FACTORS INFLUENCING FRUIT SETTING IN THE PECAN

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FACTORS INFLUENCING FRUIT SETTING IN THE PECAN[1]

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(WITH SIX FIGURES)

Introduction

This study was undertaken to gain information on the effects of some cultural practices affecting fruit setting in the pecan. Since pollination is essential to complete fruit development in many flowering plants, it has been studied in association with the morphology and cytology of the developing nut.

MATERIALS AND METHODS

MORPHOLOGY AND CYTOLOGY.—For the study of the morphology and cytology of the developing pecan nut, collections of material for imbedding were made at frequent intervals during the early growing season. The first samples were taken from swelling buds, and the next from tips of growing shoots, before the pistillate flowers actually appeared. Following the appearance of the pistillate flowers, collections were made each day up to the time of receptivity and pollination; after which samples were taken at 4-hour intervals during the first day after pollination, then daily for 3 days, and then at 2-day intervals for 6 weeks. During the same period, samples which had been sacked and not pollinated were taken. In the later stages the shell of the nut was too hard for sectioning, so nuts collected after 4 weeks were trimmed with a knife to remove the hard shell. All material was killed and fixed in medium chromo-acetic solution, and sectioned according to the paraffin method. The most satisfactory stains used were Delafield's haematoxylin, safranin-gentian violet, and acid fuchsin. The latter was satisfactory for staining pollen tubes.

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Some sections of very large fresh fruits were cut with a knife, killed in alcohol, cleared in acetone and cedar oil, and photographed with indirect light in thin glass cells filled with Canada balsam.

FRUIT DROPPING.—Field studies were undertaken with the idea of determining the amount of shedding of young pecan fruits, the time of shedding, and the factors influencing this condition. Preliminary observations and the work of other investigators indicated that the greater portion of the drop occurs early in the season. Records were taken of the dropping of the fruit during the period up to 6 weeks after time of pollination, on open-pollinated fruits and on fruits which were kept sacked until after all pollen was shed. Some further counts were made later in the season to check the relative importance of the early drop. The position of the dropped nuts on the peduncle was determined by the scar. These determinations were made twice a year, the proximal nut being counted as number "1" in all cases.

BLOSSOMING HABIT.—The first and last dates on which flowers were receptive was recorded for each tree. The period of receptivity was determined by the presence of a very perceptible viscous fluid on the stigmatic surface. The first and last dates on which pollen was shed were also recorded for each tree. The trees used for these records are in two orchards. The "old" orchard contains trees which were about 15 years old at the beginning of the study, and had been bearing moderately good crops. Seven varieties were used in this orchard, and from 3 to 12 trees of a variety, depending on the number available. In the "young" orchard the trees were 6 years old and beginning to bear well when the first data were taken in 1927. There were 10 varieties available in this orchard, and 8 or more trees of each variety.

METEOROLOGICAL DATA.—The data on temperature and precipitation were secured from the records of the Main Station Farm, Texas Experiment Station, which is about one-quarter of a mile from each orchard. Since, according to WOODROOF (35), SHUHART (30), and ISBELL (10), the staminate flowers are differentiated in the spring of the previous year and the pistillate flowers in the same spring in which they appear, it was not considered necessary to make records except for the late winter and spring, beginning January 1, of each season, so as to give a sufficient margin before the beginning of growth.

The temperature records for the periods under consideration for each year have been converted into heat units, in order to have a definite basis for comparison. The remainder system of calculating the number of heat units above 40° F. was considered adequate for this study; the yearly total from January 1 to time of maturity of staminate and pistillate flowers was determined for each variety. The weekly, monthly, and seasonal distribution of heat units and precipitation for each spring season were also calculated so that the effect of these factors on dichogamy might be determined.

The work is concerned with the functioning of the plant over a period of years. The seasonal study is based upon a 5-year period, and an inspection of the meteorological records used shows that extremes of temperature and rainfall were encountered during this time.

Structure of flowers and fruits

The morphology of the species of *Carya* has been treated by BENSON and WELSFORD (3), NAWASCHIN (25), VAN TIEGHEM (33), ROWLEE and HASTINGS (28), DE CANDOLLE (7), MEEHAN (16), LUBBOCK (14), BRAUN (6), NICOLOFF (26), and others. BILLINGS (4) and WOODROOF (37) worked with the pecan specifically.

FLOWERING HABIT.—With regard to the production of staminate flowers, WOODROOF (35) and ISBELL (10) state that the catkins are formed within the bud in early spring, the process probably extending through April and May. In any case the staminate flowers are differentiated early in the growing season a full year previous to their appearance, and there is no chance for a deficiency of pollen due to retarded differentiation of stamens. In 1928 a Burkett tree at College Station had two clusters of pistillate flowers sacked after all catkins around the basal portion had been removed. When the sacks were later removed, it was noticed that one lateral bud on each of the new shoots had produced a group of catkins. Since these catkins were on current season's growth, they had certainly been differentiated just previous to their appearance. The catkins appeared normal but were too late to be of any value in producing pollen for the current season. The stigmas had all dried several weeks previously, while the catkins were still green and immature.

WOODROOF and WOODROOF (36) state that the pistillate flowers are normally differentiated from the terminal buds of the previous season but may be produced from lateral buds. SHUHART (30) gives three cases of false terminal buds which produced pistillate flowers, and maintains that the true terminal bud is strictly vegetative. It has been observed at College Station that few true terminal buds are produced, and the greater part of the pistillate flowers arise from lateral buds near the apical end of the shoot. Buds rendered subterminal in position by cutting back the dormant shoot have in practically all cases produced pistillate flowers.

Detailed study of the structure of the nut in various stages of development showed the following facts:

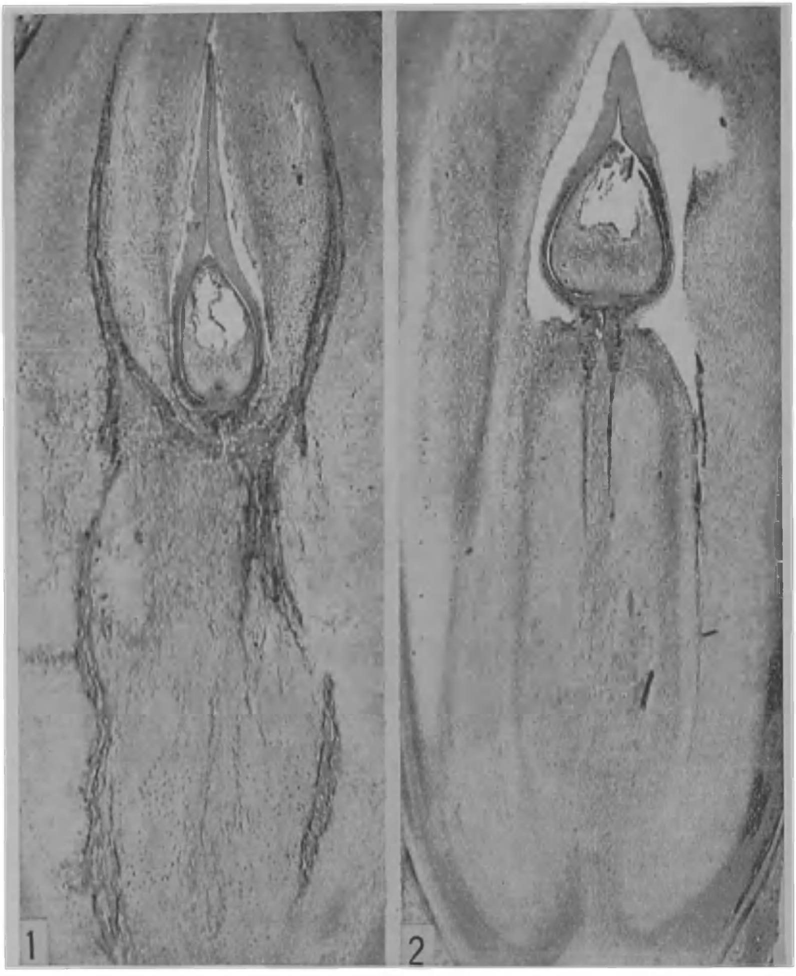
1. The middle septum of the nut is parallel to the axis of the inflorescence, and the plane of the stigmas is also parallel to this axis. In the walnut, although the plane is parallel to the axis, as in the pecan, the middle septum is perpendicular to this axis.

2. The peculiar branching of the vascular system of the walnut, as described by NICOLOFF (26) but not previously figured for the pecan, is clearly shown in this species (figs. 1, 2). NICOLOFF states that anterior and posterior to the ovule the placenta produces two bodies, in the form of horns, which are not an integument as has been represented. The ovule, exactly terminal, according to NICOLOFF, is supplied with symmetrical vascular connections from both sides by vessels (and also phloem) which come from the lateral bundles of the transverse partition, running to a point just below the ovule, and turning back to enter the integument. The development and the anatomy of the ovule, in his opinion, show that this organ has an axil dependence and not a carpellary dependence (cauline instead of foliar).

3. A vertical partition (middle septum) supports the orthotropous, sessile ovule, which has only one integument (figs. 1, 2). After fertilization, the cotyledons expand downward on either side of the partition, away from the micropyle. In the walnut (26) the ovary, at first unilocular, becomes at the time of fertilization quadrilocular in its basal portion, and also in its upper portion; this tendency is observed to a slight extent in the basal portion of the pecan.

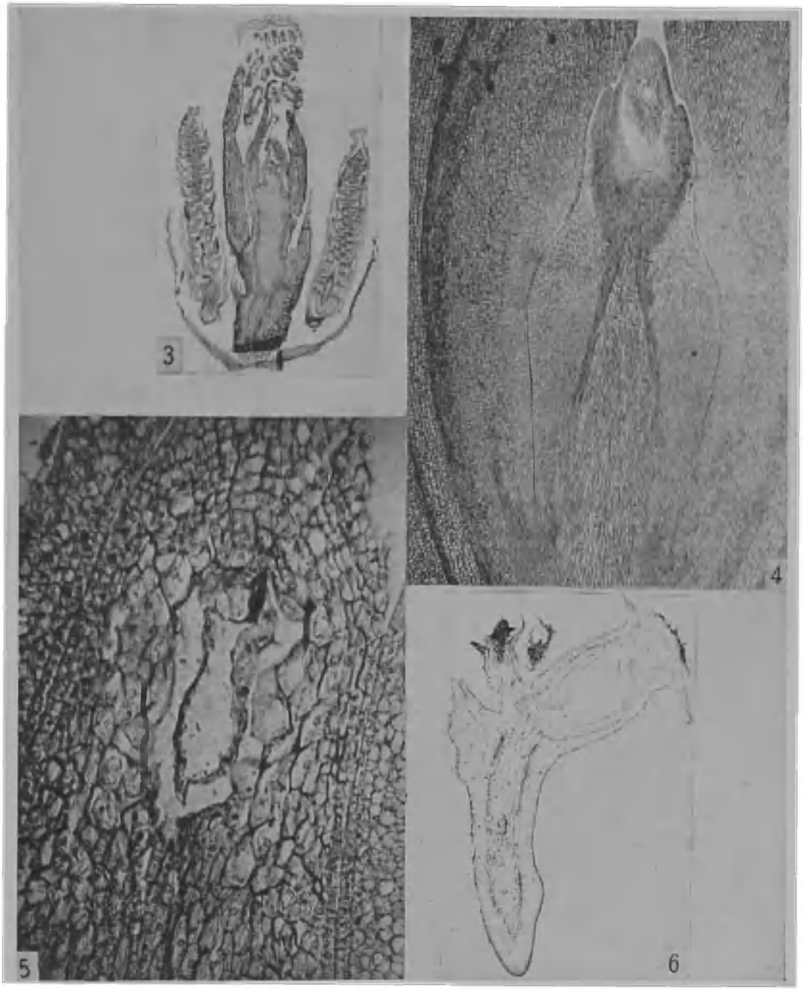
4. The normal bearing habit of the pecan at College Station is the production from a single compound bud, lateral and usually

subterminal, which separates as three buds when the heavy outer bud scales are pushed off in the spring. From the two outer buds,



FIGS. 1, 2.—Fig. 1, longitudinal view of nut in plane of septum 6 weeks after pollination, showing gross morphology and portion of vascular connection of ovule; fig. 2, longitudinal view of nut perpendicular to septum, 6 weeks after pollination; ×18.

two clusters of three catkins each arise with a central shoot, coming from the bud between these two clusters, which terminates in a pistillate inflorescence. This is not in harmony with the common conception that the staminate flowers arise from lateral buds and the pistillate flowers from terminal buds (fig. 3).



FIGS. 3–6.—Fig. 3, lateral bud of pecan at time of swelling in March, showing two clusters of catkins and central shoot with pistillate primordia, ×18; fig. 4, ovule at time of pollination, showing integument not yet inclosing nucellus, ×45; fig. 5, enlarged view of ovule 3 weeks after pollination, showing fertilized egg and disintegrated synergids, ×198; fig. 6, termination of pistillate flower cluster, showing one normal and two abortive flowers, which will shrivel and drop about time of pollination, ×18.

5. In the case of the Stuart pecan, small anther-like structures were observed on the flower axis at the bases of individual pistillate flowers. This condition was observed in two clusters, and no previous record of such structure has been found.

Pollination and fertilization

Chalazogamy, first observed by TREUB (34) in *Casuarina suberosa*, is recorded by BENSON (2) for *Betula*, *Alnus*, *Corylus*, and *Carpinus;* by NAWASCHIN (24, 25) for *Juglans regia* and *Corylus avellana;* by BILLINGS (4) in material of *Carya olivaeformis*, collected a few days after the withering of the anthers; and by WOODROOF and WOODROOF (37), also in the pecan. The writer's observations show that at the time of pollination the ovule is not completely surrounded by the integument, although it is later so inclosed. The pollen tube grows inward through the tissue of the stigma until near the central region of the style, and then grows downward, not in the stylar canal, but along the general course of its vascular tissues. It appears to go down to the chalazal region in various ways, usually in the wall of the ovary. In one case a pollen tube was unmistakably growing downward through the integument.

The ovule at the time of pollination is small and relatively undeveloped, and is not yet surrounded by the integument (fig. 4). Two weeks later the ovule is surrounded by the integument, the megaspore mother cell is discerned, and pollen tubes are present in the nucellus. There is considerable difference at this stage between the pollinated and unpollinated ovules. Although the evidence shows that considerable time elapses between pollination and fertilization, pollination is promptly followed by germination of the pollen grains, growth of the pollen tubes, and this in turn by progressive changes in the several ovarian and ovular tissues. Fig. 5 shows an ovule 3 weeks after pollination.

STERILITY

Sterility in plants has been the object of a considerable number of investigations, many of which indicate lack of pollination to be a factor of considerable importance. SAVASTANO (29) and STANCANELLI (31) record cases of sterility in pistache and filbert, both of which are wind-pollinated nut fruits, where lack of pollination and fertilization was given as the cause.

There is evidence to show that sterility in the pecan is due to lack of viable pollen rather than to self- or inter-incompatibility. Regarding sterility in the pecan in Georgia, STUCKEY (32) states that self-sterility is due primarily to the interval in time between the receptive stage of the pistillate flowers and the shedding of pollen. This type of self-sterility, lack of self-pollination instead of true self-sterility or incompatibility, is not the usual condition in commercial fruit plants.

MORRIS (21) showed that eight varieties of the pecan gave an average of 74 per cent set when self-pollinated, and that most of the varieties gave a good set if the pollen was shed shortly before or during receptivity; but when shed early in the season it was not effective on the latest-maturing stigmas.

FACTORS AFFECTING FRUIT SHEDDING.—It is apparently possible to distinguish three distinct periods of dropping in the orchards at College Station: (1) at time of pollination; (2) 2–4 weeks after pollination; (3) at irregular intervals during the remainder of the growing period. With regard to the first condition, certain flower clusters shrivel and dry with the young nuts or flowers still attached to the peduncle. In other clusters, or in fact in nearly all clusters, there are one to three immature nuts at the apical end which shed along with the tip of the peduncle about the time of pollination. This last mentioned type of shedding, however, still leaves a sufficiently large cluster of nuts to produce a good crop. The shriveling of entire clusters has not been observed to any great extent, but the disturbed nutritive conditions following over-production might be responsible for such a condition, as explained by WOODROOF, WOODROOF, and BAILEY (38). The varieties Delmas and Burkett, used in this work, have borne good crops every year during the course of this study, and there has been no opportunity to observe "off" years.

The second type of dropping, referred to as the "May drop" (38), since it has been observed to occur 2–4 weeks following pollination in April and May, has proved of greatest significance in this study. WOODROOF and WOODROOF (37) state that fertilization occurs 2–4 weeks following pollination. The amount of this second drop ranged from 11 to 52 per cent generally to 20 to 30 per cent, as indicated in table I.

The third drop later in the season, due presumably to environmental factors, does not amount to a large percentage of the total drop. The data in table I, showing the total drop to July 15 (about 10 weeks after pollination), and the work of BILSING (5) which shows the drop for the entire summer, indicate that the early or "May" fall may account for the greater part of the seasonal drop.

TABLE I

AMOUNT OF DROP UNDER CONDITIONS OF OPEN POLLINATION 1927–1929

Variety	1927 Total nuts	1927 Percentage dropped	1928 Total nuts	1928 Percentage dropped	1929 Total nuts	1929 Percentage dropped
	Four weeks after pollination					
Schley	119	11	....	....	....	....
Texas Prolific	301	10	303	22	....	....
Delmas	363	23	527	27	2100	17
Burkett	383	19	498	26	1980	41
Rome	209	52	....	....	....	....
Success	87	17	....	....	....	....
San Saba	....	....	388	23	....	....
Stuart	....	....	328	23	....	....
Moneymaker	....	....	420	20	....	....
All varieties	....	22	....	23	....	29
	To July 15					
Delmas	....	....	527	35	2100	24
Burkett	....	....	498	36	1980	48
San Saba	....	....	388	26	....	....
Stuart	....	....	328	28	....	....
Texas Prolific	....	....	303	26	....	....
Moneymaker	....	....	420	23	....	....
All varieties	....	....	....	29	....	36

In the case of the unpollinated nuts, which were sacked before any pollen was shed and kept so until no more pollen was available, there appeared to be about the same amount and character of drop during the first 3 weeks following pollination. After this time, however, the rate of dropping increased rapidly and the condition at the end of the fourth week is shown in table II. There were no unpollinated Burkett nuts to be found for collection the fifth week after pollination time, and, although the Delmas nuts persisted somewhat longer, there were only twelve of these unpollinated nuts after the sixth week. The latter nuts persisting at this time showed clearly defined abscission layers in all cases examined.

ABSCISSION.—Two general types of shedding were observed in Delmas and Burkett. In one case, which is less frequently observed,

TABLE II

EFFECT OF POLLINATION AND LACK OF POLLINATION ON EARLY DROP OF PECANS, 1928

Variety	Total no. of clusters	Percentage of clusters in which number of nuts remaining after 4 weeks was						
		0	1	2	3	4	5	6
		Sacked and not pollinated						
Delmas	392	32	7	15	20	18	7	1
Burkett	373	69	5	6	9	7	3	1
		Pollinated						
Delmas	253	0	7	21	31	28	10	3
Burkett	250	6	5	11	28	34	13	3

the entire peduncle dries up, although the nuts persist. This occurs in the early stages of development of the cluster, usually within a few days after pollination. The nuts never attain the size they do in the case mentioned later. Shedding of the entire peduncle is due in nearly all cases to mechanical injury, such as insect damage or breakage by wind.

The more common occurrence is the shedding of the individual flowers from the peduncle. The nuts in the cluster do not shed all at the same time, although there does not appear to be any regular order for the drop. Even after all the nuts have dropped from the peduncle, it persists in a green condition for a period of several weeks. The evidence presented by the basal region of unpollinated nuts indicates that the abscission layer is well defined within 3 weeks after receptivity. The abscission appears to be produced in the characteristic manner, as described by HANNIG (9), LLOYD (12, 13), and NAMIKAWA (22, 23) for various nut fruits, not including the pecan. The walls of the cells in the separation layer are softened and the cells grow longitudinally, producing considerable displacement and disruption of the tissues.

The data presented in tables I and II indicate that the latter type of drop, the shedding of the separate nuts from the peduncle, follows pollination. The few unpollinated nuts in the controlled experiments which persisted after the 6-week period may actually have been pollinated accidentally, or may have developed parthenocarpically. There are sometimes a few seedless pecans, which might be accounted for on this basis.

EFFECT UPON SHEDDING OF PEDUNCLE POSITION.—Preliminary studies were made to determine the relative ability of the nuts in different positions on the peduncle to set and mature. A large number of clusters were treated in the following ways: (1) pollination of two basal flowers only; (2) pollination of two terminal flowers only; (3) pollination of two terminal flowers and snipping off basal flowers; (4) pollination of one basal and one terminal flower. Considerable difficulty was encountered in this work, owing to the lightness of the pollen, which made it almost impossible to keep it from the other flowers in the cluster. A number of pollinations were made as outlined, after the nuts to be left unpollinated had been covered with small gelatin capsules. Because of high winds, most of these capsules were shaken off and the nuts pollinated from loose pollen in the bags. It was also attempted to kill the stigmatic surface of the nuts not to be pollinated with osmic acid. The results in both cases were of questionable value and are not included.

Later studies on open pollinated clusters, however, show that there is a rather definite relationship between the position of the nut in the cluster and the probability of its shedding. Table III indicates that in clusters of varying numbers the basal nut or flower is much more likely to be dropped than any other. The position next to the basal is the one showing the next largest percentage of drop, and the apical nut or flower third. The percentages of drop in the respective positions are 13, 7, and 4.5. Those nuts in intermediate positions are much less likely to drop. These data are not in accord with those given by WOODROOF, WOODROOF, and BAILEY (38), who found the number of nuts to the cluster influenced the position of shedding. It is frequently observed with the pecans at College Station, how-

TABLE III

RELATION BETWEEN POSITION OF NUT IN CLUSTER AND SHEDDING

Variety	No. of nuts	Percentage shed to July 2, 1928					
		1 (basal)	2	3	4	5	6
		Clusters of 6 nuts					
Delmas	264	12	8	3	2	3	6
Burkett	156	14	9	2	4	6	4
San Saba	12	18	8	0	0	0	0
Moneymaker	48	14	4	0	2	0	2
Total	480	13	8	2	3	4	5
		Clusters of 5 nuts					
Delmas	215	13	9	4	1	5	
Burkett	250	14	10	5	4	5	
San Saba	90	12	2	3	1	2	
Stuart	50	16	6	6	2	10	
Moneymaker	110	10	3	0	0	4	
Total	715	13	7	4	2	5	
		Clusters of 4 nuts					
Delmas	40	17	5	2	7		
Burkett	76	20	8	4	4		
San Saba	204	11	8	1	5		
Stuart	144	8	5	5	5		
Texas Prolific	116	20	4	1	3		
Moneymaker	200	13	7	3	3		
Total	780	13	6	3	4		
		Clusters of 3 nuts					
Delmas	9	11	0	11			
Burkett	15	20	7	0			
San Saba	84	12	13	5			
Stuart	87	12	6	6			
Texas Prolific	123	16	5	4			
Moneymaker	54	7	11	2			
Total	372	13	8	4			

ever, that the basal nut does not always complete its development in time for pollination, and the heavy shedding from this position may be attributed to lack of pollination.

Within the pistillate inflorescence, the different flowers of the cluster are at the same stage of development at the time of pollination, except for the smaller ones noted later. It has not been possible to fix a different time of receptivity for the different flowers of normal size in the cluster. According to WOODROOF and WOODROOF (37), the basal flowers are differentiated first, and there are always some undeveloped flowers at the apex of each cluster. These flowers are normal but not far enough advanced to be receptive, and are shed soon after the period of pollination (fig. 6). It has been observed in several cases, especially with Texas Prolific, that there are sometimes one or two immature flowers at the base of the cluster; these have always been observed to fall without reaching the stage for pollination. WOODROOF and WOODROOF (37) illustrate this characteristic, but state that such flowers may develop into nuts.

A careful consideration of the preceding data seems to warrant the following interpretations: (1) The so-called "May" drop of pecans occurring 2–4 weeks after pollination accounts for the greater portion of the total drop, except those which are damaged by insects and diseases, or drop later as the result of drought. (2) This "May" drop appears to be the result of lack of fertilization of the flowers, due primarily to lack of pollination, since it coincides with the drop of sacked unpollinated flowers. (3) A proper supply of pollen at the time the pistillate flowers are receptive is the primary requisite for setting and development of the nuts.

In view of the fact that pollination seems to be the limiting factor in determining the set of fruit in the pecan, a consideration of the factors influencing pollination is of primary importance. Since dichogamy nearly always occurs in monoecious or dioecious plants, investigations of this condition were made in the case of the pecan.

DICHOGAMY

The factors of primary importance in the consideration of dichogamy are the character and extent of the difference in time of maturity of pistillate and staminate flowers, and the factors which influence this difference in maturity. KERNER and OLIVER (11) state that all monoecious plants are protogynous, although other workers (15–20, 27) have shown that protogyny is not always the rule in the nut fruits. STUCKEY (32) divided the pecan varieties into two groups on the basis of dichogamy, stating that in group I the pistillate flowers of most varieties become receptive at the same time that the staminate flowers shed their pollen, while in group II the pistillate flowers become receptive 2–10 days before the staminate flowers shed their pollen.

TABLE IV

RANGE OF MATURITY OF PECAN FLOWERS, 1925–29 (DAYS AFTER MARCH 31; E.G., APRIL 10=10, MAY 10=40)

VARIETY	STAMINATE					PISTILLATE				
	1925	1926	1927	1928	1929	1925	1926	1927	1928	1929
	Old orchard									
Texas Prolific	9–16	21–26	10–15	20–30	9–14	11–22	31–40	17–21	24–34	9–15
San Saba	9–15	27–32	10–16	24–34	11–20	11–23	33–38	17–24	28–39	11–21
Delmas	14–21	31–38	17–23	31–40	20–25	8–15	32–37	19–20	23–32	10–18
Stuart	14–24	30–38	18–30	35–43	21–26	12–24	34–40	19–22	28–36	10–20
Moneymaker	17–21	31–37	14–20	29–37	16–21	10–17	31–35	14–15	24–30	11–19
Bolton	9–17	28–34	13–20	27–35	16–22	7–12	26–28	13–14	23–28	9–15
Rome	9–13	24–28	10–15	24–32	11–19	8–13	30–35	18–20	25–35	9–15
	Young orchard									
Schley	.....	.....	17–28	33–39	19–24	.....	.....	19–21	24–34	10–18
Moneymaker	.....	.....	14–21	28–36	20–27	.....	.....	12–13	27–42	10–18
Success	.....	.....	26–28	32–39	17–22	.....	.....	26–30	25–34	13–19
Alley	.....	.....	11–21	24–32	11–16	.....	.....	22–25	31–45	14–20
Moore	.....	.....	8–14	22–30	7–13	.....	.....	21–26	25–44	10–14
Burkett	.....	.....	17–28	32–40	20–26	.....	.....	18–21	24–32	9–17
Onliwon	.....	.....	11–19	26–33	14–18	.....	.....	24–30	28–44	11–16
Atwater	.....	.....	.....	33–40	20–25	.....	.....	.....	25–32	10–14
Western Schley	.....	.....	15–20	29–34	14–19	.....	.....	24–28	32–46	11–16
Delmas	.....	.....	17–30	32–41	20–26	.....	.....	19–21	25–37	10–20

The blossoming data in table IV show that the type of dichogamy in the pecan is not always fixed, and data in table V make it evident that there is a strong tendency in certain seasons toward protandry and in others toward protogyny. Some of the most important commercial varieties, as Delmas, Schley, Stuart, and Burkett, respond to these seasonal tendencies. It is also shown (table V) that there is a group of varieties which have a positive tendency toward protandry, which tendency has not been observed by previous investigators. Texas Prolific, San Saba, Moore, and Alley were protandrous every year. Another group shows a positive trend toward protogyny, although this is not so strongly marked as in the protandrous

TABLE V

CHARACTER AND EXTENT IN DAYS OF DICHOGAMY; + INDICATING PROTOGYNY AND − PROTANDRY

Variety	1925	1926	1927	1928	1929
	Old orchard				
Texas Prolific	2−	10−	7−	4−	0
San Saba	2−	6−	9−	4−	0
Delmas	6+	1−	2−	6+	10+
Stuart	2+	4−	1−	6+	11+
Moneymaker	7+	0	0	5+	5+
Bolton	2+	2+	1+	4+	7+
Rome	1+	6−	8−	2+	4−
	Young orchard				
Schley	......	......	2−	9+	9+
Moneymaker	......	......	2+	1+	10+
Success	......	......	0	7+	4+
Alley	......	......	11−	7−	3−
Moore	......	......	13−	3−	3−
Burkett	......	......	1−	8+	11+
Onliwon	......	......	13−	2−	3+
Atwater	......	......	......	8+	10+
Western Schley	......	......	7−	3−	3+
Delmas	......	......	2−	7+	10+

group. Moneymaker, Success, and Bolton were protogynous in almost every case through the entire period; Moneymaker in 1926 and 1927, and Success in 1927, matured staminate and pistillate flowers on the same date.

In view of these facts, it seems advisable to depart from previous classifications, and make three groups of pecan varieties as regards dichogamy: protandrous, fluctuating, and protogynous.

SEASONAL TENDENCIES.—The behavior of the fluctuating varieties, as well as the tendency of the positive varieties toward overlapping in blossoming, indicate that the seasons of 1925, 1928, and 1929 exerted some influence toward protogyny; the seasons of 1926 and 1927 toward protandry. It was considered advisable to ascertain whether these tendencies might be associated with definite conditions of environment, as suggested by MEEHAN (16, 18).

The critical factors which might cause a difference in maturity of the flowers were considered to be temperature and rainfall, although

TABLE VI

WEEKLY, MONTHLY, AND SEASONAL ACCUMULATION OF HEAT UNITS ABOVE 40° F. (MEAN) AT COLLEGE STATION, 1925–29

Date		1925	1926	1927	1928*	1929
January	7	72.5	51.0	113.0	20.0	40.5
	14	123.0	74.0	166.0	136.5	110.0
	21	159.0	188.5	269.0	279.5	229.0
	28	231.0	207.0	326.0	228.0	321.0
February	4	320.5	309.5	490.5	460.0	368.0
	11	483.5	432.5	602.5	570.0	387.5
	18	597.5	592.5	729.0	625.5	445.5
	25	781.5	728.5	857.5	686.5	494.0
March	4	901.5	853.0	923.0	781.5	599.5
	11	1103.0	982.0	1069.0	961.5	750.0
	18	1272.5	1067.0	1224.0	1119.0	873.0
	25	1441.0	1249.0	1322.5	1241.5	1076.5
April	1	1644.0	1316.5	1524.0	1422.0	1314.0
	8	1843.5	1487.5	1742.0	1590.0	1573.0
	15	2081.0	1621.5	1977.5	1684.0	1786.0
	22	2358.0	1799.5	2173.0	1857.5	2016.0
	29	2618.5	1982.0	2340.0	2020.5	2261.5
	30	2632.5	2010.0	2372.0	2079.5	2302.0

* Leap year, February 29 included in figures and date advanced one day, beginning March 3.

wind and atmospheric humidity probably have considerable influence upon duration of receptivity of the stigmas and shedding of the pollen.

In the consideration of the effect of temperature, the number of heat units above 40° F. mean was recorded for the first 4 months of each year, as described in the first part of this work. These figures were arranged to show weekly, monthly, and seasonal accumulations during the entire period (table VI). As shown by the totals on April 30, the year 1925 had the greatest number of heat units; 1927 and

1929 were about equal and considerably fewer than 1925; and 1926 and 1928 had still fewer than the two last mentioned.

The monthly rainfall for the entire period and the weekly accumulations are shown in table VII. The rainfall in the three protogynous seasons was considerably less than in the protandrous seasons. For the protogynous seasons, 1925 had 4 inches, 1928 had 9 inches,

TABLE VII

WEEKLY, MONTHLY, AND SEASONAL RAINFALL AT COLLEGE STATION (INCHES) 1925–29

DATE	1925	1926	1927	1928	1929
January					
7	0.00	1.55	0.00	0.29	2.53
14	1.12	1.58	1.03	0.29	4.50
21	1.69	3.97	1.30	0.35	4.84
28	1.69	4.32	1.63	0.39	5.09
February					
4	1.72	4.37	1.63	1.47	5.24
11	1.77	4.37	3.44	1.61	5.90
18	1.77	4.58	3.58	2.35	5.95
25	2.17	4.58	3.58	4.70	6.26
March					
4	2.34	5.12	7.88	4.70	1.92
11	2.34	7.80	9.07	5.97	7.04
18	2.67	8.48	9.07	6.61	7.99
25	2.67	10.46	10.76	6.69	8.92
April					
1	3.55	12.62	10.76	6.99	8.94
8	3.55	12.69	10.77	7.64	9.71
15	3.55	13.96	14.69	9.74	10.68
22	3.55	16.37	16.91	9.83	10.69
29	4.17	16.61	17.39	9.83	10.69

and 1929 had 10 inches. For the protandrous years, 1926 had 17 inches, and 1927 had 17 inches. The weekly accumulations give a better idea as to the distribution of this rainfall.

When the combined effect of temperature and rainfall is considered, it may be observed that these two factors compensate for each other to some extent. The season of 1925, which was very hot and very dry, was not so strongly protogynous as the season of 1928, which was much cooler and had more rainfall. In the same way the season of 1929, which was even more strongly protogynous than 1928, had very little more rainfall than 1928, and was much cooler up to the early part of April. The greater total of heat units is accounted for by the sustained high temperature in April, after many of the trees had blossomed.

In the two protandrous seasons of 1926 and 1927, however, there was no observed difference in blossoming which might be attributed to the difference in heat unis. The heavy rainfall is the only outstanding factor which is common to these two seasons.

When the heat units to date of maturity are considered, as shown in table VIII, two facts stand out:

1. On the basis of the means, there is a much greater variation in any one year between varieties in number of heat units to maturity of staminate flowers than to maturity of pistillate flowers. To express the same behavior in a different way, there is less difference in the date of blossoming of pistillate flowers than of staminate. This same difference is apparent in both the old and the young orchards, where both age and variety of the trees are different. The significance of these differences is greater from the fact that Delmas and Moneymaker, the only two varieties occurring in both orchards, check closely in their requirements.

2. The pistillate flowers vary much more from year to year in their total requirements than do the staminate flowers, the greatest coefficient of variability for staminate flowers, 6.1, being less than the least coefficient for pistillate flowers, 6.7. The actual range in the coefficient of variability for the staminate flowers of the different varieties is from 2.3 to 6.1, and for the pistillate flowers, 6.7 to 9.5. As shown in table IX, the odds in favor of the significance of this difference are 999 to 1.

With regard to all the observations recorded, it may be stated that the conditions of environment in the spring exert considerable influence on blossoming of the pecan. In general it appears that, although the date of maturity of both staminate and pistillate flowers is influenced by favorable conditions for growth in the spring, the staminate flowers respond more readily than the pistillate flowers. This fact would indicate a possibility that seasons favorable for early growth might be favorable for protandry. ADRIANCE (1) has previously presented data showing some effects of spring temperatures in this respect.

In confirmation of this idea, it may be stated that since the pistillate flowers of the pecan are differentiated in the same spring that

TABLE VIII

Heat units to date of maturity of flowers

Variety	Staminate								Pistillate							
	1925	1926	1927	1928	1929	Mean	S.D.	C.V.	1925	1926	1927	1928	1929	Mean	S.D.	C.V.
	Old orchard															
Delmas	2010	2010	2004	2079	1949	2010 ±14	46.1	2.3	1811	2040	2068	1926	1638	1896 ±53	176.7	9.2
Moneymaker	2117	2010	1924	2020	1816	1977 ±34	113.2	5.7	1875	2010	1924	1905	1667	1876 ±38	127.3	6.7
Texas Prolific	1843	1746	1786	1789	1604	1753 ±27	90.4	5.1	1908	2010	2004	1905	1604	1885 ±50	165.5	8.8
San Saba	1843	1904	1786	1905	1667	1821 ±29	99.2	5.4	1908	2070	2068	2002	1667	1943 ±50	167.8	8.6
Stuart	2010	1982	2035	2199	1986	2042 ±27	89.3	4.3	1939	2100	2068	2020	1638	1953 ±56	186.2	9.5
Bolton	1843	1930	1889	1980	1816	1891 ±20	65.9	3.4	1782	1881	1856	1885	1604	1801 ±35	117.9	6.5
Rome	1843	1820	1786	1980	1667	1821 ±33	112.7	6.1	1811	1982	2035	1926	1604	1871 ±51	171.1	9.1
	Young orchard															
Delmas	.....	.....	2004	2119	1949	2024					2068	1926	1638	1877		
Moneymaker	.....	.....	1924	2002	1949	1958					1856	1980	1638	1825		
Schley	.....	.....	2004	2139	1909	2017					2068	1905	1638	1870		
Success	.....	.....	2219	2119	1845	2061					2219	1926	1725	1957		
Alley	.....	.....	1822	1905	1667	1798					2162	2079	1756	1999		
Moore	.....	.....	1708	1857	1540	1702					2138	1926	1638	1901		
Burkett	.....	.....	2004	2119	1949	2024					2035	1905	1638	1859		
Onliwon	.....	.....	1822	1951	1756	1843					2185	2002	1667	1951		
Atwater	.....	.....	.....	2139	1949	2044					.....	1926	1638	1782		
Western Schley	.....	.....	1952	2020	1756	1909					2185	2109	1667	1987		

they appear, but staminate flowers are differentiated the previous spring, under these conditions apparently a "quick" season might mature the staminate flowers earlier than the pistillate. A cold or dry season, on the other hand, might retard the opening of the staminate flowers long enough for the pistillate to differentiate.

TABLE IX

SIGNIFICANCE OF COEFFICIENTS OF VARIABILITY IN TABLE VIII

C.V. Staminate A	C.V. Pistillate B	B−A	D	D^2
5.1	8.8	3.7	0.0	0.0
5.4	8.6	3.2	−0.5	0.25
2.3	9.2	6.9	3.2	10.24
4.3	9.5	5.2	1.5	2.25
5.7	6.7	1.0	−2.7	7.29
3.4	6.5	3.1	−0.6	0.36
6.1	9.1	3.0	−0.7	0.49
		7)26.1 3.7	+4.7 −4.5	7)20.88 2.98

$$P=\sqrt{2.98}$$
$$=1.726$$
$$Z=\frac{3.7}{1.726}$$
$$=2.1436$$

odds 999 to 1.

A further consideration is the fact that pistillate flowers are borne on the terminal part of new shoots, and a season favorable to strong vegetation might delay their development.

Summary

1. The pistillate flower of the pecan consists of an orthotropous ovule, surrounded by a single integument. The portion which becomes the shell consists of two carpels, which are transverse on the axis of the inflorescence. The 4-valved husk is developed from the lower portions of the calyx lobes. The flowers are sessile on the peduncle, and are borne in clusters usually of two to six.

2. The pollen tube grows down through the style and ovary wall or integument to the base of the ovule, and returns through the chalaza and nucellus to the embryo sac, fertilization occurring about 4 weeks after pollination.

3. There is a definite drop of young nuts about 4 weeks after the

time of pollination, and this drop accounts for over 75 per cent of the seasonal drop. It appears to be due to lack of pollination.

4. The varieties tested show no evidence of self-incompatibility or inter-incompatibility. Good sets of fruit were obtained from any variety of pollen available when the flowers were receptive.

5. The period of maturity of staminate and pistillate flowers of the pecan do not often coincide. This condition of dichogamy may be complete or incomplete, and the special type may be protandry or protogyny. Some varieties, such as Moore, Alley, Texas Prolific, and San Saba, have been protandrous every season, and have had pollen available in time to pollinate the earliest flowers of any variety. Some varieties, especially Moneymaker, Bolton, and Success, have been protogynous or overlapping slightly every year, and have been dependent upon other varieties for pollination in almost every case. A group of varieties, including Delmas, Burkett, Schley, and Stuart, which are frequently recommended for planting together, have been protandrous or overlapping only two years in five. These leading varieties in Texas need other varieties near them to insure availability of early pollen.

6. Certain seasons have been favorable to protandry and others to protogyny. The data on temperature and rainfall for the spring seasons indicate that moisture and high temperature in this period favor early maturity of the staminate flowers, and cool, dry seasons favor earlier maturity of the pistillate flowers. The warm seasons of heavier rainfall advance maturity of both the staminate and pistillate flowers, but the staminate flowers of any one variety are less variable in their requirement of heat units.

7. It may be said that the early dropping of fruits in the pecan is due primarily to lack of pollination, and this, in turn, is due to dichogamy. Certain varieties (Moore, Alley, Texas Prolific, and San Saba) have proved to be reliable in the production of pollen at an early date, and some of these varieties should be used in every pecan orchard.

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