borne on the same plant, or dioecious, i. e., the pistillate and staminate flowers are borne on separate plants.

"With respect to the source of the pollen, cross-pollination occurs when a stigma is pollinated with pollen from an anther borne on a different plant; close pollination when pollen borne by a perfect flower is transferred to its own stigma. Between these two extremes the intermediate type occurs when pollination takes place by the transference of pollen from the anther of one flower to the stigma of another on the same plant. Cross-pollination, or at least pollination of an intermediate type above mentioned, must occur, (a) when the species is dioecious, (b) when special morphological structures prevent close pollination, (c) when the pollen is matured and shed either before or after the stigma reaches the receptive stage, or when the pollen borne by the stamens of the flower is either sterile or for various reasons does not germinate when placed upon the stigma.

"Sterility, it should be remembered, can result from defects leading up to the formation of pollen or lack of functional power in it or in some of the structures within the ovary. It may be associated with various types of morphological abnormalities in the stamen or pistil. A distinction should be made, however, between sterility resulting from morphological causes, such as aborted structures, and that resulting from physiological causes, such as difference in the time of maturity of pollen and stigma, or 'lack of affinity', whatever this may mean, between pollen and stigma.

"The relation of parthenocarpy and parthenogenesis to seed and fruit production should not be overlooked. Parthenogenesis is the development of an egg into a plant without fertilization. In parthenocarpy fruit is developed without pollination. The stimulus resulting from pollination seems necessary in some cases in which fertilization, however, does not occur. These are cases, therefore, of parthnogenesis but not of parthenocarpy. Common instances of parthenocarpy are found in certain varieties of the cultivated grape, orange, apple, and banana. It is clear that parthenocarpic development, especially in some varieties of grapes may invalidate bagging tests of sterility unless carefully checked.

"A discussion of the general question of differentiation and of sterility in the floral parts of the higher plants has been introduced in order to show that sterility in cultivated fruits is not unlike that in other plants. In common with other plants, cultivated fruits are brought into contact with a variable environment at critical periods in their development, especially at the time of blooming and the close of the growing season. Many varieties, however, especially those which have been introduced from abroad are not so well adapted to encounter severe extremes as the native plants.

"Sterility in fruits has been investigated rather extensively. The most important fact brought by these investigations is that certain varieties are self-sterile to a greater or less extent when self-pollination takes place. A corollary to this is the further fact, which is now followed in common practice, that varieties require mixing in planting in order to facilitate the setting of fruit. The work in most cases has not been of such a nature as to determine the causes of sterility, but cytological investigations of sterility by some investigators have resulted in bringing out many interesting facts regarding structural and functional defects in essential organs."

In order to understand more clearly the above mentioned defects, it will be necessary to give brief mention to the botany of the pecan and the morphology of the pecan flowers.

The Botany of the Pecan

The pecan is a member of the Juglandaceae family which also includes the walnuts and the hickories. This family consists of a large number of species that will be omitted with the exception of the Hicora Pecan. Sargent has given the clearest and most complete description of the Hicoria Pecan.

"This particular species is distinguished from others by the bud-scales being few, valvate, the inner strap-shaped and only slightly accrescent. The fruit is more or less broadly winged at the sutures; shell of the nut thin and brittle, with large cavities. Aments of staminate flowers near sessile, usually on branches of the previous year. Leaflets 13 to 15, oblong-lanceolate more or less falcate; nut ovate-oblong, cylindrical; kernel sweet. A description of the external parts of the plant with its fruit will be given in detail:

"Leaves 12-20 inches long with slender glabrous or pubescent petioles, and 9-17 lanceolate to oblong-lanceolate more or less falcate-long-pointed coarsely often doubly serrate leaflets rounded or wedged-shaped at the unequal base, sessile, with the exception of the terminal leaflet, or short-stalked, thin and firm, dark yellow-green and glabrous or pilose above, and pale and glabrous or pubescent below, 4-8 inches long, 1-3 inches wide, with narrow yellow mid-ribs and conspicuous veins. Flowers: staminate and slender puberulous clustered aments 3-5 inches long, from buds formed in the axils of the leaves of the previous year or occasionally on shoots of the year, sessile or short-stalked; calyx light yellow-green and hirsute on the outer surface, with broadly ovate acute lobes rather shorter than the oblong or obovate bract, and nearly sessile yellow anthers; pistillate oblong narrowed at the ends, slightly 4-angled and coated with yellow scurfy pubescence. Fruits in clusters 3-7, pointed, 4-winged and angled, 1-2½ inches long, 1/2-1 inch broad, dark brown and coated with clusters of yellow articulate hairs, with a thin hard and brittle husk splitting at maturity nearly to the base and often persistent on the branch during the winter after the discharge of the nut; nut ovoid to ellipsoidal, nearly cylindrical or slightly 4-angled toward the pointed apex, rounded and usually spiculate at the base, bright reddish brown, with irregular black markings 1-2 inches long, with thin brittle walls and papery partitions; seed sweet, red-brown, its nearly flat lobes grooved from near the base to the apex by two deep longitudinal grooves.

"A tree, 70-100 feet high, with a tall massive trunk occasionally 6 feet in diameter above its enlarged and buttressed base, stout slightly spreading branches forming in the forest a narrow symmetrical and inversely pyramidal head, or with abundant room, a broad round-topped crown, and branchlets at first slightly tinged with red, and coated with loose pale tomentum, becoming glabrous or puberulous in their first, and marked with numerous oblong orange-colored lenticels and with large oblong concave leaf scars surrounded by broad thin membranaceous border embracing the lower axillary bud. Winter-buds acute, compressed, covered with clusters of bright yellow articulate hairs and pale tomentum terminal 1/2 inch long; axillary ovate, often stalked, especially the large upper one. Bark 1-1½ inches thick, light brown tinged with red, and deeply and irregularly divided into narrow forked ridges broken on the surface into thick appressed scales. Wood heavy, hard, not strong, brittle, coarse grained, light brown tinged with red, with thin light brown sapwood."

The Morphology of the Pecan Flowers

Information has been furnished by writers on the morphology of flowers of pomaceous and drupaceous fruits, but to this date no complete work has been done on the morphology of pecan flowers. For this reason, drawings have been included to show a longitudinal and cross-section of the staminate and pistillate flowers of one variety (Stuart) of the pecans grown in the orchard. To attempt to show the morphology of all the varities under consideration would involve a tremendous task that could be accomplished only by the preparation of many specimens. A discussion of the method for preparing and sectioning the pecan flowers for morphological study, and a few drawings, will give some idea as to the time and effort required for such work.

The methods of preparation of specimens are intended to preserve the structure of the protoplast in its normal form. A single cell is then cut into several sections while keeping these in their natural sequence. Finally the sections are stained so that different structures will take on different colors.

The fixing process is the preservation of the structure of the protoplasts and is accomplished by plunging the material into a solution, known as the fixative, which instantly kills the protoplasts so that the composition incident to slow dying is prevented.

The formulas for the two fixatives used are:

(1) One per cent - chromic acid ------16 parts
Two per cent osmic acid --------- 3 parts
Glacial acetic acid ------------ 1 part

(2) Chromic acid ------------------ 1 Gram
Distilled water --------------- 99 c.c.
Glacial acetic acid ------------ 0.5 c.c.

The specimens were placed in a mixture of equal parts of the two fixing reagents and allowed to remain for forty-eight hours. Then the specimens were removed to running hydrant water for a complete washing before being put into the hardening reagent.

The hardening process is to prevent an undue shrinking of the cells after they have been washed free of the killing reagent. The material that has been thoroughly washed is placed in twenty per cent alcohol for two hours. It is then carried through a series of alcohol, each of the series ten per cent stronger than the preceding, until absolute alcohol is reached. The material is allowed to remain two hours in each grade of alcohol. The process of hardening may be considered complete when the ninety per cent grade of alcohol is reached, and the sojourn in absolute alcohol is intended to complete the dehydration of the material preparatory to its embedding in paraffin or celloidin. In order to make dehydration more certain it is a good plan to have two bottles of absolute alcohol in each of which the material remains for two hours before it is transferred to the solvent of paraffin or celloidin. The process of embedding in paraffin is for the purpose of getting the specimen in such a form that it may be handled easily when the cutting of the material is begun.

The material is transferred from the absolute alcohol to equal parts of absolute alcohol and chloroform, and after two hours is placed in pure chloroform. In these instances enough chloroform to keep the material submerged is all that is needed. The chloroform is a solvent of paraffin, and the object now is to infiltrate the material with paraffin very gradually. When the material has become thoroughly infiltrated with paraffin, the container is placed on top of a paraffin oven and the cork removed. The temperature of the oven should be approximately 52° C. When the chloroform has evaporated, which condition is shown by the paraffin losing the sweetish taste that is given to it by the chloroform, the paraffin is poured into lead blocks and the material arranged in rows. The arrangements should be made while the paraffin is still in the molten condition. The blocks of paraffin should be placed in containers full of water, to give a better cutting quality to the paraffin when ready for sectioning.

The blocks of paraffin containing embedded material are cut by the microtome. Each section adheres to the next to form a ribbon, and portions of it are placed on glass slides. The ribbons are made to stick to the glass slides by the use of an albumin-glycerine adhesive prepared by shaking together the white of an egg and an equal quantity of glycerine, and then by adding to this as a preservative a piece of camphor or thymol the size of a pea. The ribbon is flattened out by the application of a few drops of water and by holding it over a flame that will heat the paraffin until it is soft. The paraffin, however, must not reach the melting point. Following the heating, the slide is allowed to cool and dry for twenty-four hours; then it is placed in a solution of xylene to dissolve the paraffin.

Staining of the sections involves a chance for error that will spoil the whole technique. The directions given by Stevens will assure one of perfect staining.

"1. After dissolving away the paraffin in xylene and rinsing in 95 per cent alcohol and then in water, stand the slide on end in the safranin for three hours.

2. Remove the slide from the safranin, drain it, rinse it quickly in water, and set it on end in the glass containing acidulated alcohol until the safranin stops coming off in clouds and the sections seem almost or quite decolorized, although the nuclei as seen under the microscope are still brigntly stained.

3. Rinse the slide quickly in 95 per cent alcohol and then in water and set it on end in the dish of gentian violet for one minute or less as results may direct.

4. Remove the slide from the gentian violet, rinse it in water, hold it horizontally, and flood the sections with orange G from a drop bottle for 1 to 8 minutes, rocking the slide meanwhile.

5. Rinse off the orange G in water, drain the slide, and while holding it slightly downward thoroughly dehydrate the sections by having absolute alcohol flow over them from the drop bottle.

6. Set the slide horizontally and flood the sections with clove oil from the drop bottle, and rock the slide occasionally. This will gradually extract the gentian violet, and the preparation should be watched under the lower power of the microscope so that this action may be stopped as soon as the gentian stain has lost its too great density and become transparent while yet distinct. Then drain off the clove oil thoroughly, flood the slide with xylene, rocking the slide, drain, and set the slide in the dish of xylene to remove completely the clove oil.

7. Remove the slide from the xylene, drain it, place a drop of canada balsam towards one end of the group of sections and lower a cover glass over it, beginning at the end where the drop of balsam is, by bringing the cover glass into con-

tact with the slide first at that end and gradually lowering it toward the opposite side so as to drive forward any air bubbles that may be entangled with the balsam."

The above method of staining has to be changed slightly when floral parts of the pecan are used. In comparison with many other materials, the pecan tissue will stain very fast. Several lots were run through the safranin stain, and three hours gave the best staining which required less washing in the acidulated alcohol. The time required for a good stain from the gentian violet was one minute.

The parts of the flowers will be named and shown in the following plates. Each plate will be accompanied by a description to give a detailed account of the structure of the flowers.

To show the pistillate flower after it has been pollinated and reached maturity, a series of drawings have been made of this fruit. The variety of pecan used for the flowers and fruit is the Stuart. This variety is one of the best improved varieties in our orchard.

Description of Plates

Plate 1

Fig. 1. Longitudinal sections cut radially through one, a, of the three aments of a staminate infloresence, and tangentially through the short lateral branch, b, of the current year: c, peduncle; c'', rachis; d, short basal stalk (lower portion of the peduncle) of the ament; e, pedicel; f, inner scale of the terminal bud on a short branch of the current year; g, very young staminate flowers in the axil of an oblong involucral bract. X 75.

Plate 2

Fig. 2. Cross section of the young ament showing three staminate flowers. Corresponding parts lettered as in Fig. 1: h, one of the sections of three sepals of the staminate flower; i, section of the involucral; j, section of the upper bract borne on a flower lower down on the peduncle; k, vascular elements in the peduncle. X 75.

Plate 3

Fig. 3. Tangential longitudinal sections of a pistillate flower cut near the radius in a plane indicated by the line, x-y, in Fig. 4: l, pedicel; m, winged angle of the perianth - like involucre, n, which encloses the ovary and style of the fully developed pistil; o, vascular elements of the involucre; p, exocarp; q, vascular elements of the exocarp; r, endocarp; s, ovule; t, style; u, two-lobed stigma; u-w, line indicating the plane at which the section in Fig. 4 is cut. X 75.

Plate 4

Fig. 4. Cross section of a pistillate flower. Parts lettered as in Fig. 3: x-y, line indicating plane at which the section in Fig. 3 was cut: z, involucral bract; a', b', the two involucral bractlets; c', the single lobe of the calyx; d', central cavity in the ovule, s. X 75.

Plate 5

Fig. 5. Sketch of the upper half of a main branch of five weeks growth in the current year. The terminal short spike, e', bears three pollinated pistillate flowers: Parts lettered as in Fig. 4: f', one of the two beaks of the stigma; g', base of the petiole of a leaf; h', bud of the current year; i', tip of the peduncle of the spike. X 1.5.

Plate 6

Fig. 6. Sketch of the broad face of the obovoid nut slightly four-angled toward the pointed apex and rounded at the base: j', angle; k', apex tipped by the hardened remnants of the style (l'); m', base; n', irregular black marking. X 1.

Fig. 7. Sketch of the narrow face of the nut. Corresponding parts lettered as in Fig. 6; o', vascular elements forming the rough area at the base of the nut. X 1.

Fig. 8. Sketch of apex of the nut. Corresponding parts lettered as in Fig. 7. X 1.

Fig. 9. Sketch of basal end of the nut. Corresponding parts labeled as in Fig. 7. X 1.

Plate 7.

Fig. 10. Sketch of the seed (kernel) showing the broad outer face, p', of the cotyledon, q', apex of the seed; r', ridge over apex and extending downward; centrally on the outer face of each cotyledon in a plane perpendicular to the faces of the cotyledons, s', one of the two deep horizontal grooves on both sides of the central longitudinal ridge of the outer face of the cotyledon; t', one of two short basal grooves on the cotyledon; u', small grooves in each; v', of the two lobes of the cotyledons; w', border of the central endocarpic plate which separates all but the apices of the two cotyledons; x', vascular elements at base of the central longitudinal endocarpic plate. The elements are a continuation of similar elements extending from the receptacle of the fruit up through the base of the pistil to the placenta (fig. 13, d") located at the base of the groove (fig. 13,a") at the tip of the endocarpic plate (fig. 13, y'). X 1.

Fig. 11, Apex of the seed (kernel). Corresponding parts lettered as in fig. 10. X 1.

Fig. 12. Basal end of the seed (kernel). Corresponding parts lettered as in Fig. 10. X 1.

Fig. 13. The inner broad flat face of each of the two longitudinal portions of the seed (kernel) after it is split apart. Superimposed on the one portion is the central longitudinal plate, y', of the endocarp flat above but ridged, z', below at right angles toward the base to form the innermost walls of the nut which is two-celled at the apex and four-celled at the base. Corresponding parts labeled as in fig. 10; a", groove between two apical forks of the central endocarpic plate, (y'); b", placenta at base of the groove, (a"); c", rough area of the broken vascular elements at the base of the central endocarpic plate; d", longitudinal ridge of the endocarpic plate which indicates the course of the vascular elements from

the rough area (c'') at the ba-e of the plate to the placenta (b'') in the base of the apical groove (a''), e'', nilum; f'', embryo; g'', connective of the two cotyledons; h'', of the small grooves on the flat inner face of a cotyledon. X 1.

Fig. 14. Radical longitudinal section of the seed (kernel). Corresponding parts lettered as in fig. 13: i'', narrow side of cotyledon; j'', space made by splitting of the connective between cotyledons in sectioning the seed; k'', space between the embryo and cotyledons; l'', dark line to indicate the course of the vascular elements through the central endocarpic plate from the basal roughened area (c'') to the placenta (b'') at base of the apical groove (a''); f''', lower and inner portion of the cotyledon separated from the upper and outer half by the space, k''; m'' micropyle. X 1.

Fig. 15. Cross section of the seed (kernel) cut through the tip of the central endocarpic plate which lies between the inner broad faces of the two cotyledons. Corresponding p-rts labeled as in fig. 14: n'', space made by an undulating tangential split of a cotyledons. X 1.

Plate I.

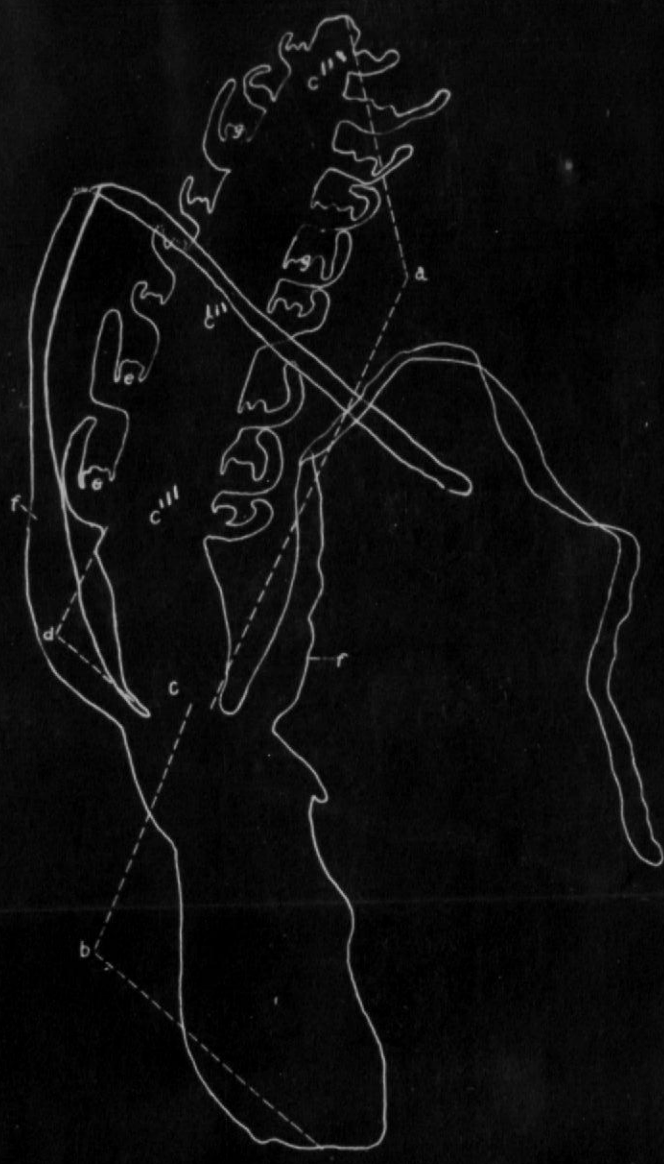

Fig. 1

Plate III

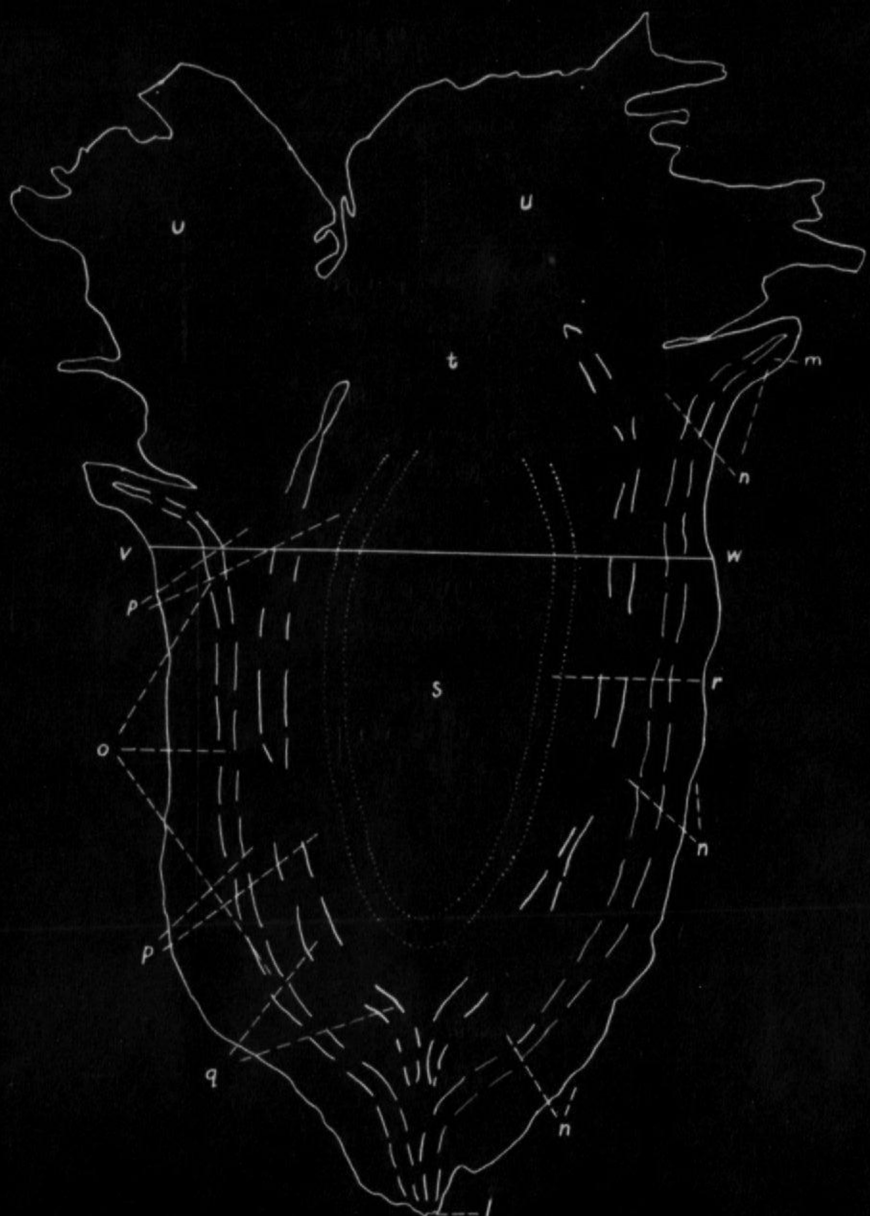

Fig. 3

Plate IV

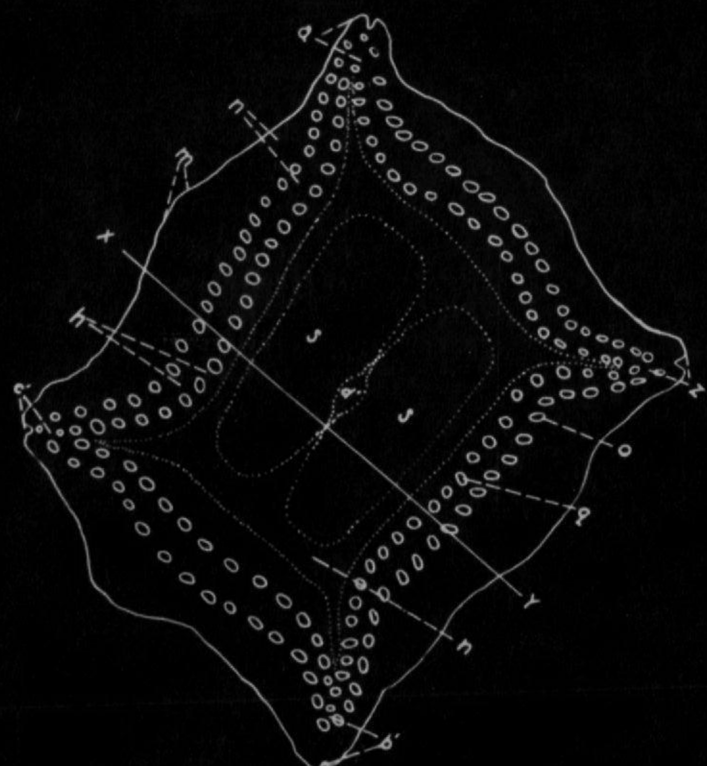

Fig. 4

Plate V

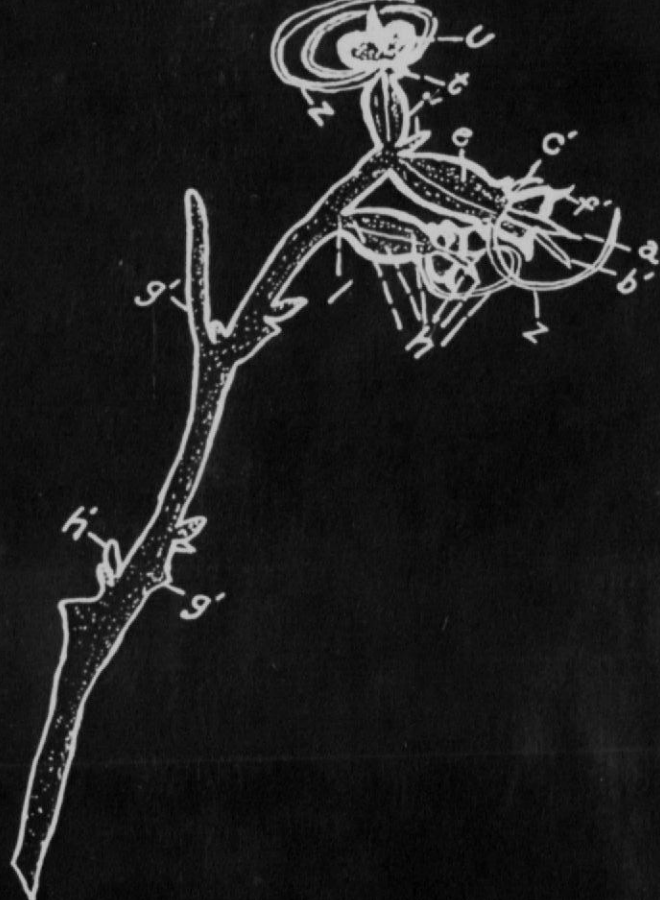

Fig. 5

Plate VI

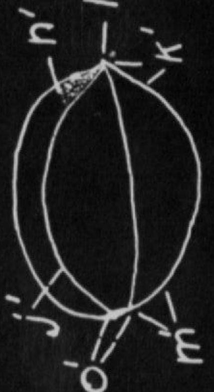

Fig. 7

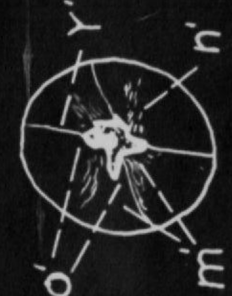

Fig. 9

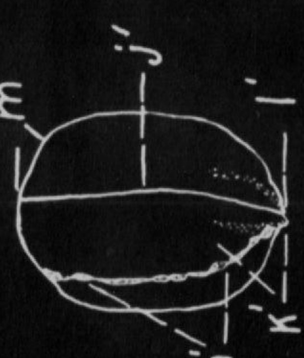

Fig. 6

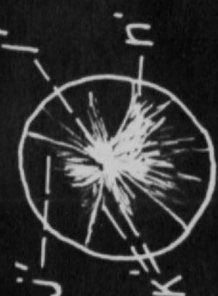

Fig. 8

Plate VII

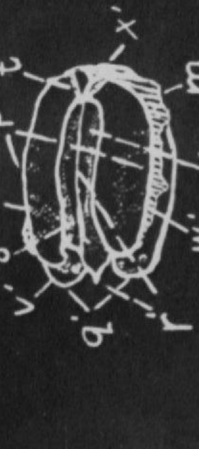

Fig. 10

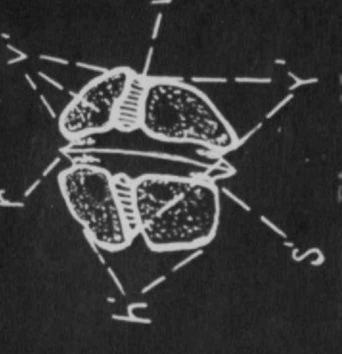

Fig. 11

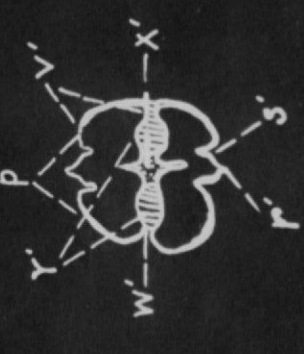

Fig. 12

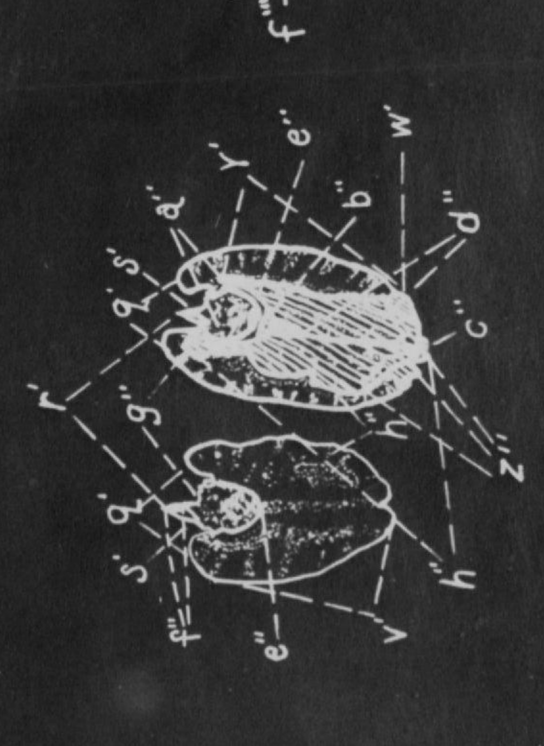

Fig. 13

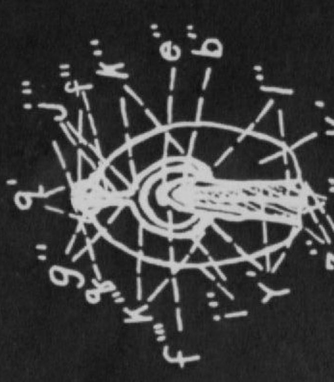

Fig. 14

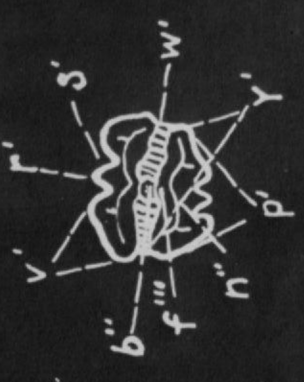

Fig. 15

The Blossoming Dates of Varieties of Pecans Artificially Cross-Pollinated

In order to obtain sufficient data on the trees used in this problem, a complete set of notes on their blossoming were taken.

The trees were closely observed from the date that the buds showed signs of opening, through the development of flowers, to the date on which the fruit was set, and notes were taken to show the variations among individual trees within the same variety. The dates of the appearance of the first catkins, and the first and the last shedding of pollen were recorded. Similar notations were made on the appearance of the pistillate flower, and the beginning and ending of the receptive stage.

The notes giving the dates of blossoming will help one to understand why certain varieties were not cross-pollinated, and why some which were cross-pollinated did set fruit. It might be briefly mentioned here that pollen from varieties shedding rather early, had lost its germinative power before it was placed on the stigmas of the receptive pistillate flowers. The varieties, shedding their pollen just after the pistils were passing out of the receptive stage, were not able to fertilize the pistillate flowers at that stage.

The facts stated above indicate that both the staminate and pistillate flowers, whatever their stage of development, must be closely observed in each variety, if the success or failure of pollination is to be understood.

Table 2 - Phenological Data - Row 1

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date All of Pollen Shed	Ultimate Length of Catkins mm
Stuart	2	3-18	4-	4-8	4-14	4-18	4-20	145
Delmas	2	3-30	none	none	4-15		4-22	150
San Saba	1	3-20	4-2	4-12	4-8	4-17	4-15	135
Delmas	2	3-16	4-2	4-8	4-14	4-17	4-20	148
Delmas	2	3-16	4-1	4-7	4-14	4-14	4-20	130
Delmas	2	3-17	4-2	4-8	4-14	4-14	4-20	150
Seedling		3-17	4-1	4-8	4-13	4-14	4-19	140
Rome	1	3-22	4-1	4-12	4-10	4-20	4-18	130
Delmas	2	3-17	4-3	4-7	4-11	4-16	4-18	150
Rome	1	3-19	4-5	4-11	4-7	4-19	4-14	130
Stuart	2	3-27	4-7	4-14	4-12	4-20	4-20	145
Rome	1	3-19	4-3	4-8	4-8	4-14	4-13	130
San Saba	1	3-23	4-1	4-9	4-7	4-21	4-14	130
Rome	1	3-20	4-9	4-11	4-14	4-18	4-17	130

Table 3 - Phenological Data - Row 2

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date all of Pollen Shed	Ultimate Length of Catkins mm
Bolton	1	3-17	3-30	4-7	4-9	4-13	4-14	125
Delmas	2	3-15	4-1	4-7	4-13	4-17	4-21	145
San Saba	1	3-20	4-4	4-12	4-11	4-17	4-19	130
Pabst	1	3-26	4-13	4-18	4-11	4-24	4-17	110
Success	1	3-26	4-3	4-12	4-13	4-18	4-19	135
Schley	1	3-25	4-2	4-11	4-9	4-18	4-21	135
Rome	1	3-17	4-3	4-8	4-5	4-11	4-12	130
Texas - Prolific	1	3-21	4-6	4-11	4-13	4-11	4-18	130
Rome	1	3-19	3-31	4-6	4-6	4-11	4-11	130
Stuart	2	4-1	none	none	4-16		4-23	145
Moneymaker	2	3-28	4-4	4-13	4-19	4-21	4-23	150
Burkett	1	3-26	4-6	4-11	4-18	4-19	4-26	145
Moneymaker	2	3-26	4-9	4-10	4-14	4-17	4-22	150

Table 4 - Phenological Data - Row 3

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date all of Pollen Shed	Ultimate Length of Catkins mm
San Saba	1	3-20	4-1	4-9	4-8	4-22	4-14	135
Bolton	1	3-19	4-1	4-7	4-11	4-12	4-20	130
Bolton	1	3-15	3-31	4-7	4-10	4-11	4-21	130
Bolton	1	3-15	3-30	4-7	4-10	4-11	4-20	130
Kincaid	2	3-20	4-5	4-11	4-15	4-21	4-25	90
San Saba	1	3-17	4-4	4-11	4-10	4-23	4-14	135
San Saba	1	3-20	4-2	4-11	4-7	4-24	4-14	130
Rome	1	3-19	4-6	4-9	4-9	4-12	4-14	130
Rome	1	3-16	4-2	4-6	4-5	4-11	4-12	125
Schley	1	3-20	4-9	4-13	4-14	4-22	4-18	135
Rome	1	3-20	4-6	4-6	4-9	4-11	4-20	120
Bolton	1	3-19	3-28	4-6	4-9	4-12	4-15	120
Moneymaker	2	2-20	4-3	4-7	4-14	4-14	4-19	140

Table 5 - Phenological Data - Row 4

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date all of Pollen Shed	Ultimate Length of Catkins in mm
San Saba	1	3-23	4-1	4-12	4-11	4-22	4-20	140
San Saba	1	3-23	4-2	4-12	4-11	4-20	4-22	130
San Saba	1	3-25	4-8	4-13	4-14	4-25	4-20	135
Texas - Prolific	1	3-16	4-5	4-11	4-7	4-20	4-25	130
Delmas	2	3-26	4-4	4-12	4-15	4-20	4-25	155
Rome	1	3-20	4-5	4-6	4-8	4-12	4-14	120
Bolton	1	3-17	3-30	4-7	4-8	4-12	4-16	130
Bolton	1	3-15	3-27	4-6	4-7	4-12	4-15	125
Stuart	2	3-22	none	none	4-18		4-26	150
Bolton	1	3-15	3-26	4-4	4-8	4-12	4-16	125

Table 6 - Phenological Data - Row 5

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date All of Pollen Shed	Ultimate Length of Catkins in mm
Texas Prolific	1	3-20	4-6	4-16	4-10	4-24	4-16	135
Texas Prolific	1	3-12	4-4	4-14	4-8	4-24	4-14	135
Texas Prolific	1	3-22	4-2	4-7	4-7	4-24	4-16	130
Texas Prolific	1	3-25	4-1	4-7	4-7	4-22	4-13	135
Seedling		3-20	none	none	none	none	none	120
Atwater	1	3-21	3-31	4-8	4-4	4-20	4-25	120
Alley	1	3-15	4-3	4-9	4-4	4-19	4-12	110
Texas Prolific	1	3-15	3-31	4-9	4-7	4-22	4-13	130
San Saba	1	3-19	4-1	4-9	4-8	4-24	4-14	130
San Saba	1	3-27	4-8	4-14	4-14	4-24	4-15	135
San Saba	1	3-23	4-3	4-11	4-7	4-25	4-15	125
Alley	1	3-15	4-3	4-6	4-7	4-22	4-14	110
Seedling		3-20	3-31	4-10	4-13	4-13	4-20	125
Rome	1	3-21	4-9	4-11	4-13	4-15	4-19	130

Table 7 - Phenological Data - Row 6

Variety	Variety Group	Date Catkins Appear	Date Pistillate Flowers Appear	Date Pistillate Flowers Receptive	Date First Pollen Shed	Date Stigma Surface Dried	Date all of Pollen Shed	Ultimate Length of Catkins in mm
Stuart	2	3-27	4-7	4-11	4-14	4-20	4-21	150
Alley	1	3-23	4-4	4-9	4-11	4-16	4-20	110
Delmas	2	3-23	4-3	4-7	4-11	4-15	4-22	160
Delmas	2	3-23	3-31	4-9	4-14	4-14	4-22	155
Seedling		3-25	4-14	4-14	4-14	4-20	4-20	125
Seedling		3-21	4-2	4-9	4-14	4-18	4-20	130
Seedling		3-21	4-7	4-14	4-14	4-14	4-23	125
Seedling		3-15	4-2	4-9	4-7	4-17	4-23	130
				Row - 7				
Stuart	2	3-27	4-9	4-14	4-15	4-22	4-25	145
Stuart	2	3-27	4-3	4-14	4-15	4-22	4-25	145
Stuart	2	3-27	4-3	4-7	4-14	4-23	4-24	150
Stuart	2	3-27	4-9	4-14	4-15	4-24	4-24	140
Stuart	2	3-27	4-10	4-14	4-15	4-23	4-24	150

The Two Groups of Hicoria Pecan and Their Distinguishing Characters

When self-sterility is considered as a means to the division of this species, we find that there are two groups which are easily distinguished from each other by the floral characters of the staminate flowers, and also by the difference in the development of the pollen grains. The following observations on the two groups of pecans as given by Stuckey, were found to hold true for the pecans at College Station.

"In Group I, the embryonic catkins of staminate flowers are enclosed in rather short, broad, bud scales, one on each side of the leaf bud. The catkins themselves are rather short and broad as compared with their length, and the individual flowers of the catkins are shielded by short, rather small and inconspicuous bracts. The catkins of Group I protrude from one to five days before those of Group II, and shed their pollen from five to ten days before those of Group II. With most of the varieties of this group, the pistillate flowers become receptive at about the same time that the staminate flowers shed their pollen. However, a few varieties of this group have a considerable percentage of their pistillate flowers to become receptive after the maximum dehiscence of pollen.

"In Group II, the embryonic catkins of staminate flowers are enclosed in long and rather slender bud scales. These catkins are usually narrower and longer than those of Group I and the individual flowers are shielded by long, narrow, conspicuous bracts. In this group, the pistillate flowers become receptive from two to ten days before the staminate flowers shed their pollen; and, in most cases, a large percentage of the stigmas of the pistillate flowers have become dried or calloused before the pollen is shed."

The varieties of pecans used in this work were observed as to their characteristics in order to determine to what group they belong, the percentage of fruit set in self-fertile varieties was also observed. The results of these observations are given in the following table.

Table 1 - The Varieties Listed in Their Respective Groups, with D ta on Per Cent of Fruit Set.

Group I

Variety	Dates Stigmas Receptive	Date First Pollen Shed	Per Cent of Fruit Set
Schley	4-11	4-9	80
Burkett	4-11	4-18	70
San Saba	4-9	4-8	80
Success	4-12	4-13	85
Alley	4-9	4-4	65
Atwater	4-8	4-4	70
Bolton	4-7	4-10	65
Texas Prolific	4-11	4-11	80

Group II

Variety	Date Stigmas Receptive	Date First Pollen Shed	Per Cent of Fruit Set
Delmas	4-8	4-14	0
Kincaid	4-11	4-15	0
Stuart	4-14	4-12	0
Moneymaker	4-13	4-19	0

Table 19 - Classification of Varieties According to Time of Maturity of Pollen and Stigma.

Dates Coinciding	Dates Partly Coinciding	Dates Not Coinciding to Any Extent.
	Stuart	
	Delmas	
San Saba		
Rome		
Bolton		
		Pabst
Success		
Schley		
Texas Prolific		
	Moneymaker	
	Burkett	
	Kincaid	
	Atwater	
Alley		

Method of Pollination Work

The pecan trees selected for the experimental project are those located in the commercial pecan orchard. This orchard lies just back of the Bachelor's Club in the western part of the campus.

The site is well drained and has been in cultivation with cover crops ever since the orchard was set out. The soil is a sandy loam with a hard pan subsoil about six inches below the surface.

The orchard was planted with trees of the following varieties; Rome, Delmas, San Saba, Stuart, Bolton, Texas Prolific, Moneymaker, Kincaid, Atwater, and Alley. Since Rome has proved a poor variety, some of those trees were top-worked to the Schley, Burkett, and Success varieties.

The orchard was closely observed from the time the bud scales started splitting, and data were taken on the following points: splitting of bud scales, time of appearance of catkins or of vegetative growth, dehiscence of the pollen sacs, receptivity of pistillate flowers, last shedding of pollen, and passing of pistillate flowers to a non-receptive condition.

A few days prior to the shedding of pollen from the earliest varieties, paraffin sacks were placed over catkins of each variety to insure a supply of pollen for use in cross-pollination and to prevent contamination by the wind blowing pollen from other varieties to that variety. Just as the pistillate flowers were advanced enough to show that they were present, sacks were placed over them to prevent pollination when they became receptive.

When the pistillate flowers became receptive, pollen from other varieties was placed on the stigmas by using a camel's hair brush, and the sack was placed over the flower again and left until the investigator was assured that the fruit was set. When this stage was reached the sacks were removed, and a count was made of the nuts set as a result of the cross-pollination.

To carry on this work of cross-pollination twelve varieties were used, the Rome being the only one in the orchard not used. This is such an inferior variety that it was thought not advisable to recommend it for the orchard. One hundred and thirty two reciprocal pollinations were made on these twelve varieties. These were repeated five times, making a total of 660 cross-pollinations.

A check was made on each variety as to its self-fertility. The pistillate and staminate flowers were sacked together; after the setting of fruit the sack was removed and a count made to determine the percentage of nuts resulting from self-pollination.

Table 8 - Results of Crosses Using Stuart as Pollen Parent

Staminate Variety	Pistillate Variety	Date Cross-Pollinated	Date Final Observation Made	Per Cent of Fruit Set
Stuart	San Saba	4-16	4-28	50
Stuart	Delmas	4-16	4-28	60
Stuart	Success	4-16	4-28	0
Stuart	Schley	4-16	4-28	0
Stuart	Texas Prolific	4-16	4-28	100
Stuart	Moneymaker	4-16	4-28	100
Stuart	Burkett	4-16	4-28	50
Stuart	Atwater	4-16	4-28	60
Stuart	Alley	4-16	4-28	100

Table 9 - Results of Crosses Using San Saba as Pollen Parent

Staminate Variety	Pistillate Variety	Date Cross-Pollinated	Date Final Observation Made	Per Cent of Fruit Set
San Saba	Stuart	4-15	4-27	100
San Saba	Delmas	4-9	4-21	100
San Saba	Bolton	4-9	4-21	0
San Saba	Success	4-15	4-27	60
San Saba	Schley	4-11	4-23	100
San Saba	Texas Prolific	4-11	4-22	100
San Saba	Moneymaker	4-9	4-21	80
San Saba	Burkett	4-11	4-23	100
San Saba	Kincaid	4-11	4-23	0
San Saba	Atwater	4-9	4-21	100
San Saba	Alley	4-11	4-23	80

Table 10 - Results of Crosses Using Schley as Pollen Parent

Staminate Variety	Pistillate Variety	Date Cross-Pollinated	Date Final Observation made	Per Cent of Fruit Set.
Schley	Stuart	4-16	4-28	60
Schley	Delmas	4-16	4-28	80
Schley	Texas Prolific	4-16	4-28	100
Schley	Success	4-15	4-27	100
Schley	Moneymaker	4-16	4-28	100
Schley	Burkett	4-16	4-28	100
Schley	Atwater	4-16	4-28	60
Schley	Alley	4-16	4-28	60
Schley	San Saba	4-16	4-28	100

Table 11 – Results of Crosses Using Texas Prolific as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set.
Texas Prolific	Stuart	4-14	4-26	100
Texas Prolific	San Saba	4-11	4-23	40
Texas Prolific	Delmas	4-9	4-21	90
Texas Prolific	Bolton	4-9	4-21	20
Texas Prolific	Success	4-13	4-25	100
Texas Prolific	Schley	4-13	4-25	100
Texas Prolific	Moneymaker	4-9	4-21	0
Texas Prolific	Burkett	4-11	4-23	100
Texas Prolific	Kincaid	4-11	4-23	0
Texas Prolific	Atwater	4-9	4-21	0
Texas Prolific	Alley	4-11	4-23	100

Table 12 - Results of Crosses Using Delmas as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set
Delmas	Stuart	4-16	4-28	80
Delmas	Success	4-16	4-28	100
Delmas	Moneymaker	4-16	4-28	60
Delmas	Burkett	4-16	4-28	70
Delmas	Atwater	4-16	4-28	100
Delmas	Alley	4-16	4-28	100
Delmas	San Saba	4-16	4-28	100

Table 13 - Results of Crosses Using Bolton as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set
Bolton	Schley	4-13	4-25	100
Bolton	Stuart	4-16	4-28	100
Bolton	Delmas	4-9	4-21	100
Bolton	Success	4-13	4-25	60
Bolton	Texas Prolific	4-13	4-25	100
Bolton	Moneymaker	4-9	4-21	0
Bolton	Burkett	4-11	4-25	100
Bolton	Kincaid	4-14	4-26	0
Bolton	Atwater	4-19	4-21	40
Bolton	Alley	4-14	4-26	50
Bolton	San Saba	4-11	4-23	0

Table 14– Results of Crosses Using Success as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date of Final Observation Made	Per Cent of Fruit Set
Success	Stuart	4-14	4-26	100
Success	Delmas	4-13	4-25	0
Success	Schley	4-13	4-25	100
Success	Texas Prolific	4-13	4-25	90
Success	Moneymaker	4-13	4-25	60
Success	Burkett	4-13	4-25	100
Success	Kincaid	4-14	4-26	0
Success	Atwater	4-13	4-25	0
Success	Alley	4-14	4-26	100
Success	San Saba	4-13	4-25	0

Table 15 - Results of Crosses Using Moneymaker as Pollen Parent

Staminate Variety	Pistiliate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set
Moneymaker	Stuart	4-15	4-27	90
Moneymaker	Delmas	4-15	4-27	50
Moneymaker	Texas Pro-lific	4-15	4-27	100
Moneymaker	Success	4-15	4-27	50
Moneymaker	Schley	4-15	4-27	100
Moneymaker	Burkett	4-15	4-27	100
Moneymaker	Atwater	4-15	4-27	100
Moneymaker	Alley	4-15	4-27	100
Moneymaker	San Saba	4-15	4-27	60

Table 16 - Results of Crosses Using Kincaid as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross Pollination	Date Final Observation Made	Per Cent of Fruit Set
Kincaid	Stuart	4-17	4-29	100
Kincaid	San Saba	4-17	4-29	90
Kincaid	Delmas	4-17	4-29	90
Kincaid	Atwater	4-16	4-28	100
Kincaid	Alley	4-17	4-29	0

Table 17 - Results of Crosses Using Atwater as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set
Atwater	Stuart	4-14	4-26	100
Atwater	San Saba	4-14	4-28	70
Atwater	Texas Pro-lific	4-14	4-26	100
Atwater	Burkett	4-15	4-27	100
Atwater	Alley	4-14	4-26	0
Atwater	Success	4-14	4-26	100
Atwater	Delmas	4-14	4-26	70
Atwater	Schley	4-14	4-26	100

Table 18 - Results of Crosses Using Alley as Pollen Parent

Staminate Variety	Pistillate Variety	Date of Cross-Pollination	Date Final Observation Made	Per Cent of Fruit Set
Alley	Stuart	4-16	4-28	100
Alley	San Saba	4-16	4-28	80
Alley	Success	4-16	4-28	100
Alley	Moneymaker	4-9	4-21	60
Alley	Burkett	4-16	4-28	100
Alley	Atwater	4-9	4-21	100
Alley	Delmas	4-7	4-19	100
Alley	Bolton	4-7	4-19	60

Discussion and Interpretation of Data

The writer does not wish to give the impression that the results of the observations made for the year 1925 will be the same fo all years. There are many minor factors, such as climatic conditions, nutrient supply, diseases, and soil conditions that may cause variations.

The Stuart gave very good results as a pollen parent. It also showed an unusually high percentage of fruit set when pollen from other varieties having the same blooming dates was used.

The pollen from the San Saba gave the highest percentage of fruit set on other varieties. On the other hand, when pollen from other varieties was used for pollination of the San Saba, only 70 per cent of fruit was set.

The Schley was a very vigorous tree. It is a four year old scion upon a thirteen year old stock. About 90 per cent of fruit was set when this plant was used on other varieties as a pollen parent, and 75 per cent when it was pollinated by other varieties.

The Texas Prolific, one of our heaviest producers, gave a rather low percentage of fruit set when used as pollen parent for other varieties. However, it was somewhat more prolific as a maternal plant, when other varieties were used as pollen parents.

The Delmas gave good results when used on other varieties as a pollen parent, with about 90 per cent of fruit set. When other pollen was used for the cross-pollination, a very small amount of fruit was set, approximately 40 to 45 per cent.

The Bolton when used as a pollen parent gave a medium set of fruit on other varieties, the results varying from 40 to 60 per cent. When other varieties were used as pollen parents, a very small amount of fruit was set on the Bolton, approximately 30 to 35 per cent. There were very few crosses made on the Bolton because of the early date at which its stigmas passed the receptive stage.

The Success set about 75 per cent of fruit on other varieties when used as a pollen parent. The pollen from other varieties on Success gave results of about 65 to 70 per cent of fruit set.

The Moneymaker when used as a pollen parent on other varieties produced a good set of fruit, the per cent ranging from 85 to 90. This variety does not accept pollen very readily from others; in only one instance did we have over 60 per cent of fruit set.

The Atwater is a good cross-pollinator when used as a pollen parent. Though the results varied from 0 to 100 per cent, the 100 per cent pollinations are in the majority. It readily accepts other pollen from the varieties having the same blooming period.

The Alley when used on other varieties as a pollen parent gave an unusually high percentage of fruit set. The average was about 95. It sets about 85 per cent of fruit when used as a maternal plant.

A study of the results obtained in these experiments in cross-pollination, as shown in the foregoing tables, will give valuable information as to pollen relationships between the different varieties used. In order to get the best results from a pecan orchard, the varieties should be so grouped as to insure an abundant supply of pollen throughout the entire receptive season of the pistillate flowers.

Among the earliest varieties to shed pollen are Texas Prolific, San Saba, Rome, and Bolton. Of these four, only the Texas Prolific is worthy of a place in a commercial orchard. In addition to being a very early and very heavy producer of pollen, Texas Prolific, from the standpoint of yield and quality of nuts, is one of the most satisfactory varieties grown at this place. For these reasons, it is advisable to include a rather generous proportion of this variety in the orchard.

The Alley shows some variation in production of pollen, but on the average it is r ther close to the Texas Prolific, and may be classed with this variety as a pollinator.

Following the Texas Prolific and Alley in the time of production of pollen but at an interval of three to eleven days, are Schley, Success, Stuart and Delmas, and finally Moneymaker and Burkett. All of these are good commercial varieties and show 90 to 100 per cent set of fruit with pollen from Texas Prolific. Most of these varieties also show a good set with pollen from Alley.

An orchard planted to the above mentioned varieties should produce an abundance of pollen during the entire season at the time when it will be needed for fertilization. For best results no one variety should be planted in a solid block. On the contrary it is advisable to plant the varieties in alternate rows laid out across the direction of the prevailing wind.

In addition to securing pollination of the strongly dichogamous varieties, the plan outlined above will give a maximum of cross-pollination among all varieties. This decided benefit is indicated from the results obtained from other deciduous fruits. Many of these fruits, formerly thought to be completely self-fertile, have shown marked increases in yield when planted so as to permit cross-pollination. Resultr in the College, as well as other pecan orchards, seem to justify this practice.

As an illustration, the following orchard plan, which include all the varieties used in this investigation, is included.

Chart 1. Plan of an Orchard to Insure Cross-Pollination *

North

	L		J		D		I		H		B		A		I		
West		I		E		H		K		I		G		F		D	East
	E		B		C		A		C		I		C		H		
		G		J		J		L		K		F		G		D	

South

* Legend

Letters Indicate Varieties

A - Stuart

B - Delmas

C - Kincaid

D - Atwater

E - Alley

F - Texas Prolific

G - San Saba

H - Bolton

I - Moneymaker

J - Success

K - Burkett

L - Schley

Summary

1. Varieties of pecans of commercial importance should be examined as to self-sterility, and to determine what variety or varieties will fertilize them if self-sterile.

2. The varieties of Group I are apt to be self-fertile, while those of Group II will be largely self-sterile.

3. The results of this investigation show that there is in general a definite relationship between the dates of maturity of staminate and pistillate flowers and self-sterility, or respectively, self-fertility, in the pecan. The Stuart was a notable exception to this observation in that its pollen was shed either two days before the pistillate flowers became receptive or after the pistillate flowers had passed the receptive stage.

4. The data of the cross-pollinations show that the majority of the varieties will cross-pollinate when their blossoming dates coincide.

5. In any plan recommended for a pecan orchard, the self-fertile varieties should be placed in the outer row. Those varieties used as pollinators should be planted to the windward of the self-sterile varieties.

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December 9, 1938