SOME OBSERVATIONS OF THE FLOWERING HABITS OF CACAO

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OF THE
FLOWERING HABITS OF CACAO

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INTRODUCTION

Although man has used and appreciated cacao as a food and has cultivated it for centuries, very little has been done to improve the crop as to yield until recent years. Among other undesirable characteristics of cacao, there is a striking disparity between the number of flowers produced, the number that set fruit, and the number of fruit that reach maturity on a given cacao tree.

In Trinidad it has been estimated that on the average only 2.0 to 2.5% of the flowers are pollinated, whereas Van Hall (cited by Wellensiek,1932) in Java estimated the percentage there at from 3.9 to 5.9%. Here at Turrialba, and in the lowland farms around Madre de Dios, Waldeck, Zent, and others, the same tendency is conspicuous; trees may be loaded with flowers but mature relatively few pods.

Thus one problem of increasing cacao yield necessitates increasing the proportion of flowers that set fruit and the proportion of the fruits that are carried to maturity. Knowledge of the flowering of cacao, therefore, is necessary. This paper reports the results of a study of the development of the flowers from bud initials through anthesis, pollination, and fruit setting to maturity of the fruit.

LOCATION OF INVESTIGATIONS

The observations and investigations of the flowering habits of cacao were made at 2 locations:

1. El Chino. This is the experimental cacao area located at Turrialba on the Institute grounds. The El Chino planting consists of from 1 to 3 rows of the different clonal selections obtained from the United Fruit Company. Rooted cuttings of clones 11, 12, 221, 613, 650, 667, 676, and 677 were planted here in 1946. The soil is rocky, well drained, and has a pH of 6.3. The area is near the Reventazon river at an elevation of approximately 600 meters. The rainfall from 1942-1948 varied from 1.74 to 3.88 meters per year with a yearly average of 2.42 meters. The mean annual temperature for 1948 was 22.8ºC.*

2. La Lola. Prior to 1948 this was a commercial cacao plantation. It is located near Madre de Dios, some 55 kilometers from Turrialba on the Northern Railway. The farm, lying in the Atlantic coastal lowlands. is now being rehabilitated. The soil is a deep sandy loam and clay loam, naturally well drained and has a pH of aproximately 6.0.

* Rainfall and temperature data was obtained through the courtesy of the U. S. Rubber Station, Turrialba

Seeds of cacao were planted on the farm in 1915, 1916, and 1917 so that a majority of the trees are now 32 to 34 years of age. Rainfall in the area varies from an estimated 2.5 to 3.5 meters per year.

Some investigations were conducted in the laboratory of the Institute.

OBSERVATIONS AND INVESTIGATIONS

Flowering Habits of Cacao

The cacao inflorescence occurs on old wood. The buds first appear as white or pink points on bumps or cushions that arise in the original leaf axils. On trunk wood these cushions occur in a spiral formation, whereas, on branch wood they occur alternately. An occasional cushion may arise from on adventitious bud, but the extent of this type of formation has not been determined. Cushions and flowers seldom appear on trunk or branchwood younger than 3 or 4 flushes behind the growing point; 2 cases were observed in which flowers formed on green, actively growing tissue, 1 each on clones 11 and 12. After its first appearance the flower bud expands and the various parts gradually become visible. It reaches normal size in 18 to 22 days; its pedicel then ceases to lengthen. At this time the still-closed bud measures about 5 mm. in diameter and 7 mm. in length.

The pedicel is composed of 2 parts one of which joins onto the branch and the other onto the bud. Where these come together there is a marked line, the line of abscission. Numerous measurements were made of pedicel length from the abscission line to the bud and from the abscission line to the flower cushion. The means of these measurements are shown in table 1.

Table 1. Mean length of pedicel from abscission line to bud, and from abscission line to flower cushion. Measurements were taken at El Chino in January 1949.

Length of Pedicel in mm.

Clone	From abscission line to bud*	From abscission line to cushion **
11	19.85	3.90
12	20.15	4.72
221	18.35	4.60
613	23.35	4.70
650	19.85	4.70
667	20.45	5.30
676	21.45	4.08
677	20.50	5.88

* Mean of 20 measurements

** Mean of 25 measurements

The distance from the abscission line to the bud varied from 13 to 31 mm.; from abscission line to cushion, 1 to 7 mm. There was considerable variation in the individual measurements in each of the different clones. The data, although not conclusive, indicate that the length of the basal part of the pedicel may be a clonal characteristic. The abscission line shows clearly on the pedicel even up to maturity of the fruit. The flower withers from this line when fertilization is not effected.

Anthesis: Opening of the flower begins by the formation of a shallow furrow between adjacent sepals; this furrow increases slowly in size until the opening is complete. Anthesis usually begins the day preceding the time of complete opening of the flower. In August 1948, buds were observed beginning to open between 10 a.m. and 5 p.m. These buds were all open the following morning by 5:30 a.m. In January 1949, 54 buds were marked as beginning anthesis at approximately 3 p.m. These buds were observed at 2 hour intervals during the succeeding night. Thirty-eight of the buds were completely open by 8 a.m. the following morning. The 16 remaining buds did not open until 24 hours later. On bright warm days anthesis may begin as early as 8 a.m., whereas, on dull, cloudy days it may not begin until 5 p.m. The rate of opening apparently is slower in cooler environments; it begins earlier and proceeds faster in the lowland areas than at Turrialba.

<u>Structure of the flowers</u>: The cacao flower is perfect, and has most of its parts in fives. Each of the 5 stamens, however, has only 4 pollen sacs. The anthers are almost completely enclosed in pouches formed by the petals. Each petal encloses 1 anther and ends in a spatulate flap. The androecium consists of 5 long, conical, reddish-purple staminodes covered with fine hairs from base to mid-point and 5 fertile stamens. Sepals, petals, stamens, and staminodes are all joined at their bases into a short tube. The style is a white, needle like structure 2 to 3 mm. in length arising from the center of the ovary and ending in a 5 lobed stigma.

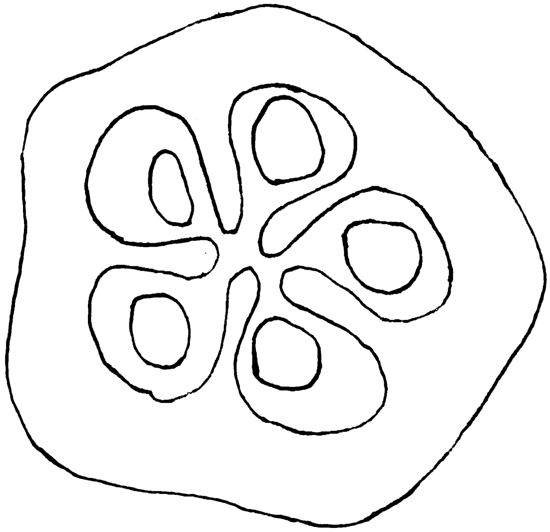
The ovary is oval in shape; contains 5 locules with a maximun of 10 ovules in each locule. A count was made of the number of ovules present in the ovaries of the different clones. The ovaries were cut longitudinally; the contents squeezed out onto a glass slide and stained with acid fuchsin-lactophenol solution. The data are presented in table 2.

The mean number of ovules per ovary for the different clones varied from 33.6 for clone 676 to 39.0 for 11. The mean number for the 40 ovaries examined was 36.1 ovules per ovary. The ovules varied in size from 197 to 265 µ. The number of beans were counted in each of 79 pods havested from 9 different trees at La Lola. The number of beans per pod varied from 20 to 47 with a mean bean number of 34. Thus the number of beans in a mature pod seems to be set by the number of ovules in the young ovary.

Table 2. The number of ovules counted in 5 ovaries of each of the different clones planted at El Chino.

Clone	Number of ovules per ovary					Mean
11	38	40	40	39	38	39.0
12	38	33	35	35	36	35.4
221	36	37	29	39	31	34.4
613	39	40	42	35	38	38.8
650	34	32	38	35	37	35.2
667	28	36	40	36	39	35.8
676	35	31	39	32	31	33.6
677	41	31	34	42	36	36.8
Average						36.1

In figure 1 are shown sketches made from free-hand cross sections of an ovary. Figure 1-a is a section cut near the tip of the ovary, 1-e is from near the base; 1-b, 1-c, and 1-d are consecutive intermediate sections from the



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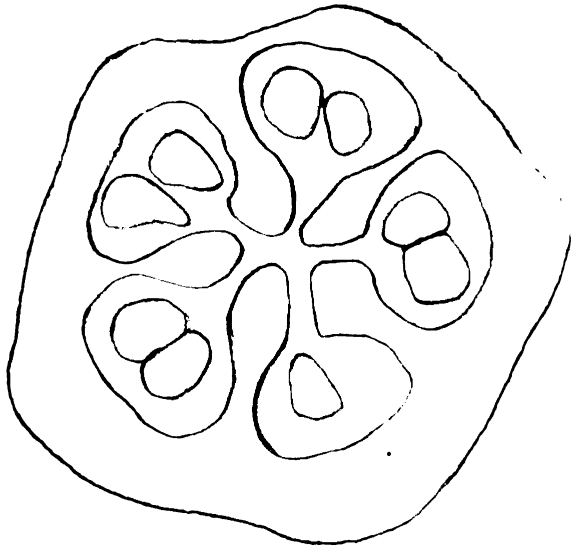

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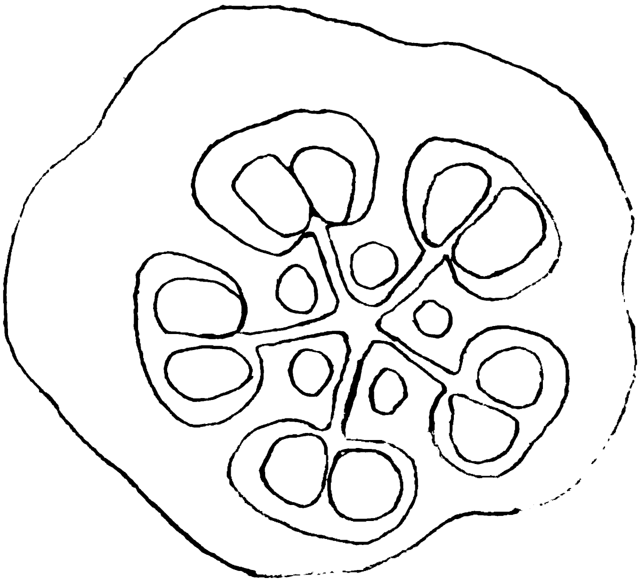

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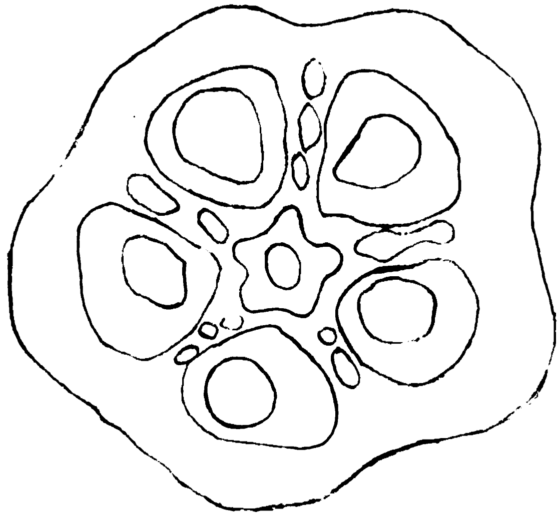

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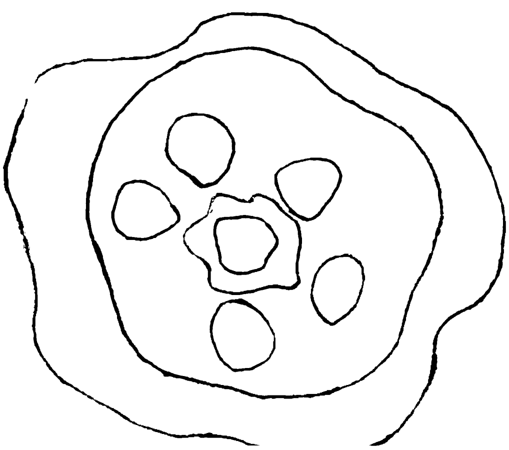

Fig.1. Cross sections through a young ovary of cacao showing the position of the ovules in the locules. a - cross section near tip of ovule; b, c, and d - consecutive cross sections toward the base of the ovary; and e - cross section near base of the ovary.

tip to the base. It may be observed that the ovules in a locule do not necessarily occur in a single line, such as peas in a pod, but that 2 ovules frequently lie side by side, as depicted in figures 1-b and 1-c.

The color of the flowers is an indication of the color of the fruit. White flowers give rise to green pods that are yellow at maturity, and pink flowers give rise to red pods which remain red or orange at maturity. The flowers of clones, 11, 12, 676, and 677 are white; those of 221, 613, 650, and 667 are pink.

Density of flowers: The number of flowers varies greatly from tree to tree and apparently from season to season. Certain clones, 613 for example, bear an abundance of flowers, whereas others have very few. This, however, is not an indication of production. Many self-incompatible clones and plantation trees produce large numbers of flowers and yet yield poorly, whereas some clones and trees which seemingly produce a minimun number of flowers, yield satisfactorily.

Cycles of flower production: It has been reported that when a tree is flushing heavily the intensity of flowering is reduced considerably. Environmental factors have also been reported to exert a marked effect upon flowering, flushing and setting of fruit. In Trinidad, flowers are produced intermittently throughout the wet season, and setting of fruit occurs only at some of these periods.

At La Lola farm, the number of flowers and of flushes per tree for 10 trees in each of 2 sections were counted. The trees in section I were pruned heavily and cleaned in May 1948; those in section VII were not pruned, although the trees were cleaned of parasitic and epiphytic plants. These counts were made at weekly intervals from July to December for most of the trees. The flower counts were obtained by counting all the flowers occurring within a representative foot length of the trunk, the main branches, and the small branches, and adding these 3 figures together. The numbers of flushing branches were counted on each tree. These data are presented in tables 3, 4, 5 and 6. A study of these data shows that there was extreme variation in the numbers of flowers, and/or flushes for each individual tree and likewise from week to week during the period of investigation. Flower production in section I apparently reached its peak September 30; in section VII on November 4.

In the 2 sections, these flower production peaks coincided with relatively dry weather. There were no clear cut peaks in flushing. A graphic study of the number of flowers per tree and, the number of flushes per tree with weekly rainfall data obtained from Bataan (6.5 kilometers east of La Lola) indicated that there were no correlations between the 3 variables. Each individual tree apparently has its own independent characteristics.

Table 3. The estimated number of flowers per tree in section I at La Lola farm for the period from July 22 to December 3, 1948.

TREE NUMBER

Date	1	2	3	4	5	6	7	8	9	10
July 22	71	25	132	76	21	-	-	-	20	134
" 28	100	29	91	90	19	1	15	36	-	149
Aug. 19	147	30	85	112	17	4	26	42	80	200
" 26	98	11	58	-	-	10	19	58	59	104
Sept. 2	-	-	-	-	-	4	16	-	49	-
" 8	130	24	109	110	40	12	24	32	43	152
" 16	117	13	68	116	18	3	12	30	24	133
" 30	226	71	192	-	-	10	31	8	98	206
Oct. 8	150	62	105	159	16	22	21	32	54	175
" 14	-	-	-	-	-	-	-	-	-	-
" 22	76	30	106	95	16	17	12	17	34	80
" 28	40	24	182	107	14	16	23	31	51	102
Nov. 5	45	14	56	129	16	24	17	20	52	80
" 12	17	21	118	118	20	40	26	36	35	92
" 18	58	18	57	82	14	-	22	16	9	73
" 25	41	15	38	113	6	52	14	10	7	98
Dec. 3	48	14	21	70	5	37	9	14	14	69
Total	1424	401	1418	1377	222	252	287	382	629	1847

Table 4. The estimated number of flowers per tree in section VII at La Lola farm for the period from July 22 to December 3, 1948.

TREE NUMBER

Date	1	2	3	4	5	6	7	8	9	10
July 22	-	-	-	-	14	20	-	21	-	-
" 29	92	12	-	-	-	24	12	24	5	27
Aug. 27	77	14	56	-	28	50	13	20	10	34
Sept. 3	-	-	-	-	-	26	-	-	-	-
" 9	134	17	50	-	30	51	58	38	28	44
" 17	90	25	17	-	22	39	36	35	10	48
Oct. 1	-	-	-	-	-	36	48	72	37	38
" 9	61	9	18	28	15	27	21	37	22	20
" 14	-	-	-	-	-	-	-	-	-	-
" 21	116	12	13	0	13	3	3	20	5	8
" 29	170	27	41	3	33	50	36	36	20	46
Nov. 4	196	38	40	0	44	59	27	45	14	36
" 12	140	35	33	7	32	27	29	29	25	47
" 19	81	29	10	8	23	26	20	19	15	25
" 26	130	26	21	0	33	28	59	53	32	38
Dec. 3	116	10	11	6	24	29	68	61	42	69
Total	1403	254	310	52	311	495	430	510	265	480

Table 5. The number of flushing branches per tree in section I at La Lola farm for the period August 19 to December 3, 1948.

TREE NUMBER

Date	1	2	3	4	5	6	7	8	9	10
Aug. 19	16	20	34	29	37	-	-	-	10	20
" 26	13	31	-	-	-	22	13	23	31	12
Sept. 2	-	-	-	-	-	22	17	-	-	-
" 6	14	15	34	21	69	19	20	18	29	2
" 16	15	13	51	23	48	13	23	18	37	4
" 30	26	24	36	-	-	10	26	26	20	34
Oct. 8	23	44	59	61	15	15	26	47	24	49
" 22	20	38	51	18	26	24	13	27	12	14
" 28	12	26	37	15	64	21	10	14	22	9
Nov. 5	7	17	49	21	102	12	10	8	32	1
" 12	18	22	75	40	77	7	16	8	35	2
" 18	15	11	49	34	20	6	18	11	26	2
" 25	21	4	43	23	20	1	19	5	13	3
Dec. 3	24	4	24	18	14	1	16	3	11	14
Total	224	269	542	303	492	173	227	208	302	166

Table 6. The number of flushing branches per tree in section VII at La Lola farm for the period August 28 to December 3, 1948.

TREE NUMBER

Date	1	2	3	4	5	6	7	8	9	10
Aug. 28	2	6	7	10	2	9	2	2	2	2
Sept. 3	-	-	-	-	-	21	-	-	-	-
" 9	14	6	21	24	-	41	15	7	8	8
" 17	63	11	38	30	100	70	41	33	25	47
Oct. 1	-	-	-	-	-	54	40	36	33	29
" 9	51	24	31	13	30	11	30	51	34	54
" 21	30	4	13	0	2	2	3	16	13	18
" 29	6	4	22	-	1	2	0	3	4	15
Nov. 4	2	5	47	1	4	2	0	15	3	11
" 12	28	14	41	2	7	27	1	7	2	5
" 19	38	17	29	2	6	32	3	8	4	3
" 26	15	16	21	4	3	41	9	4	5	3
Dec. 3	6	13	28	7	4	38	30	19	19	7
Total	255	120	298	93	159	350	174	201	152	202

POLLINATION OF CACAO

Characteristics of pollen: After the flowers are completely open, the anthers dehisce, liberating the pollen. It has been observed that pollen is best collected after 10 a.m. in Costa Rica. The pollen sacs become light-brown in color in contrast to their former whiteness, just before dehiscing. According to Jones (cited by Wellensiek, 1932) dehiscence of the anthers occurs approximately 2 hours after the flower is completely open. Observations in Costa Rica concur.

As shown in figure 2, the pollen grain of cacao is almost spherical and has 3 minute indentations on its surface, although, sometimes only 1 or 2 of these are visible. These indentations are probably the pores thorough which the pollen tubes emerge.

One hundred pollen grains of each of the 8 clones at El Chino were measured in January, 1949. These data are presented in table 7. The mean diameter of the 800 pollen grains was 20.21 µ. They varied in size from 14.00 to 29.75 µ.

Fig. 2. Sketches of mature pollen grains of <u>Theobroma cacao</u> L. showing the spherical shape and germination furrows. Mean diameter of 800 pollen grains -- 20.21 µ.

Table 7. Size frequency distribution of 100 pollen grains of each of the 8 clones grown at El Chino.

SIZE CLASS (µ) AND FREQUENCY										
Clone:	14.00	15.75	17.50	19.25	21.00	22.75	24.50	26.25	28.00	29.75
11		1	2	39	54	4				
12			11	54	32	3				
221		1	14	39	39	6	1			
613			2	9	62	23	2		1	1
650			9	41	41	5	2	2		
667			2	32	48	15	2	1		
676			5	58	36	1				
677	1	1	16	38	44					

An attempt was made to determine the number of pollen grains produced in individual flowers. Three anthers from a single flower were placed in separate drops of lactophenol-acid fuchsin solution. These were covered with cover glasses which had been marked with india ink into 36 squares of approximately 3 mm. each. The mounts were then pressed enough to force out and distribute the pollen grains on the slide. The pollen grains in each square were then counted at 100 X magnification. Because of the difficulties envolved, counts were made for only 5 flowers. Regardless of the care exercised, and precautions observed, some of the pollen was lost in the process. The pollen counts thus obtained are given in Table 8. The number of pollen grains per flower were calculated by multiplying the total for 3 anthers by 5/3.

Table 8. The number of pollen grains counted in 3 anthers from flowers of clones 631, 667, and 677, and the calculated total number of pollen grains per flower.

Clone	Number of pollen grains per anther			Calculated Total per Flower
	1	2	3	
613	983	1729	1567	7130
667	1019	1938	1702	7665
667	857	1007	1130	4990
677	1190	950	1358	5830
677	2019	1657	1954	9380

The mean number of pollen grains per anther was 1,404, and per flower, 7,020. The pollen-ovule ratio in one flower thus is 7,020/36 or 195: 1. That is, on the basis of these pollen counts, which are undoubtedly low, there are 195 pollen grains for each ovule to be fertilized.

Germination of pollen: Pollen grains of the different clones were germinated in the laboratory in the following manner. The medium consisted of 0.5% agar - 5% sucrose solution. The solution was sterilized, cooled to 43ºC and then a drop of it placed on a slide with a sterilized brush. An anther was then shaken gently over the drop. A tiny piece of stigma was placed in the edge of each drop, and observations made with a microscope at 100 X magnification. The pollen tubes were observed beginning to form approximately 20 minutes later. They continued to increase in length for about 2 hours, at which time the pollen grains appeared to be empty of cytoplasm. Representative examples of germinated pollen grains are shown in figure 3. The results of the germination tests for each clone are presented in table 9.

Dissemination of pollen: Many diverse opinions have been offered in the past concerning the pollinating agent of cacao. Wind was believed to be the pollinating agent in Java (de Haan, cited by Voelcker, 1938, and Wellensiek, 1932). Personal observations support the thesis that wind can be and probably is responsible, at least in part, for some self and cross pollinations in cacao. The morphological characters of different parts of the flower are so adapted that pollen transfer by wind may be effected. The flower is usually

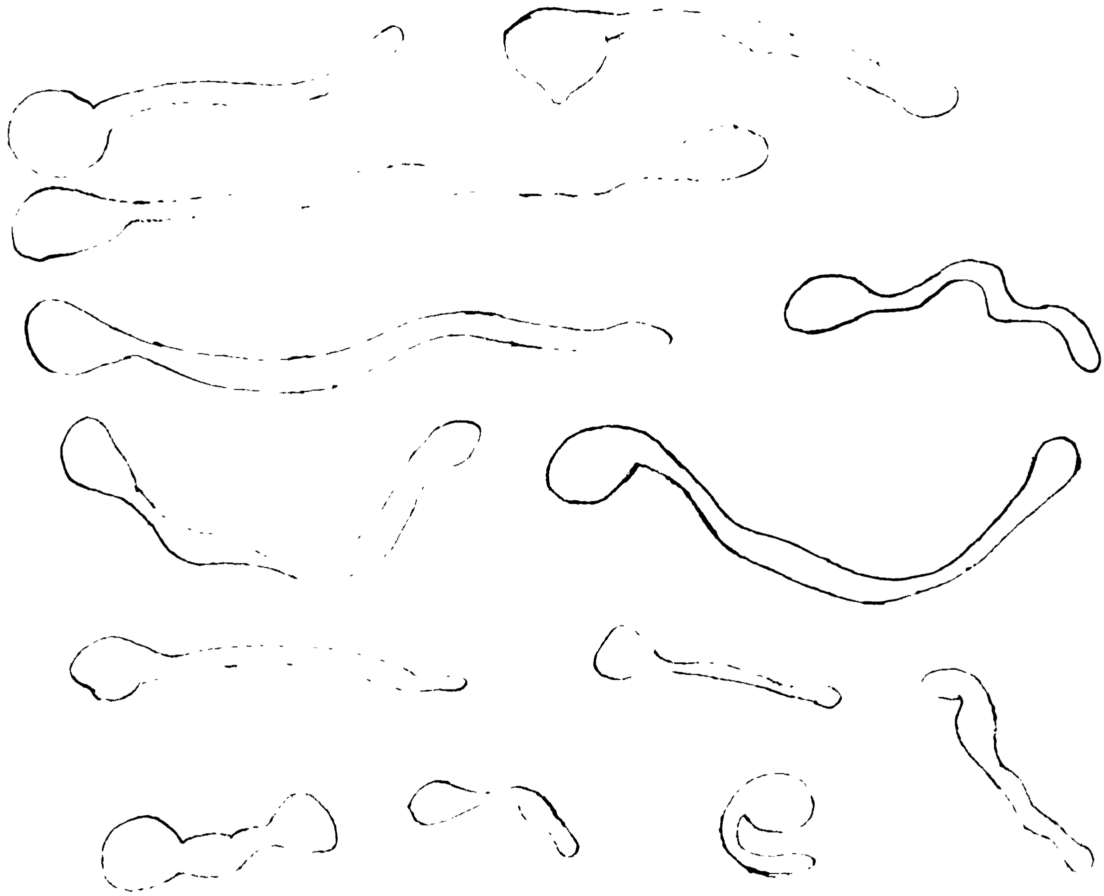

Fig. 3. Representative sketches of germinated pollen grains of <u>Theobroma cacao</u> L. The longest pollen tube depicted measured 107 μ.

turned downward, and the shape of the petal pouch is such that, when the wind enters thorough the petals, this pouch is inflated. The pollen grain could be blown out and across the space occupied by the stigma and style. The excess of pollen not caught by the stigma on the same flowers could float out into the air. Because of their small size, the pollen grains could be carried to a considerable distance, even by a mild breeze.

Table 9. The percentage germination of the pollen of the different clones planted at El Chino.

Clone	Number of slides	Number of Pollen grains	Number germinated	Percentage germination
11	12	2616	1512	58.15
12	11	2172	1146	57.09
221	8	1819	1255	69.41
613	9	1456	883	63.60
650	8	1371	556	40.02
667	11	2139	1439	69.20
676	10	2347	1318	59.65
677	9	1750	1304	75.64
Average				61.59

In records obtained at La Lola, it was noted that of 24 fruit sets observed, 16 were located in spots exposed to the prevailing wind. At El Chino, there are 2 trees of clone 613 which are located at opposite extremes of one row. This is a self-incompatible clone, hence must receive pollen from one of the neighboring trees of a different clone. Of the 2 trees, the one protected from the wind produces an abundance of flowers but few fruit, whereas the other, more exposed to the wind produces fewer flowers but more fruits.

In attempts to remove the petals from a cacao flower it has been observed that pollen grains dust out at the slightest movement. By blowing gently on flowers held in front of moist slides one can collect pollen grains. The mean size of 20.21 μ of cacao pollen is within the range of good floaters as classified by Wodehouse (1935). Wodehouse classified pollen falling in the size range of 17 to 58 μ as good floaters and generally belonging to anemophilous plants. Naturally there are some exceptions.

On the other hand, there are many arguments against the above thesis. The ovule-pollen grain ratio of cacao reported above is much smaller than similar ratios reported by Erdtman (1943) for wind pollinated plants. Some of the ratios reported were: Corylus avelana, 1:2,550,000; Fagus silvatica, 1:637,000; Acer pseudoplatanus, 1:94,000; Secale cereale, 1:57,000; Tilia cordata, 1:43,300; and Betula verucosa, 1:6,7000. The pollen grain of cacao is sticky; small clumps of pollen are frequently observed on the stigma and style of the flower. The construction of the flower is such that insects would appear necessary to effect pollination. Van Hall (1932) wrote: "The structure of the flower is that of a typical insect flower. The basal part of each petal has three carmine-coloured ridges provided with hairs pointing towards the centre, and along the staminodes we find similar ridges. These ridges are typical honey guides. The flower is without smell."

Some investigations believe that cacao pollen is too sticky for wind dissemination, and credit thrips, red ants, and aphids as the important agents of pollination. Cope (1939) showed that the maximun curves of insect density and fruit setting corresponded in their peaks. In an investigation intended to establish the role of insects, Posnette (1938) surrounded 2 trees with fine cloth, 2 with insect proof girdles, and 2 trees were left unguarded. After 91 days, he observed 0.2% fruit setting in the first group, 1.3% in the second, and 5.2% in the third. Posnette* has indicated more recently that species of midges (family, Ceratopogonidae) are the important pollinating agents of cacao.

*Information included in letter from A. F. Posnette to Geo. F. Bowman, Jan. 1949.

In Costa Rica, many small black ants are frequently observed present on branches and flowers of cacao; aphids likewise are quite common. Small black thrips are usually seen in and about the flower and are surprisingly active; they often fly out while one is observing the flower. Observations have been directed toward ascertaining the probable insect pollinator in Costa Rica but to date, the observations are not conclusive. Only 1 midge has been observed thus far.

It may be that both wind and insects are involved in the pollination of cacao. The low fruit production relative to the high flower production indicates that, the pollinating agent, or agents, is not very effective. It has been established that a high degree of cross fertilization occurs. Harland and Frecheville (cited in Cheesman, 1932) reported that 30% of the pods produced in Trinidad were the result of cross pollination. The following quotation (General Foods Corporation Report, 1945) emphasizes the high degree of crossing encountered in cacao: "Most characteristics of the Trinitarios and to a lesser extent of all significant cacao populations today is their hybridism. With Trinitarios from tree to tree in the same forest it is not uncommon to find all variations approaching in character the extremes of the original Criollo and Amazonian Forastero types. This is the result of the marked tendency of cacao to interbreed, and the reason for the difficulty in finding any pure stock in cacao today." This extreme hybridism is clearly evident in the cacao growing regions of Costa Rica.

FRUITFULNESS OF CACAO

Cherelle wilt: Cacao fruit has been considered as set 14 days after pollination (Voelcker, 1937) at which time it is 7 to 12 mm. long. Quite often, growth of the cherelle stops and the young fruit shrivels and dries up. This development is known as cherelle wilt; its incidence appears to vary from tree to tree, with environmental conditions and the number of fruits formed on a tree. Hewison and Ababio (1930) observed that a great proportion of cherelle wilting occurred during one short period in each month and that the period was not the same for all trees. A period of appreciable loss occurred when fruits were 3 to 4 weeks old; losses became much less important after the ninth week. Maximum loss from cherelle wilt has been reported to occur within the first 52 days after fertilization. Humphries (1940) gives the maximum danger period as 70 days.

It has been shown that the end of this danger period corresponds with the time of the first division of fertilized eggs within the ovules. It has been assumed that the early stages of the growth of the embryo are associated with biochemical changes that might account for the period of susceptibility to failures under adverse conditions of nutrition and water balance.

In El Chino, almost all of the fruits set in 1948 on the young plants of clones 11, 12, 613, 650, 667, and 677 were lost by cherelle wilt. The mean length of cherelle wilted pods collected at El Chino in December, 1948 was 4.05 cm.; the smallest was 1.8 cm. and the largest 8.5 cm. The mean length of 23 such fruits collected at La Lola in November 1948, was 5.8 cm.; the smallest 2.5 cm. and the largest, 11.0 cm.

The total number of fruit produced and the incidence of cherelle wilt in 20 cacao trees was determined at La Lola during the period July to December, 1948. These data, presented in table 10, showed extreme variation in cherelle wilt losses from tree to tree. The percentage losses per tree ranged from 0.0% to 53.0%. Comparisons between individual trees are not valid, except to point out the extreme variation. In Trinidad, the losses due to cherelle wilt were reported by Rounce and Smart (cited by Cheesman, 1932) to be 46%, and in the Gold Coast (Hewison and Ababio, 1930) the losses varied from 22 to 84%

Compatibility and Incompatibility: When fertilization of the cacao flower occurs, the style and petal flaps wilt and the ovary swells and turns red or green according to the inherent color characteristics. Within 6 days the ovary is about 4 mm. in length. It has been observed, however, that flowers, even though pollinated, may fail to set fruit. This phenomenon known as self-incompatibility, was discovered by Pound (1932) in Trinidad. The reason for self-incompatibility, is still unknown. It is believed to be due either to pollen-tube failure, lack of gametic fusion, or the operation of a lethal factor in the fertilized ovum.

Table 10. The total number of fruit produced and incidence of cherelle wilt for each of 20 trees in sections I and VII at La Lola for the period, July to December, 1948.

Tree	Total fruit produced		Cherelle wilt		Percentage	
	Sect.1	Sect.VII	Sect.I	Sect.VII	Sect.I	Sect.VII
1	111	14	8	0	7.2	0.0
2	44	3	4	1	9.0	33.0
3	188	70	80	18	42.0	25.7
4	80	0	14	14	17.0	0.0
5	41	83	22	11	53.0	12.0
6	24	38	0	6	0.0	15.5
7	32	86	12	11	37.0	12.7
8	48	73	12	3	25.0	4.1
9	88	44	35	3	40.0	7.0
10	15	76	1	5	6.6	6.5
			Mean		23.68	14.5

Cope (1939) followed the development of the pollen tube, first through the style and then in the ovum through the locule, and did not find any difference in the loculus between self-incompatible and self-compatible pollen. Incompatible pollen tubes reached and fertilized ovules as easily as did compatible tubes. Nothing was noted in the morphological appearance of the flowers that could be related to self-incompatibility. Voelcker (1937) in a study of self-incompatibility made hand pollinations in many plants and obtained the following results: self-incompatible x self-incompatible, 0.4% set; self-incompatible x self-compatible, 83.3% set; and self-compatible x self-compatible, 83.3% set.

In the lowland areas of Costa Rica many cacao trees have been observed that seemingly always produce enormous numbers of flowers but set very few fruits. These trees are generally considered to be self-incompatible. At Quepos, Costa Rica, an isolated plot of clone 613 was established in 1945. This is a self-incompatible clone and in 3 years time there has been no fruit set, although, clone 613 produces well when interplanted with other clones.

SUMMARY

The flowering habits of cacao were observed and investigated at Turrialba and in the coastal lowlands of Costa Rica. These observations may be summarized as follows:

Anthesis usually started one day preceding the day of complete opening of the flower. Anthesis began earlier and proceeded faster in the lowland areas than at Turrialba. Flowers were usually completely open early in the morning.

The mean number of ovules per ovary of the 8 clones studied varied from 33.6 to 39.0 with a mean of 36.1 for 40 ovaries. The number of mature beans per pod varied from 20 to 47 with a mean of 34 for 79 pods harvested at La Lola. Studies of cross sections of ovaries showed that ovules may lie side by side in a locule, not necessarily in a straight line.

Data were obtained on the number of flowers and the number of flushing branches for 20 different trees at La Lola. These data indicated that there is extreme variation from tree to tree of these 2 characteristics. It was not possible to correlate the differences with other phenomena.

The pollen grain of cacao is typically spherical and has 3 indentations on its surface. The mean diameter of 800 pollen grains was 20.21 µ; they varied in size from 14.00 to 29.75 µ. Counts of the number of pollen grains per anther indicated that there was minimum mean number of 1404 grains per anther, or approximately 7,020 per flower. The ovule-pollen grain ratio was calculated to be 1:195 which is markedly low in comparison to similar ratios for well-known anemophilous plants. Pollen grains for the 8 clones studied were observed to average about 62% germination.

Dissemination of pollen is discussed. No definite conclusions can be drawn from the data at hand. It is believed that possibly both wind and insects are involved in the pollination of cacao.

The incidence in cherelle wilt on 20 trees at La Lola was observed to vary from 0.0 to 53.0%. Almost all of the fruits set in the first crop on the clonal planting at El Chino in 1948 were lost by cherelle wilt.

Compatibility and incompatibility in cacao is discussed. Trees have been observed which produce enormous numbers of flowers but exceedingly few fruits. An isolated plot of clone 613, a self-incompatible clone, 3 years of age has not been observed to produce fruit.

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