Pollination Mechanism of the Cacao Flower

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THE CACAO tree being cauliflorous produces its inflorescence on the trunk and the older branches; no flowers are produced on either the current or the previous season's growth. The flower bud first originates on cushions that arise in the original leaf axis on the old wood. The number of flower buds per cushion varies from three to twenty-five with an average of ten flower buds per cushion. From its first appearance the flower bud takes 18 to 21 days to reach normal size.

Morphology of the Flower

The cacao flower is hermophrodite with five sepals and five petals. The petals consist of a basal cup-shaped part with a ribbon like petaloid structure which terminates in a spatulate end. Petals are rosy in colour, while the ribbon part is yellowish. The stamens are five in number and are arranged alternately with 5 staminodes. The stamens, staminodes, sepals and petals are fused at the base to form a tube. The five stamens are white in colour and much shorter than the staminodes, and are curled inside the cup-like structure of the petal so as to conceal the anthers. Each stamen consists of a filament and 4 anthers. The anthers consist of pollen sacs which dehisce inside the cup-like structure of the petal.

The pistil consists of a five segmented stigma, style and ovary. The ovary is simple, oval shape, and superior in position. Dissection of the ovary shows 5 loculi with ovules on central placenta.

Biology of the Flower

A humid atmosphere is favourable for satisfactory setting of pods. Under favourable environmental conditions a fully developed bud commences to open by splitting of the sepals from 4 p.m. to 6 p.m., and continues to open throughout the night. At about 9 p.m. the flower is $\frac{1}{4}$th open with sepals unfolded and the staminodes still touching one another. By about mid-night the flower is nearly half open with staminodes separated. At about 3 a.m. the flower is $\frac{3}{4}$th open with sepals in one plane and the staminodes fully expanded. By about 5.30 a.m. the flower is fully open with the petals unfolded and the sepals expanded and reverted. The total time required for opening is from 12 to 14 hours. The stigma is receptive after opening. The flower is protogynous and exhibits incomplete dichogamy, dehiscence of the anthers taking place a few hours after the opening of the flower. At the time of dehiscence the pollen grains are released from the pollen sac into the pouch of the petals, from where they are removed by pollinating agents and transferred to receptive stigmas.

Receptivity of Stigma

The length of receptivity of stigma varies from tree to tree. In trials carried out at Kundasale on three self-compatible trees, tree No. 46 was receptive even after 24 hours of opening, while in the others the degree of receptivity was poor after 12 hours of opening. The receptivity of stigma was tested by enclosing

well developed buds in cloth-covered test tubes. The flowers were hand pollinated with pollen 2 hours after opening, 12 hours after opening and 24 hours after opening. The relevant data are given in the following table :—

Table 1

	Tree No. 46			*Tree No. 34*			*Tree No. 35*		
	No. pollinated	*No. set*	*Percentage*	*No. pollinated*	*No. set*	*Percentage*	*No. pollinated*	*No. set*	*Percentage*
2 hours after opening	28	20	71·4	27	15	55·5	10	7	70
12 hours after opening	26	16	61·5	10	7	70	18	14	77·7
24 hours after opening	20	13	65·0	25	2	8	5	0	0

Tree No. 46 is able to set pods in profusion due to the long period of receptivity, and is likely to get pollinated during both day and night.

Viability of Pollen

Dehiscence of anthers take place by bursting of the pollen sacs an hour or two after opening. At the time of liberation much of the pollen falls inside the pouch of the petal, while some being sticky remain attached to the anthers. Cacao trees show great variation in their capacity to produce pollen, some trees produce pollen in abundance while some others produce little or no pollen. Tree No. 46 a self-fertile tree and tree No. 11, a self-sterile tree produce pollen in plenty. Tree No. 15 another self-sterile tree produces very little pollen, while a completely sterile cacao tree produces no pollen at all. The viability of the pollen was tested on self-compatible trees by hand-pollinating guarded flowers, using pollen from freshly opened flowers 12 hours after opening, and 24 hours after opening.

Table 2

	Pollinated flowers	*Flowers on after 6 days*	*% set*
1. 2 hours after opening	93	60	64·5
2. 12 hours after opening	44	30	68·1
3. 24 hours after opening	15	1	6·6

The pollen grains remain viable for a period of 12 hours after which they seem to loose their viability. Pollen grains from tree No. 46 (self-fertile) and tree No. 11 (self-sterile) were sown two hours after opening in nutrient agar containing 2% agar and 5% dextrose ; germination was noticed in both cases 48 hours after sowing. Germination counts taken on different groups at random in both cases revealed a high percentage germination. It is possible that the pollen may germinate much quicker on the stigma of the flower.

Table 3

Group No.	Tree No. 46			Tree No. 11		
	No. of pollen grains seen	No. germinating	Percentage	No. of pollen grains seen	No. germinating	Percentage
1.	22	14		29	13	
2.	13	12		9	8	
3.	15	7		14	6	
4.	19	8		10	10	
Total	69	41	59·4	62	37	59·6

Pollination

Cacao is normally cross-pollinated. The superior position of the ovary and the curling of the stamens inside the pouch of the petal do not permit pollen to fall on the stigma without the assistance of a pollinating agent. The trials carried out at Kundasale to find out whether any self-pollination took place by enclosing well-developed flower buds with cloth-covered tubes showed that the flowers remain on the tree from 24 to 96 hours after opening after which they wither and drop.

Table 4

Tree No.	No. of flowers enclosed for selfsetting	Number of flowers on after opening				
		24 hours	48 hours	72 hours	96 hours	120 hours
1	9	9	6	4	2	0
2	8	6	5	4	1	0
42	13	13	12	10	6	0

The falling off of so many flowers is not due to defective floral parts, but due to lack of adequate pollination ; self-incompatible trees bear flowers in abundance and the falling off of unfertilized flowers is more conspicuous in them than in self-compatible trees.

The pollinating agent for cacao has not been determined with certainty. It is not clear as yet whether the flower is entomophilous (insect-pollinated) or anemophilous (wind-pollinated). The chances of wind-pollination are remote as the anthers dehisce inside a cup-like structure of the petals, and pollen for wind-pollination has to be produced in abundant quantity. The possibility of wind-pollination cannot altogether be excluded. The flower attracts insects such as midges, thrips, aphids and ants. Red ants which normally crawl on the tree in search of mealy bugs do not seem to assist in bringing about pollination as a number of flower buds enclosed on self-compatible trees with red

ants in cloth-covered tubes failed to set. Red ants are too big to reach the pollen from the pouch of the petal. Small black ants may probably help to some extent in bringing about pollination in self-compatible trees. Crawling insects may act as pollinating agents on self-compatible trees, but pollination taking place on self-incompatible trees necessarily implies activity by a disseminating agent. The disseminating agents may be either wind or flying insect but most probably the latter. Midges are found in plenty during the blossoming period and may help in pollinating both self-compatible and self-incompatible trees.

Studies on Pollen Compatibility

In cacao, a considerable number of trees show incompatibility between the pollen and pistil of the same plant. All the provisionally selected trees at Kundasale were tested for pollen compatibility by controlled hand-pollination. Controlled hand-pollination was carried out by enclosing well-developed flower buds, one in each cushion, with cloth-covered test tubes which were held in position with rubber bands and putty. The pollination was carried out in the morning as the flowers opened using freshly opened flowers as the source of pollen. The method of pollination was to rush the anthers on the stigma. One flower is sufficient to pollinate one to two flowers at a time. Any flowers that remained on the tree 6 days after pollination were regarded as *Set*. If the flower is fertilized, a definite swelling of the ovary is seen with fresh persistent sepals. In unfertilized flowers, the sepals are not fresh and the whole flower withers and falls off by this time.

Out of 19 trees tested, for pollen compatibility, only 5 trees were found to be self-compatible as would be seen from Table 5.

Table 5

Tree No.	*No. of flowers pollinated*	*No. set after 6 days*	*Percentage*	*Remarks*
1	20	0	0	Self-incompatible
11	36	0	0	do.
15	20	0	0	do.
17	10	0	0	do.
18	10	0	0	do.
34	37	22	59·4	Self-compatible
35	10	7	70	do.
36	13	7	53·8	do.
44	10	0	0	Self-incompatible
46	64	43	67·1	Self-compatible
63	10	0	0	Self-incompatible
77	10	0	0	do.
101	15	11	73·3	Self-compatible
114	20	0	0	Self-incompatible
115	25	0	0	do.
118	10	0	0	do.
121	20	0	0	do.
132	10	0	0	do.
133	10	0	0	do.

The following cross-pollinations (see Table 6) were made to test the cross-compatibility :—

Table 6

Female	*Male*	*No. of crosses made*	*No. set after 6 days*	*Percentage*	*Remarks*
101	46	15	7	46·6	Cross-compatible
46	101	16	10	62·5	do.
11	35	10	10	100	do.
35	11	10	8	80	do.
34	11	10	5	50	do.
11	34	5	4	80	do.
1	11	10	0	0	Cross-incompatible
11	1	10	0	0	do.
15	77	10	0	0	do.

Trees No. 101, 46, 35, 34, 36 are both self-compatible and cross-compatible, while others are self-incompatible but cross-compatible with self-compatible trees. Two self-compatible trees are always cross-compatible. Two self--incompatible trees are generally not cross-compatible. Self-incompatible trees set pods satisfactorily when pollen from self-compatible tree is used. Self-compatible trees set pods with pollen from self-incompatible as well as self-compatible trees, and therefore are apparently able to set more freely than the others. Self-incompatible trees set all their pods as a result of cross-pollination.

Self Compatibility and its Effect on Yield

The presence of self-compatible trees in a field has a definite influence over the yield of the crop. Since they set pods with pollen from any trees, they produce a heavy crop as compared to self-incompatible trees which are productive only when situated in the midst of self-compatible trees.

All the self-compatible trees under observation at Kundasale have produced more than 100 pods during the last cropping season as indicated in the following table :—

Table 7.—Yield in Number of Pods

Tree No.	*Aug. 52–July 53*	*Sept. 53–Oct. 53*
34	152	34
35	126	40
36	173	44
46	131	125
101	239	285

Sterility among Cacao Trees

The cacao population is of a heterogeneous type which includes heavy yielders, low-yielders and non-yielders. Under the last category comes the so called sterile tree. The sterility in cacao may be due to self-incompatibility in which case the sterility is conditional, or it may be due to structurally sterile organs.

While surveying the cacao trees at Kundasale to select high yielding clones, a barren type of cacao tree was noticed. This tree is very vigorous in growth as compared to its neighbour and flowers very profusely. It produces numerous vegetative shoots from the flowering cushions, and they in turn produce flowers. The pods or the pseudo-cherelles are set in profusion. The cherelles grow to varying sizes and wilt before reaching the size of a capsicum.

Floral Morphology

The flower is hermoprodite with its non-vital floral members similar to that of a bearing tree. The stamens are normal in appearance except that the pollen sacs are absent and the anthers constitute a mass of dis-organized cells indicating that the tree is male sterile. It was thought that the failure to set pods may be due to lack of adequate pollination but a number of cross-pollinations carried out with pollen from self-compatible trees failed to bring about any set indicating that the tree was female sterile as well.

Table 8

	No. pollinated	*No. set*
♀ Sterile Cacao × 36 (self-compatible)	20 ..	0
♀ Sterile Cacao × 46 (self-compatible)	15 ..	0

Dissection of the ovary shows 5 loculi with few ovules massed at the base of the ovary. In some cases the loculi were absent, and instead there was a central cavity with few ovules. The ovules were small in size as compared to ovules from fertile trees.

Some of the flowers set and produce malformed cherelles but no seeds develop in them. Such trees should be removed from the field or may be budgrafted at ground level to desirable types.

Summary

This paper deals with the flowering habit of the cacao tree with reference to the mechanism of pollination. The morphology of the cacao flower clearly shows that the flower is more adapted to cross-pollination than self-pollination. From the trials carried out at Kundasale it was evident that the flowers do not set any pods without the aid of any pollinating agent to bring about pollination. It is not clear as yet whether the flower is entomophilous or anemophilous

but the chances of wind-pollination are remote as the anthers of the cacao flower dehisce inside the cup-like structure of the petals.

Pollen compatibility and its effect on the yield of the crop is also discussed. Self-compatible trees produce a heavy crop as compared to self-incompatible trees which are productive only when situated in the midst of other self-compatible trees. The self-compatible trees are generally cross-compatible with self-incompatible trees but two self-incompatible trees are not cross-compatible.

Reference is also made to the occurences of sterility among cacao trees, the cause of sterility and the uselessness of such types to a cacao grower. The sterility may be due to (1) self-incompatibility (2) structurally sterile organs.

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