REPRODUCTIVE MECHANISM IN CARDAMOM

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Reproductive mechanism in cardamom" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

VENKITARAMAN, S.

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27th October 1982.

CERTIFICATE

Certified that this thesis entitled "Reproductive mechanism in cardamom" is a record of research work done independently by Sri. VENKITARAMAN, S., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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cavity was full of secretion which gradually dried up in the evening. This shows that the receptivity is maximum in the morning. This was confirmed by the percentage of capsule setting obtained by hand pollination of flowers during the different hours of the day. Flowers pollinated during forenoon hours gave high percentage of fruit setting (51 to 61 per cent). Flowers pollinated late in the afternoon gave a poor setting of 13 per cent.

Nature of pollination

Purseglove (1975) reported that cardamom is a naturally cross pollinated species. Shankar and Kumaresan (1979) also reported on the same line. Pattanshetty and Prasad (1972) stated that cardamom is cross pollinated because of the very structure of the flower, where the stigma is placed well above the anther lobes and which is surrounded by cilia. Parameswar (1973) also reported that cardamom is invariably cross pollinated by insects. Madhusoodanan et al. (1981) reported that although considerable amount of self pollination occurs in cardamom by way of geitonogamy, it is principally a cross pollinated, entomophilous crop. Under open pollination it had 54.55 per cent fruit setting while by natural self pollination it had only 7.14 per cent fruit setting.

Agent of pollination

Pattanshetty and Prasad (1972) reported that honey bees are the principal agents of pollination. Bee-free panicles had only 11 per cent fruit set as against 50.66 per cent in the case of panicles open to bee activity. Parameswar (1973) also reported that cardamom is pollinated by insects, especially honey bees.

Pattanshetty and Prasad (1974) reported that flowering panicles of the prostrate type of cardamom were often covered by a layer of fallen dry leaves from shade trees which were not removed until harvest time. When these panicles were exposed at flowering time, the average number of capsules per panicle has increased from 2.1 to 27.4 due to increased insect activity. Parameswar et al. (1978) suggested that by maintaining bee hives in the cardamom plantations the percentage of pollination and in turn cardamom yield can be increased. Jose (1980) reported that giant rock bees (Apis domestica) are the primary agents of pollination in cardamom and the Indian honey bees (Apis indica) are the secondary agents.

Self sterility

There are conflicting reports on the occurrence of sterility in cardamom. Sarma and Visweswara (1969) and Purseglove (1975) have reported self sterility in the crop.

Pattanshetty and Prasad (1972) based on their study of the prostrate type, on the other hand, have reported that cardamom is self compatible as they obtained 69 per cent fruit set on self pollination. Shankar and Kumaresan (1979) opined that there is no self-incompatibility in cardamom but due to its floral modification it needs an agent for pollination. Jose (1980) reported that there is no self sterility in cardamom, eventhough cross pollination is the rule, because there was 100 per cent fruit set when artificial self pollination was done.

Madhusoodanan et al. (1981) have reported that there is considerable amount of self pollination occurring in cardamom through geitonogamy. Also the crop is self compatible as proved by artificial self pollination where fruit set was 70.59 per cent. Shankar et al. (1981) have reported that there are different sex forms in cardamom, which have been evolved through the years of evolution from the purely vegetatively propagated form to completely sexually propagated form. It ranges from partially incompatible to completely compatible form.

Seed germination

Usually cardamom seeds take 8 to 10 weeks for germination. Earliness in germination can be induced by adopting different methods of seed treatment.

Kololgi et al. (1973) reported that germination of cardamom seeds was better when sown in a plastic house maintained at 23 to 26°C and 58 to 95 per cent relative humidity. Germination further increased when seeds were pretreated with concentrated nitric acid for five minutes. Reddy et al. (1973) reported that treatments with nitric acid, acetic acid (25 per cent) and hydrochloric acid (50 per cent) for ten minutes each were found to be better, giving 97.6 per cent, 98.9 per cent and 91.5 per cent germination respectively. Prasad et al.(1974) reported that treatment of freshly extracted cardamom seeds with concentrated nitric acid for five minutes significantly improved the germination.

Sulikeri and Kololgi (1977) on a study of viability and treatment effect on cardamom seeds reported that seed treatment with nitric acid at 25 per cent for ten minutes markedly increased germination. Old seeds when kept as capsules gave germination of 26 per cent as compared to one per cent for old seeds kept as seeds. For fresh seeds the germination was, however, 66 per cent.

Pattanshetty et al. (1978) reported that cardamom seeds germinated well upto four months of storage, and thereafter germination decreased considerably. Their results also showed that treatment of seeds with organomercurials and storage in air tight containers led to reduction in germination.

Materials and methods

MATERIALS AND METHODS

I. MATERIALS:-

Three popular cultivars of cardamom viz., Malabar, Mysore and Vazhukka were used for the study conducted during 1981 at the Cardamom Research Station, Pampadumpara.

The salient features of the cultivars are given below:

(1) Malabar: Plants are of medium height. Leaves are 30 to 45 cm long and short petioled. Lower surface of leaves are pubescent. Panicles are prostrate which trail on the ground. Flowers have long pedicels. Capsules are small, globose, rounded or ovoid and highly ribbed (Fig. 1).

(2) Mysore: Plants are more robust and taller than those of the Malabar type. Leaves are long petioled, broad and non-pubescent. Panicles are erect or recumbent and flowers are borne on short pedicels. Fruits are fusiform, long, three angled and ribbed (Fig. 2).

(3) Vazhukka: Plants are medium tall. Leaves are non-pubescent. The panicles are semi-erect.

Figure 1. A clump of 'Malabar'

Figure 2. A clump of 'Mysore'

Figure 1

Figure 2

Capsules long. It is intermediate in type between 'Malabar' and 'Mysore' (Fig. 3).

The panicle and capsule characters of the three cultivars are represented in Fig. 4 and 5.

Studies were conducted on a number of true to type plants selected at random in each of the three cultivars.

II. METHODS:-

(1) Number of shoots and panicles

Fifteen clumps in each of the three cultivars were labelled. The number of shoots produced by each clump was counted at monthly intervals from May to July 1981. Shoots with leaves alone were counted. The number of panicles produced in each clump was also counted at monthly intervals from May to July 1981.

(2) Panicle characters

The study of panicle characters such as length of panicle, length of internode, number of racemes per panicle and number of flowers per raceme was made during the late flowering season. Four clumps were selected from each cultivar. In each clump five well developed panicles were selected at random. Thus in each cultivar 20 panicles were selected.

Figure 3. A clump of 'Vazhukka'

Figure 4. Panicles of 'Malabar', 'Mysore' and 'Vazhukka'

Figure 3

Figure 4

Figure 5. Capsules of 'Malabar',
'Mysore' and 'Vazhukka'

Figure 5

(i) The "length of panicle" was measured from the point of its attachment to the pseudostem, to the tip.

(ii) The distances between two successive racemes in the proximal, mid and distal portions of each panicle were measured and the mean value was taken as the "length of internode".

(iii) The total number of racemes were counted in each panicle and recorded.

(iv) The number of flowers per raceme was estimated by counting the number of barren stalks of abscised flowers and the capsules.

(3) Floral characters

Fifty flowers were selected from each cultivar at random and the following observations were made.

(i) Length of pedicel
(ii) Length of flower
(iii) Length of corolla tube
(iv) Length of anther
(v) Length of style
(vi) Length of filament
(vii) Number of ovules per ovary and
(viii) Size of pollen

Observations (i) to (v) were made with a scale and recorded in cm. Length of filament was measured with

an ocular micrometer at 16 x 10 combination of eye-piece and objective. One ocular division at this magnification corresponded to 10.01 microns. Number of ovules per ovary was counted under a dissection microscope by cutting open the sides of the ovary wall and scooping out the ovules one by one.

The size of pollen was measured by collecting pollen from flowers at anthesis and staining with glycerine aceto-carmine. Pollen grains which appeared normal and deeply stained were taken as fertile and others as sterile. The diameter of the fertile grains was measured using the ocular micrometer at 16 x 40 combination of eye-piece and objective. At this magnification one ocular division corresponded to 2.41 microns. 100 pollen grains were measured at random in each cultivar.

(4) Spread of flowering

Twenty panicles which are about to start flowering were selected in each cultivar. The number of flowers opening in each panicle was recorded every day from the first to the last day of anthesis to assess the spread of flowering.

(5) Time of anthesis

The time and pattern of flower opening was studied in the three cultivars. Cut panicles were used for making

these observations. Panicles having three to four mature buds were detached late in the evening and kept by inserting the stalk in water, contained in glass troughs.

The different stages of anthesis were identified initially in a preliminary observation. Four distinct stages were identified. The time of anthesis time was studied, by observing the opening of flowers from 2 AM onwards using a magnifying glass and recording the time of completion of each stage.

In each cultivar 25 flowers belonging to different panicles of different clumps were observed.

(6) Fertility of pollen

Pollen grains were collected from flowers at anthesis and stained with glycerine acetocarmine. They were observed under the microscope after about one hour. Those pollen grains which appeared normal and deep purple stained were scored as fertile and those which were broken and lightly stained or unstained were scored as sterile. The count of fertile and sterile grains were taken in five different fields per slide chosen at random. The observation was made on 20 slides per cultivar prepared from 20 flowers.

(7) Viability of pollen

In vitro culturing of pollen grains was made in a germination medium containing 20 per cent sucrose solution

and 100 ppm boric acid in equal proportions.

Flowers were collected from each cultivar at random from 6 AM to 12 noon at hourly intervals. Pollen grains were scooped out and put in the germination medium on a cover slip. It was allowed to rest on a cavity slide as a "hanging drop". After about three hours, the drop was observed under a microscope. Those grains which showed germination were taken as viable and those which did not as non-viable. Then the percentage of viability was worked out. The test was repeated for four days.

(3) Receptivity of stigma

Mature flower buds were emasculated in the evening and covered. Emasculation was done by cutting the tip of the labellum which projects out in a mature bud. The bud was opened and the filament was cut and stamen pulled out. Pollination was done on the next day at the specific hour using pollen from other cultivars or clumps and tagged.

Twenty flowers (five flowers per day for four days) were pollinated in each cultivar every hour from 6 AM to 12 noon.

The capsule development in each pollinated flower was checked on the tenth day after pollination and setting percentage was recorded. The number of seeds per capsule was also determined.

(9) Mode of pollination

Two similar, well developed panicles were selected in each clump. One panicle was tagged as 'open' and left exposed for insect (honey bee) activity. The other panicle was tagged as 'natural self' and kept in an insect proof cage consisting of a bamboo frame covered with nylon net all around (Fig. 6 and 7). The flowers produced in each panicle were scored every day and labelled.

The observation was made on 15 clumps per cultivar and in 30 pairs of panicles (15 open and 15 caged).

The capsule production in each panicle for the scored flowers was observed later. At maturity, these capsules were harvested and seeds were extracted. Germination tests were conducted on these seeds. Capsule setting percentage, number of seeds per capsule and seed viability were estimated.

(10) Self sterility

15 clumps were selected in each cultivar and five panicles were selected in each clump. Five different types of pollinations were practised on the five panicles of each clump.

(i) Panicle left for open pollination

(ii) Panicle kept for controlled self pollination (which

Figure 6. Pollination cage - I
(for prostrate cultivar)

Figure 7. Pollination cage - II
(for erect cultivar)

Figure 6

Figure 7

was covered by nylon net cylinder and the flowers were self pollinated artificially).

(iii) Panicle used for crossing with the second cultivar.

(iv) Panicle used for crossing with the third cultivar (the panicles were covered and everyday the flowers were cross pollinated using the pollen from the particular male parent).

(v) Panicles in which mature flowar buds were emasculated and covered to detect any parthenogenesis.

In all the cases the flowers were counted daily and labelled. After 10 to 15 days, the capsule setting was observed. At maturity the capsules were harvested and the seeds were extracted and counted. Seed viability percentage was estimated.

Seeds were washed four to five times in water to remove the mucilagenous coating. Then they were rubbed with wood ash and kept for drying in the shade. After 20 to 24 hours they were scarified by treating with concentrated sulphuric acid for two minutes and washed thoroughly for four to five minutes.

They were sown in petridishes over cotton wool and blotting paper. The petridish, blotting papers and cotton wool were sterilised in an autoclave. Watering was done with sterilized water whenever necessary. After 30 to 35

days, germination was observed and recorded upto 90 days. The percentage of germination in each case was calculated.

(11) Statistical analysis

The data collected on the three cultivars were tabulated and analysed statistically.

The number of shoots and panicles per clump, the length of panicle and internode and the number of racemes per panicle and flowers per raceme were analysed using the Nested classification (Hierarchal classification) as proposed by Bliss (1967).

Analysis of Variance for individual character

Source of variation	df	SS	MS	F
Variation between 'A' class (cultivars)	a-1	$\leqq \frac{Ta^2}{fa} - CF = Sa$	Va	Va/Vb.a
B within A (within cultivar)	bi-a	$\leqq \frac{Tb^2}{fb} - CF-Sa = Sb$	Vb.a	Vb.a/Vr
Within observations (within plants)	N-$\leqq$bi	(Subtracted value)	Vr	
Total	N-1	$\leqq y^2-CF$		

Where, 'a' - Number of levels of 'A' classes

fa - Frequency of 'a'

bi - Number of replications (observations) in a cultivar

fb - Frequency of 'b'

Sa - Sum of squares for between cultivars

Sb - Sum of squares for within cultivars

Va - Mean square for between cultivars

Vb.a - Mean square for within cultivars and

Vr - Mean square for within clumps (plants)

Data on pollen fertility were analysed according to the proposed schedule for Completely Randomized Designs (Federer, 1955).

Analysis of Variance for individual character

Source of variation	df	SS	MS	F
Total	Tt-1	SS_T	MS_T	
Cultivars	T-1	SS_t	MS_t	MSt/MSE
Error	T(t-1)	SS_E	MS_E	

Where, SS_T - Sum of squares for Total

SS_t - Sum of squares for cultivars

SS_E - Sum of squares for error

MS_t - Mean square for cultivars and

MS_E - Mean square for error.

For floral characters the mean, standard deviation and coefficient of variation were worked out.

Results

RESULTS

The data collected on the various morphological features like number of shoots and panicles per clump, panicle characters and floral morphology of the three cultivars of cardamom were statistically analysed. The observations on the time and mechanism of anthesis, pollen viability, stigma receptivity and self sterility have also been tabulated and analysed. The results are presented below.

(1) Number of shoots per clump

The analysis of variance for the number of shoots per clump is presented in table 1.

Table 1. Analysis of variance for the number of shoots per clump (Nested classification)

Source	df	SS	MS	F
Cultivar	2	173.91	86.955	1.794
Months within cultivar	6	290.89	48.482	<1
Clumps within same month	126	12590.93	99.928	
Total	134	13055.73		

The 'F' values for cultivars and for months within cultivars were not significant. There was no significant difference between the three cultivars with respect to the number of shoots per clump. The difference between the number of shoots per clump in the different months were also not significant. The mean number of shoots per clump during different months for each cultivar is given in table 2.

Table 2. Mean number of shoots per clump

Month	Malabar	Mysore	Vazhukka
May	39	40	39
June	44	43	39
July	41	42	39
Mean	41.3	41.7	39.0

(2) Number of panicles per clump

The analysis of variance for the number of panicles per clump is presented in table 3.

Table 3. Analysis of variance for the number of panicles per clump (Nested classification)

Source	df	SS	MS	F
Cultivar	2	814.059	407.03	8.01*
Months within cultivar	6	304.945	50.82	<1
Clumps within same month	126	13631.066	108.18	
Total	134	14750.07		

* Significant at 5 per cent level

The 'F' value for cultivars was significant but for months within cultivar it was not significant. Hence there was significant difference between the three cultivars with regard to panicle production. The mean number of panicles per clump is given in table 4.

Table 4. Mean number of panicles per clump

Month	Malabar	Mysore	Vazhukka
May	42	32	36
June	41	36	36
July	38	35	37
Mean	40.3	34.3	36.3

C.D = 3.68

It can thus be inferred that the cultivar Malabar produces the maximum number of panicles (40.30 per clump). It produced significantly larger number of panicles than 'Vazhukka' (36.3) and 'Mysore' (34.3). The cultivars Vazhukka and Mysore were on par in respect of panicle production.

(3) Length of panicle

The analysis of variance for the length of panicle is presented in table 5.

Table 5. Analysis of variance for the length of panicle (Nested classification)

Source	df	SS	MS	F
Cultivars	2	8599.9	4299.5	28.75*
Between clumps of the same cultivar	9	1345.5	149.55	<1
Between panicles of the same clump	48	12138.40	252.88	
Total	59	22083.80		

* Significant at 5 per cent level

The 'F' value for cultivars was significant, whereas it was not significant between clumps of the same cultivar. Thus, there was significant difference between the three

cultivars with regard to length of panicle. The mean length of panicle of each cultivar is given in table 6.

Table 6. Mean length of panicle (cm)

Cultivar	Clump I	Clump II	Clump III	Clump IV	Mean
Malabar	59.9	58.9	56.4	57.2	58.1
Mysore	43.8	31.4	42.8	45.0	40.8
Vazhukka	76.4	68.3	74.0	60.9	69.9

C.D = 8.75

'Vazhukka' had the maximum length for panicle (69.9cm). It was followed by 'Malabar' (58.1 cm) and 'Mysore' (40.8 cm).

(4) Length of panicle internode

The analysis of variance for the length of internode is presented in table 7.

Table 7. Analysis of variance for the length of internode (Nested classification)

Source	df	SS	MS	F
Cultivars	2	1.812	0.902	5.089*
Between clumps of the same cultivar	9	1.602	0.178	<1
Between panicles of the same clump	48	17.700	0.36875	
Total	59	21.114		

* Significant at 5 per cent level

The 'F' value for cultivars was significant, while between clumps of the same cultivar it was not significant. So there was significant difference between the three cultivars with regard to length of internode. The mean length of internode in each cultivar is given in table 8.

Table 8. Mean length of internode (cm)

Cultivar	Clump I	Clump II	Clump III	Clump IV	Mean
Malabar	2.3	2.4	2.6	2.1	2.4
Mysore	2.2	2.0	2.4	2.2	2.2
Vazhukka	2.6	2.6	2.9	2.5	2.6

C.D = 0.30

'Vazhukka' was on par with 'Malabar' but significantly more than 'Mysore', while 'Malabar' was on par with 'Mysore'.

(5) Number of racemes per panicle

The analysis of variance for the number of racemes per panicle is presented in table 9.

Table 9. Analysis of variance for the number of racemes per panicle (Nested classification)

Source	df	SS	MS	F
Cultivar	2	1452.10	726.05	29.83*
Between clumps of the same cultivar	9	219.10	24.34	1.31
Between panicles of the same clump	48	891.8	18.58	
Total	59	2563.0		

* Significant at 5 per cent level

The 'F' value for cultivars was significant, while between clumps of the same cultivar it was not significant. So there was significant difference between the three cultivars with regard to the number of racemes per panicle. The mean number of racemes per panicle of each cultivar is given in table 10.

Table 10. Mean number of racemes per panicle

Cultivar	Clump I	Clump II	Clump III	Clump IV	Mean
Malabar	24	22	20	25	22.8
Mysore	17	15	16	20	17.0
Vazhukka	33	27	28	29	29.3

C.D = 3.53

Among the three cultivars, 'Vazhukka' had the maximum number of racemes per panicle (29.3) followed by 'Malabar' (22.8). 'Mysore' had the minimum number of racemes (17.0). It was significantly inferior to both 'Vazhukka' and 'Malabar'.

(6) Number of flowers per raceme

The analysis of variance for the number of flowers per raceme is presented in table 11.

Table 11. Analysis of variance for the number of flowers per raceme (Nested classification)

Source	df	SS	MS	F
Cultivars	2	32.5272	16.2632	2.3274
Between clumps of the same cultivar	9	62.8916	6.9879	2.2432*
Between panicles of the same clump	48	149.5290	3.1152	
Total	59	244.9478	4.1517	

* Significant at 5 per cent level

The 'F' value for cultivars was not significant, while between clumps of the same cultivar it was significant. So there was no significant difference between the cultivars with regard to the number of flowers per raceme. The mean number of flowers per raceme of each cultivar is given in table 12.

Table 12. Mean number of flowers per raceme

Cultivar	Clump I	Clump II	Clump III	Clump IV	Mean
Malabar	10	7	9	9	8.8
Mysore	7	7	6	7	6.8
Vazhukke	8	7	10	8	8.3

(7) Floral characters

The flowers of the three cultivars did not differ in general morphology (Fig. 8). The flowers are pedicellate, zygomorphic and bisexual. The floral parts are arranged in trimerous whorls. Membraneous bracteoles enclose the flower buds individually. Calyx is tubular or bell shaped, membraneous, divided into three short teeth at the tip. Corolla is tubular at the base and is lobed at the tip into three petals of pale green colour. Androecium consisting of one stamen two staminodes and one labellum is in adhesion to the corolla tube. The stamen is inserted in the throat of the corolla tube. It has a short filament and two anther lobes, between which is found a groove. The two other stamens are represented by 'staminodes' located at the base. The most conspicuous part of the flower is the large central lip (labellum) which is placed dorsally. It is white coloured

Figure 8. Flowers of 'Malabar', 'Mysore' and 'Vazhukka'

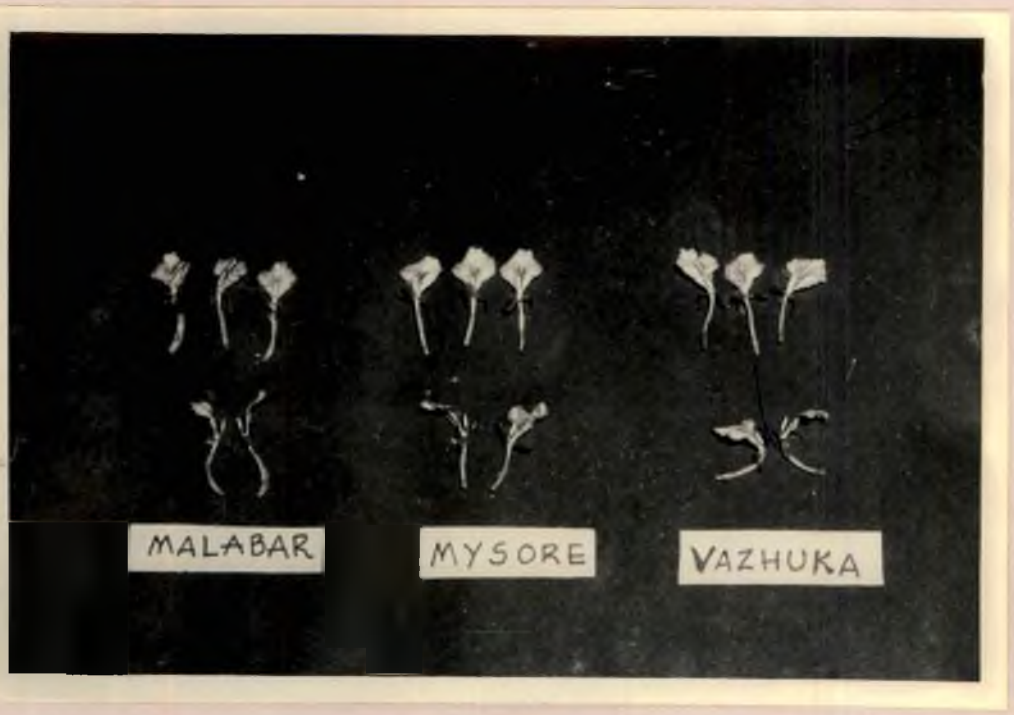


Figure 8

with pink or violet streaks originating from the centre. It gives the false appearance of a petal and is made of three stamens. It covers the fertile stamen in the bud stage. The gynoecium consists of an inferior ovary, filiform style and a funnel shaped stigma. Ovary is green in colour and small in size, with three locules. Ovules are arranged on axile placentation. The filiform style passes through the groove provided by the stamen between its two anther lobes. The stigma projects above the anther. The stigmatic cavity is surrounded by cilia.

The data on biometrical observations of the flower are given in table 13.

There was no difference between the three cultivars in the mean length of flower and the length of different floral parts such as flower stalk, corolla tube, anther and style. The length of filament was, however, slightly different. Pollen grains of 'Vazhukka' were slightly larger (90.35 microns) than those of 'Mysore' (85.68 microns) and 'Malabar' (83.90 microns). The number of ovules were also the same in the three cultivars.

Pollen grains were spherical or oval in shape with small spines on the exine. They appeared as a white sticky or powdery mass according to the prevailing environmental conditions. This may be because of the spiny nature of the exine which made them cling together. In any case, they did not get separated into individual grains and were not carried away by the wind.

Table 13. Floral characters

Sl. No.	Characters	Malabar		Mysore		Vazhukka	
		Mean	C.V.	Mean	C.V.	Mean	C.V.
i	Length of flower (cm)	5.040	6.37	5.000	7.24	5.020	6.70
ii	Length of pedicel (cm)	0.483	28.28	0.402	22.67	0.432	34.78
iii	Length of corolla (cm)	2.030	9.26	2.100	4.86	2.070	6.09
iv	Length of filament (microns)	890.089	11.87	828.828	10.80	858.457	8.49
v	Length of anther (cm)	0.599	4.20	0.600	3.33	0.604	3.24
vi	Length of style (cm)	2.920	5.27	2.890	7.67	2.900	5.83
vii	Diameter of pollen (microns)	83.890	4.35	85.680	25.93	90.350	41.61
viii	Number of ovules per ovary	18	20.70	17	16.51	17	15.62

(8) Spread of flowering

The number of flowers opening on different days (1st to 85th day) in panicles of the different cultivars is given in table 14.

The data indicate that the cultivars Mysore and Vazhukka had protracted flowering and produced larger number of flowers than 'Malabar'. 'Malabar' produced 572 flowers in a period of 50 days in 20 panicles whereas 'Mysore' and 'Vazhukka' produced 1682 and 1399 flowers respectively in a period of 85 days. Thus, the cultivar Mysore produced maximum number of flowers. On an average, the percentage of flowers opening per day per panicle in 'Malabar' was 2.00 and in 'Mysore' and 'Vazhukka' it was only 1.18.

In 'Malabar', 50 per cent of flowering was over in 15 days; in 'Mysore' it took 25 days and in 'Vazhukka' 30 days. A high percentage of flowering was recorded from the beginning itself in all the three cultivars. It was continued for a period and then reduced at the end of the flowering period. There was no distinct 'peak' in flowering (Fig. 9).

(9) Time of anthesis

In cardamom flowers, anthesis occur during the early hours of the day. The flower buds which are to open the

FIG. 9 SPREAD OF FLOWERING IN THE 3 CULTIVARS OF CARDAMOM

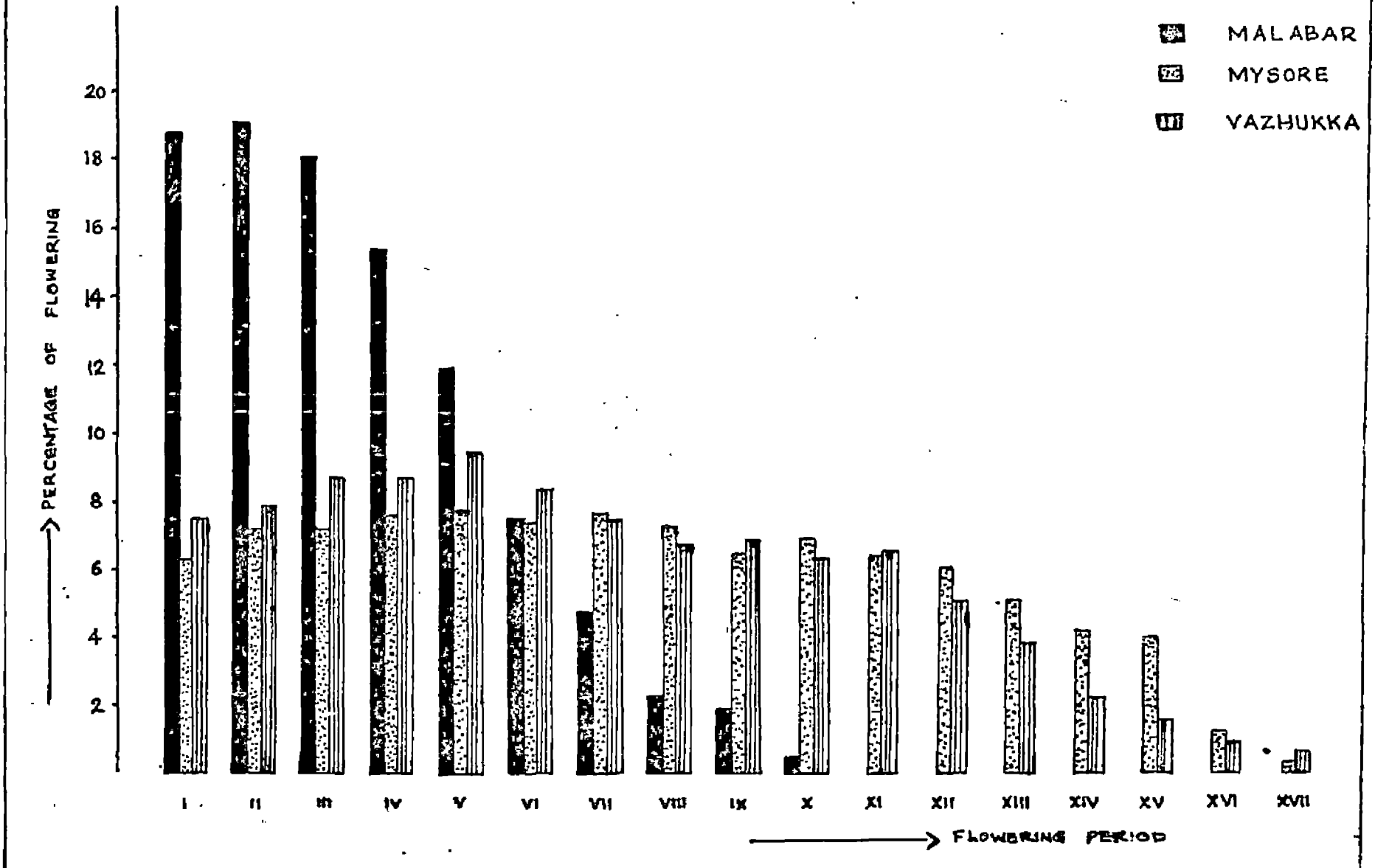


Table 14. Spread of flowering (number of flowers opening on different days)

Sl. No.	Days	Malabar		Mysore		Vazhukka	
		Number	%	Number	%	Number	%
I	1 to 5	107	18.7	107	6.3	110	7.5
II	6 to 10	109	19.1	121	7.2	110	7.9
III	11 to 15	103	18.0	121	7.2	122	8.7
IV	16 to 20	88	15.4	127	7.6	123	8.7
V	21 to 25	68	11.9	130	7.7	131	9.4
VI	26 to 30	43	7.5	124	7.4	117	8.4
VII	31 to 35	27	4.7	130	7.7	105	7.5
VIII	36 to 40	13	2.3	126	7.5	95	6.8
IX	41 to 45	11	1.9	110	6.5	97	6.9
X	46 to 50	3	0.5	118	7.0	90	6.4
XI	51 to 55	-	-	110	6.5	93	6.6
XII	56 to 60	-	-	103	6.1	71	5.1
XIII	61 to 65	-	-	87	5.2	54	3.9
XIV	66 to 70	-	-	72	4.3	32	2.3
XV	71 to 75	-	-	69	4.1	24	1.7
XVI	76 to 80	-	-	22	1.3	15	1.1
XVII	81 to 85	-	-	5	0.4	10	0.7
	Total	572	100	1682	100	1399	100

next morning could be clearly identified in the evening by their hood-like appearence. The floral parts project out of the membraneous bracteole and were in a "swollen" condition. The purple streaks on the folded labellum could be seen through the translucent corolla.

The mechanism of anthesis consisted of four stages, in all the three cultivars.

(i) Anthesis began by the splitting open of the two lateral lobes of the corolla (petals) to both sides.

(ii) The second stage was marked by the unfurling of the labellum. The ventral lobe of the corolla facing the labellum and holding it in a hooked condition opens out and releases the labellum.

(iii) The labellum opens out fully. The stamen with the style and stigma (which were kept as a unit) moves away from the labellum and becomes straight.

(iv) The dehiscence of the anther.

The observations on time of anthesis are given in table 15. The time given corresponds to the completion of each stage of anthesis. The beginning of the first stage was erratic. It started from the previous evening to about 45 minutes before its completion.

Table 15. Time of anthesis (Mean of 25 flowers)

Stage	Malabar	Mysore	Vazhukka
I stage	4.25 AM	3.16 AM	4.22 AM
II stage	5.40 AM	4.11 AM	5.26 AM
III stage	7.01 AM	6.09 AM	7.18 AM
IV stage	8.03 AM	8.22 AM	8.14 AM

From the above observation it could be seen that the cultivar Mysore was slightly early in flower opening at all stages except at anther dehiscence. In that respect it appeared to be slightly late. 'Malabar' and'Vazhukka' were almost on par with regard to the time of anthesis at all stages.

(10) Fertility of pollen

The analysis of variance for the fertility of pollen is presented in table 16.

Table 16. Analysis of variance for the fertility of pollen (Completely Randomized Design)

Source	df	SS	MS	F
Total	59	4763.83		
Cultivar	2	334.89	167.45	2.155
Error	57	4428.94	77.701	

The 'F' value for cultivars was not significant. Hence there was no significant difference between the three cultivars. The mean fertility of pollen is presented in table 17.

Table 17. Mean fertility of pollen (%)

Cultivar	Mean fertility (%)	Range	
		Minimum (%)	Maximum (%)
Malabar	91.82	63.07	99.40
Mysore	89.79	75.32	98.43
Vazhukka	88.36	66.91	99.78

(11) Viability of pollen

The in vitro analysis showed that germinability of pollen gradually increased from 6 to 10 AM in 'Malabar', upto 11 AM in the other two cultivars and then decreased. The mean germinability percentage of each cultivar at every hour is given in table 18.

In 'Malabar', the pollen germinability increased rapidly from 6 AM and reached a peak of 60.25 per cent at 10 AM. It then decreased to 41.25 per cent by 12 noon. In 'Mysore' the germinability showed a gradual increase from 6 AM onwards, reaching a peak of 42.36 per cent at

11 AM and then dropped to 33.18 per cent by 12 noon. In the case of 'Vazhukka', a similar pattern of gradual increase in germinability was noticed reaching a peak of 42.33 per cent at 11 AM and then decreasing to 27.21 per cent by 12 noon (Fig. 10).

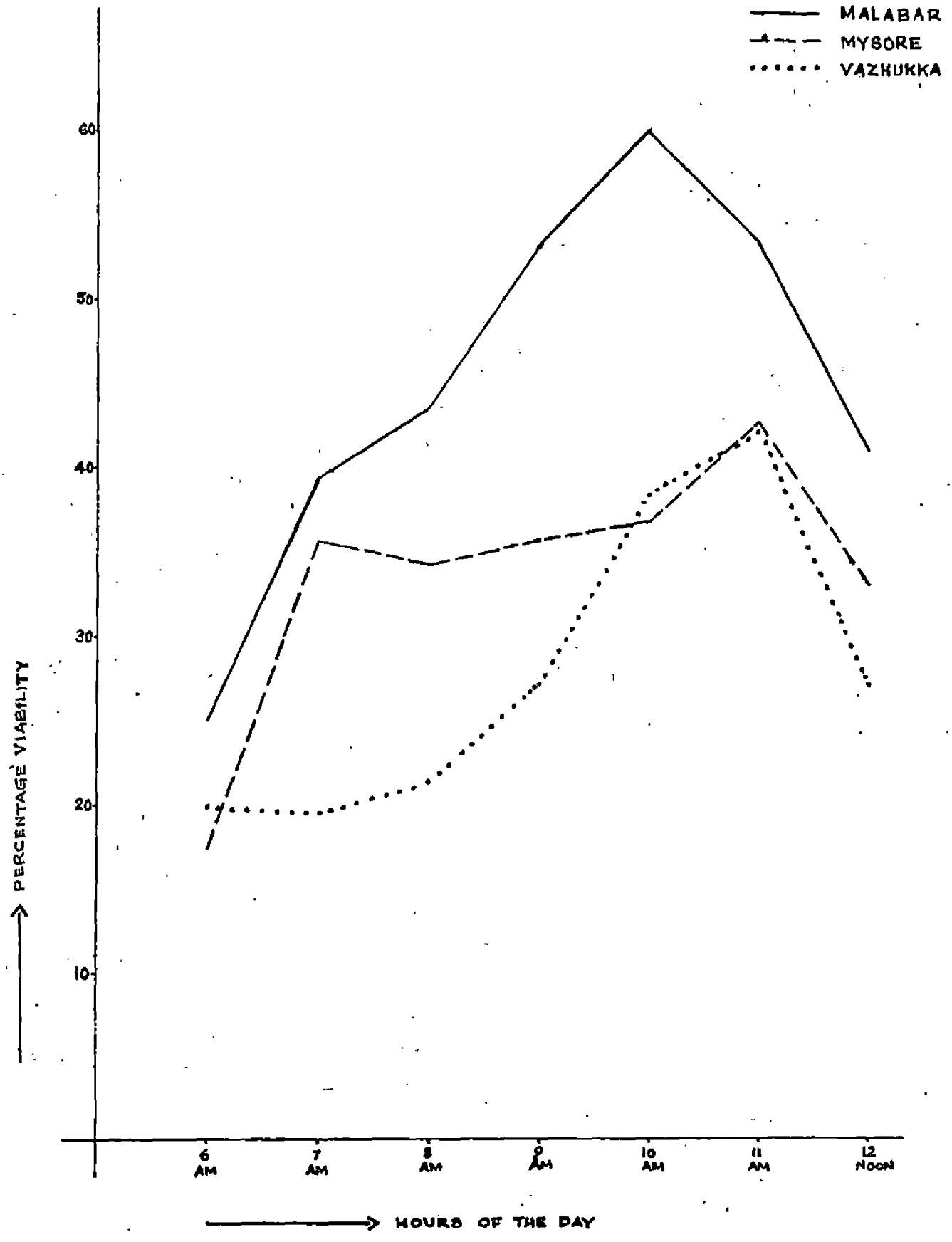
Table 18. Mean germinability of pollen (%)

Time	Malabar	Mysore	Vazhukka
6.00 AM	25.06	16.39	19.90
7.00 AM	39.44	35.75	19.50
8.00 AM	43.66	34.30	21.38
9.00 AM	53.26	35.80	27.17
10.00 AM	60.25	36.98	38.48
11.00 AM	53.56	42.86	42.33
12.00 Noon	41.25	33.18	27.21

The data also reveals that the germination percentage of pollen in the cultivar Malabar is uniformly higher at all the stages of testing. In general, it can be inferred that the pollen grains showed maximum germinability between 10 and 11 AM in cardamom.

A comparative study of data on pollen fertility and viability indicates that all the fertile grains were not viable. The fertility percentages were as high as 91.82, 89.79 and 88.36 in cultivars Malabar, Mysore and Vazhukka

FIG.10 VIABILITY PERCENTAGE OF POLLEN



respectively, whereas at peak viability, the percentages of germinability were only 60.25, 42.86 and 42.33 in the three cultivars respectively.

(12) Receptivity of stigma

The receptivity of stigma at the different timings is expressed as percentage of capsule setting and presented in table 19.

Table 19. Receptivity of stigma (as percentage of capsule setting)

Cultivar	Time						
	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 Noon
Malabar	30	40	40	35	30	30	15
Mysore	45	35	50	45	70	25	55
Vazhukka	20	25	50	35	15	20	25

The data reveal that in the cultivars Malabar and Vazhukka, the stigma receptivity increased gradually from 6 AM reaching a peak at 8 AM and decreased thereafter. In the cultivar Mysore receptivity showed an erratic behaviour. In cultivars Malabar and Vazhukka, the maximum percentages of capsule setting were 40 and 50 respectively while in 'Mysore' it was as high as 70 (Fig. 11).

The mean seed set per capsule following pollination at each hour from 6 AM to 12 noon in the three cultivars is presented in table 20.

FIG.11 RECEPTIVITY OF STIGMA (% OF CAPSULE SETTING)

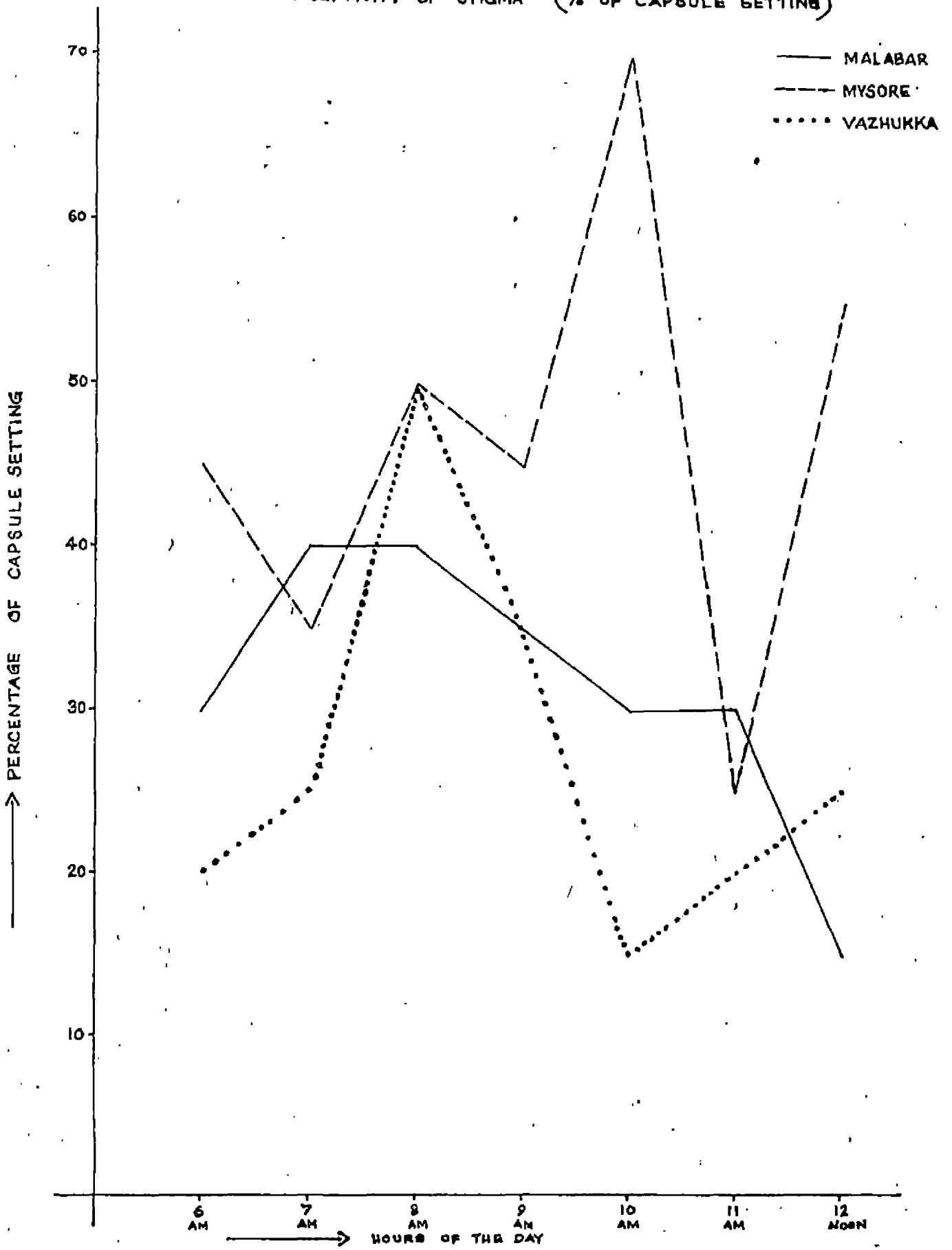


Table 20. Mean seedset per capsule (Number of seeds per capsule)

Cultivar	Time						
	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 Noon
Malabar	15	14	15	14	15	15	14
Mysore	14	14	16	15	16	13	15
Vazhukka	16	16	17	17	16	17	18

The data indicate that there was no difference in seedset at the different hours of the day eventhough the receptivity of stigma differed at different hours. 'Malabar' had a mean number of 14.57 seeds per capsule whereas 'Mysore' had 14.71 seeds and 'Vazhukka' had 16.71 seeds. So it could be inferred that the cultivar Vazhukka has high seed set as compared to the other two cultivars.

(13) Mode of pollination

Capsule setting, seed setting and seed viability in 'open' and 'caged' panicles of the three cultivars are presented in table 21.

Capsule setting in 'open' panicle was 55.42, 43.33 and 55.26 per cent respectively in the three cultivars Malabar, Mysore and Vazhukka. This was much higher than

the capsule setting percentage of 'caged' panicles of the three cultivars (15.07, 16.39 and 2.82 for 'Malabar', 'Mysore' and 'Vazhukka' respectively). The high capsule setting in 'open' panicles in comparison to 'caged' ones clearly indicates that all the cultivars are predominantly cross pollinated. The low capsule setting in the 'caged' panicles might be due to self pollination through very small insects like ants creeping into these cages.

Table 21. Quantitative estimations on the mode of pollination

Observations	Malabar		Mysore		Vazhukka	
	Open	caged	open	caged	open	caged
Number of flowers	83	73	60	61	76	71
Number of capsules	46	11	26	10	42	2
Capsule setting (percentage)	55.42	15.07	43.33	16.39	55.26	2.82
Number of seeds per capsule (seed setting)	12.59	10.33	12.21	10.67	13.65	10.50
Seed viability (germination percentage)	56.60	55.79	46.84	19.05	46.15	0

The mean number of seeds per capsule was the same in 'open' panicles of all the three cultivars (12.59, 12.21 and 13.65 for 'Malabar', 'Mysore' and 'Vazhukka' respectively).

Seed setting was similar in 'caged' panicles also (10.33, 10.67 and 10.50 for 'Malabar', 'Mysore' and 'Vazhukka' respectively). The slight reduction in 'caged' panicles might be due to the lack of sufficient pollen for effective fertilization.

There was no appreciable difference between the three cultivars in seed viability in the 'open' panicles (56.60, 46.84 and 46.15 per cent for 'Malabar', 'Mysore' and 'Vazhukka' respectively). For the 'caged' panicles, seed viability was 55.79, 19.05 and zero per cent in the three cultivars. The low seed germination for 'Mysore' and 'Vazhukka' might be due to the very small number of seeds which were available for conducting the germination tests.

(14) Self sterility

The data on the study of self sterility are given in table 22.

(i) Capsule setting

There was no capsule setting under 'emasculation and covering' in all the three cultivars. This indicates that there is no parthenocarpy in cardamom.

'Assisted self pollination' resulted in high capsule setting in all the three cultivars (66.67, 63.33 and 76.74 per cent for 'Malabar', 'Mysore' and 'Vazhukka' respectively).

Moreover, the different cross combinations of the three cultivars also showed high capsule setting. The data thus indicate the absence of self or cross incompatibility in these cultivars of cardamom.

Capsule setting was comparatively low in all the three cultivars under 'open pollination' where the panicles were exposed to insect activity and to the natural method of pollination. The capsule setting was 55.42, 43.33 and 55.26 per cent in 'Malabar, 'Mysore' and 'Vazhukka' respectively. This might be due to lack of adequate pollination on days of adverse environmental conditions.

(ii) Seed setting

The data on seed setting indicates that there is no parthenogenesis in cardamom as the seed setting on 'emasculation and covering' was zero in all the three cultivars.

The number of seeds per capsule was not different in any of the treatment for the three cultivars. The mean seedset was 13.44 for 'Malabar', 13.61 for 'Mysore' and 13.42 for 'Vazhukka'.

(iii) Seed viability

The data on seed viability showed high variability in the different treatments and cultivars. Seed viability was very poor under 'assisted self pollination' in

comparison to normal 'open pollination'. In cultivar Malabar, viability was as low as 6.78 per cent for 'assisted self pollination' and as high as 56.60 per cent for 'open pollination'. In 'Mysore' it was 9.33 per cent and 46.48 per cent whereas in 'Vazhukka' it was 33.54 per cent and 46.15 per cent respectively. Seed viability in the different cross combinations was also lower than that under 'open pollination'. In all the three cultivars highest seed germination was recorded under 'open pollination'. Seed germination was low under self pollination and in the different cross combinations.

Discussion

DISCUSSION

Cardamom is a crop in which a lot of natural variation exists. In the strict sense, each plant is different from the other. Originally it grew as a wild plant in the hilly forest areas. Realising the economic importance this plant has been domesticated in the recent past. It is now grown on a plantation scale in the high ranges. Eventhough three cultivars viz., Malabar, Mysore and Vazhukka have been recognised, their distinct features have not yet been worked out. A clear understanding of the reproductive mechanism in this crop is also lacking. There are conflicting reports on the mode of pollination and existence of self sterility in cardamom. A thorough knowledge of the reproductive mechanism is essential to initiate breeding programmes in any crop. Hence a detailed study was undertaken at the Cardamom Research Station, Pampadumpara to understand the reproductive mechanism in cardamom with special emphasis on the mode of pollination and self sterility.

Purseglove (1975) in his general description of the plant states that 10 to 20 pseudostems (shoots) per clump are present. No significant difference was found for the number of shoots per clump between the three cultivars.

So it could be assumed that the three cultivars are on par with respect to shoot production. It could also be inferred that shoot production takes place actively by the month of May. The shoot number did not increase significantly in the subsequent months.

The panicle

Highly significant differences could be seen between the three cultivars in the number of panicles per clump. But within each cultivar, the number of panicles were the same during different months. Maximum number of panicles was produced by 'Malabar'. The other two cultivars were on par. Since the number of shoots produced by the three cultivars was equal it can be inferred that the cultivar Malabar produces a large number of panicles in relation to number of shoots. There was no significant increase in the number of panicles during the period from May to July. Pattanshetty and Prasad (1972) and Parameswar (1973) on the other hand, have reported that most of the panicles emerge during the post monsoon and winter season.

Length of panicle differed significantly in all the cultivars. Such differences were not significant between clumps of a cultivar. Hooker (1894) and Gamble and Fischer (1935) have reported that panicles are upto two feet long which may be erect or prostrate in the different

cultivars. According to Purseglove (1975) panicles in cardamom were 60 to 120 cm long in general and in the cultivar Malabar they were between 60 and 90 cm in length. However, in the present study, the panicles of 'Vazhukka' had the maximum length (69.9 cm) which was followed by 'Malabar' (58.1 cm) and 'Mysore' (40.3 cm).

The internodal length of panicle was significantly different in the cultivars. The length in 'Vazhukka' was on par with that in 'Malabar' which was on par with 'Mysore'. 'Vazhukka' and 'Mysore' differed significantly in this respect. The length of panicle seems to have a direct influence on the length of internode also, as the cultivar having the longest panicle has the maximum length of internode and vice versa.

The number of racemes per panicle also differed significantly in the three cultivars. But there was no significant difference between the different clumps of the same cultivar. 'Vazhukka' had the maximum number of racemes per panicle followed by 'Malebar' and 'Mysore'. The latter two cultivars showed significant difference between themselves.

With respect to panicle characters, 'Vazhukka' seems to be the best cultivar. The long internodes are compensated by long panicle and more number of racemes per panicle. 'Malabar' seems to be intermediate followed by

'Mysore'. The panicle characters usually have a relation with the yield potential of the cultivar.

The number of flowers per raceme, was not significantly different in the cultivars. But the different clumps within a cultivar showed significant difference. The mean number of flowers per raceme was 3.8 for 'Malabar', 6.8 for 'Mysore' and 8.3 for 'Vazhukka'.

Floral morphology

The flowers of the three cultivars did not differ quantitatively as well as qualitatively. The length of flowerwas 5.04, 5.00 and 5.02 cm in cultivars Malabar, Mysore and Vazhukka respectively. However, Pattanshetty and Prasad (1972) and Purseglove (1975) reported that the length of flower in cardamom is 3.7 and 4.0 cm respectively. The stalk of the flower was 0.488, 0.402 and 0.432 cm long in the three cultivars. This is in conformity with the report of Pattanshetty and Prasad (1972) that the mean length of flower stalk of prostrate variety was 0.5 cm. The mean lengths of corolla tube was 2.03, 2.10 and 2.07 cm, of filament was 890.1, 828.8 and 858.5 microns, of anther was 0.599, 0.600 and 0.604 cm in 'Malabar', 'Mysore' and 'Vazhukka' respectively. Pattanshetty and Prasad (1972), however, have reported that anthers were on an average 0.7 cm long in the prostrate variety. The mean length of

style was 2.92, 2.89 and 2.90 cm in 'Malabar', 'Mysore' and 'Vazhukka' respectively. The number of ovules per ovary was 18, 17 and 17 respectively in the three cultivars.

Pollen grains were largest in 'Vazhukka' (90.35 microns) and smallest in 'Malabar' (83.90 microns). This is not in agreement with the report of Venugopal and Parameswar (1974 b) that pollen grains of the erect type were the largest and those of the semi-erect were the smallest. The pollen grains were spherical to oval in shape with small spines on the exine. They appeared as a white sticky or powdery mass according to the environmental conditions. These observations are in agreement with the reports by Pattanshetty and Prasad (1972), Parameswar (1973) and Venugopal and Parameswar (1974 b).

As stated earlier, there is no difference between the three cultivars in floral morphology such as colour and shape. Also in quantitative aspects such as length of the flower stalk, corolla tube, anther and the style and in the number of ovules per ovary there exists no difference. But in the length of filament and diameter of pollen grains there is a slight difference between the cultivars.

Anthesis

Flowering was more protracted in cultivars Mysore and Vazhukka than in Malabar. It was almost complete within 50 days from first flowering in 'Malabar', but was prolonged upto 85 days in 'Mysore' and 'Vazhukka'. This is not in agreement with the report of Pattanshetty and Prasad (1972) that flowering in the prostrate variety crossed 75 per cent during the months of June to August and the total duration of flowering was six months from May to October. Parameswar (1973) and Parameswar and Venugopal (1974 c) however, reported that flowering was observed throughout the year, under Mudigere conditions. The difference in flowering pattern can be due to the climatic difference at Mudigere and Pampadumpara.

No distinct 'peak' for flowering was observed in the panicles. In 'Malabar', at the beginning, the percentage of flowering was 18.7 which came down gradually to 11.9 by the 25th day and further to 0.5 by the 50th day. In 'Mysore' and 'Vazhukka' where a more protracted pattern was observed the rate of flowering was almost constant at 6.5 to 7.0 per cent upto the 55th day of flowering. This was reduced to 0.4 and 0.7 per cent respectively by the 85th day.

The mature flower buds were in a compact condition on the previous evening of opening. The mechanism of flower opening in cardamom was found to involve the following four distinct steps.

(i) Splitting open of the two lateral lobes of the corolla (petals).

(ii) Unfurling of the labellum following its release by the petal which holds it in a hooked condition.

(iii) Opening of the labellum fully followed by the straightening of the stamen with the style and stigma.

(iv) Dehiscence of the anther.

These observations are in agreement with the reports of Pattanshetty and Prasad (1972) and Parameswar and Venugopal (1974 c).

The first three stages of anthesis were completed in 'Mysore' slightly earlier than in 'Malabar' and 'Vazhukka'. But the key process of anther dehiscence occurred almost at the same time in all the three cultivars. Anther dehiscence took place at 8.03, 8.22 and 8.14 AM in 'Malabar', 'Mysore' and 'Vazhukka' respectively. This is in general agreement with the report of Parameswar and Venugopal (1974 c) that anthesis in cardamom commenced between 3.30 and 4.30 AM and continued till 7.30 AM. Anther

dehiscence was reported to be maximum between 5.30 AM and 6.30 AM and after 7.30 AM there was no dehiscences at all. However, Pattanshetty and Prasad (1972) reported that flower opening in the prostrate variety began at 4.30 AM and anther dehiscence took place at 6 AM. Jose (1980) has also reported that flower opening started by 4 AM and attained a peak by 7 AM.

Flower opening and anther dehiscence are highly influenced by the climatic conditions such as temperature, humidity and sunshine. Hence, the difference in the timings reported by previous workers from that observed in the present investigation could be attributed to changes in one or more of these factors due to change in location of study and possibly time also.

The mean pollen fertility percentages were 91.82, 89.79 and 88.36 for 'Malabar', 'Mysore' and 'Vazhukka' respectively. No significant difference was found between these cultivars in fertility of pollen grains. These observations are in conformity with the reports of Venugopal and Parameswar (1974 b) that the pollen fertility percentages were 92.00 and 82.64 in semi-erect and erect types respectively.

The germinability of pollen grains increased gradually from 6 to 10 AM in 'Malabar', upto 11 AM in the other two cultivars and then decreased. The maximum

germinability in 'Malabar' was 60.25 per cent at 10 AM. In 'Mysore' and 'Vazhukka' it was at 11 AM with 42.86 and 42.33 per cent respectively. Emergence of pollen tube could be generally seen within two hours of dusting. It may be inferred that the pollen grains of 'Mysore' and 'Vazhukka' have low germinability in comparison to those of 'Malabar'. This observation on the germinability of pollen grains of the prostrate cultivar (25.06 to 60.25 per cent) does not agree with the report of Pattanshetty and Prasad (1972) that the percentage of germination was 75 to 90.

The present observations indicate that fertility of pollen estimated by acetocarmine staining technique cannot be taken as a reliable index of viability since the maximum fertility was 99.40, 98.43 and 99.78 per cent in 'Malabar', 'Mysore' and 'Vazhukka' respectively as against the maximum germinability of 60.25, 42.86 and 42.33 per cent for the three cultivars. These observations are in agreement with the reports of Parameswar (1974) and Parameswar and Venugopal (1974 b).

Receptivity of stigma showed a regular pattern for 'Malabar' and 'Vazhukka' from 6 AM to 12 noon. The percentage of capsule setting increased upto 8 AM and then decreased slowly. In 'Mysore', it showed an irregular

pattern without a clear trend. The observation on the cultivar Malabar is in conformity with the report by Pattanshetty and Prasad (1972) that flowers have maximum receptivity during the morning hours. They obtained 51 to 61 per cent capsule setting when pollinated in the morning. In the present study the maximum setting was 40 per cent at 7 and 8 AM. The setting was reduced to 15 per cent by 12 noon. This is in agreement with the report of Pattanshetty and Prasad (1972) that capsule setting was as low as 13 per cent in the afternoon hours.

There was no significant difference between the three cultivars in the mean number of seeds per capsule at the different timings of pollination. This shows that if the stigma is receptive, normal seedset takes place irrespective of the time of pollination. Also it was seen that the number of seeds per capsule was slightly higher in 'Vazhukka' as compared to 'Malabar'.

Pollination

The capsule setting percentages were 55.42, 43.33 and 55.26 in 'open' panicles of 'Malabar', 'Mysore' and 'Vazhukka' respectively whereas they were only 15.07, 16.39 and 2.82 respectively in the 'caged' panicles. As the capsule set was considerably higher in 'open' pollinated panicles than in the 'caged' panicles the crop is

predominantly a cross pollinated one. This is in conformity with the reports of Pattenshetty and Prasad (1972), Parameswar (1973), Purseglove (1975), Shanker and Kumaresan (1979) and Madhusoodanan et al.(1981). The cross pollinated nature of the crop is predominantly due to the special morphological feature of the flower that the stigma is placed well above the anther lobes and that the stigmatic cavity is surrounded by cilia. This necessitates the involvement of an external agent for effecting pollination. Similar conclusions were drawn by Pattenshetty and Prasad (1972).

The cross pollinated nature of the crop can also be attributed to the large size of the pollen grains and their occurrence as a sticky mass. This makes difficult the transfer of pollen to the stigmatic surface during anther dehiscence. Moreover, the panicles are so close to the ground, especially in 'Malabar' that wind will not be intense around that area to enable the natural transfer of pollen grains from anther to stigma.

Self pollination was recorded upto a small extent such as 15.07, 16.39 and 2.82 per cent in 'Malabar', 'Mysore' and 'Vazhukka' respectively in the protected panicles. This might be due to the movement of crawling insects such as ants and lice which have access to the

above panicles even under caged conditions. Madhusoodhanan et al. (1981) have also reported that there is considerable amount of self pollination by way of geitonogamy.

Seedset per capsule was 12.59, 12.21 and 13.65 in 'Malabar', 'Mysore' and 'Vazhukka' respectively, in 'open' panicles, whereas it was 10.33, 10.67 and 10.50 respectively in protected panicles. The slight reduction in seedset could be attributed to the lack of sufficient pollen for effective pollination.

The seed viability estimates for 'caged' as well as 'open' panicles have also shown different trends. It was 56.60, 46.84 and 46.15 per cent respectively in 'Malabar', 'Mysore' and 'Vazhukka' for 'open' panicles as against 55.79, 19.05 and zero per cent respectively for 'caged' panicles. The low percentage of germination of self pollinated seeds of 'Mysore' and 'Vazhukka' (19.05 and zero per cent respectively) can be attributed to the lack of sufficient seeds for the experiment (only 10 and 2 capsules were available for the trial in 'Mysore' and 'Vazhukka' respectively) due to the poor capsule setting under self pollination.

The agent involved in the cross pollination was inferred to be the honey bee as there was high bee activity in the flowering season during the morning hours

around the clumps. Moreover, the protected panicles which were actually covered by a nylon mesh cylinder could keep out only large flying insects like the bees and such flowers showed low capsule setting. These observations are in conformity with the earlier reports by Pattanshetty and Prasad (1972), Parameswar (1972), Pattanshetty and Prasad (1974) and Parameswar et al. (1978). However, Jose (1980) had reported that giant rock bees (Apis domestica) were the primary agents of pollination and honey bees (Apis indica) were only secondary agents.

Self sterility

Sarma and Visweswara (1969) and Purseglove (1975) have reported the occurrence of self sterility in cardamom. Shankar et al. (1981) have reported that there are different 'sex forms' ranging from partially in-compatible to completely compatible ones. Capsule setting percentage was zero after emasculation and covering in all the three cultivars indicating that there is no parthenocarpy in cardamom. It can be inferred that the low capsule set obtained in protected panicles of all the three cultivars was purely due to self pollination assisted by crawling insects.

Capsule setting percentage under 'open' pollination were 55.42, 43.33 and 55.26 in 'Malabar', Mysore and

'Vazhukka' respectively. But these percentages were low in comparison to the capsule setting percentages of 66.67, 63.33 and 76.74 for the three cultivars respectively, obtained after assisted self pollination. These observations rule out the possibility for the occurrence of self sterility in cardamom. Similar conclusions were drawn by Pattanshetty and Prasad (1972) in the prostrate cultivar, where capsule setting under self pollination was as high as 69 per cent. Shankar and Kumaresan (1979), Jose (1980) and Madhusoodanan et al. (1981) have also reported that there is no self sterility in cardamom.

High percentages of capsule setting were obtained in all the six cross combinations between the three cultivars, the maximum being 80.85 in 'Vazhukka x Malabar' and the minimum being 60.92 in 'Malabar x Vazhukka'. These results therefore indicate that, there is no cross incompatibility in this crop.

Estimates of the number of seeds per capsule were almost similar in all the treatments and ranged from 12.21 to 14.52. This confirms the absence of any self or cross incompatibility in the crop.

The percentages of seed germination in the different treatments showed high variation. High germination percentages were recorded under 'open pollination' in all the

three cultivars. Comparatively low germination percentages were shown by the seeds under 'assisted self pollination' especially in 'Malabar' and 'Mysore'. Seeds of the cross 'Vazhukka x Malabar' exhibited low germination percentage in spite of high seed setting. This might be attributed to 'facultative parthenogenesis' where unfertilized ovules develop under the stimulus of pollination or hybrid inviability where the hybrid embryos fail to germinate. This aspect however, needs further detailed investigation.

The present study indicates that although the three cultivars are similar in many aspects, they as well show some dissimilarity in certain features. 'Vazhukka' seems to have panicle characteristics which lead to higher capsule production and consequently increased yield. There is essentially no difference between the three cultivars in floral morphology. In pollen fertility, germinability and stigma receptivity also, the three cultivars follow almost a similar pattern. Anthesis occurs in the early morning in cardamom. The crop is predominantly cross pollinated and the agent is honey bee. The study also revealed that there is neither self sterility nor parthenocarpy in the three cultivars.

Summary

SUMMARY

A study on the reproductive mechanism in cardamom was undertaken in the three popular cultivars viz., Malabar, Mysore and Vazhukka. Field studies were conducted at the Cardamom Research Station, Pampadumpara and laboratory studies at the College of Agriculture, Vellayani during 1981. Plants true to type in each of the three cultivars were selected at random. Observations were made on floral morphology, time and mechanism of anthesis, pollen viability, stigma receptivity, mode of pollination and self sterility. The data were analysed statistically and results interpreted.

There was no significant difference between the three cultivars in the number of shoots per clump. But, the number of panicles per clump was higher in 'Malabar' than in 'Mysore' and 'Vazhukka'. This indicates that 'Malabar' produces more number of panicles per shoot than the other two cultivars.

The panicles of 'Vazhukka' were significantly longer than those of other two cultivars. 'Mysore' had the shortest panicles. Length of panicle internode was significantly more in 'Vazhukka' than in 'Mysore'.

'Malabar' was intermediate. 'Vazhukka' produced significantly more racemes per panicle than the other two cultivars. 'Mysore' had the minimum number of racemes per panicle. The number of flowers per raceme was mostly the same in all the three cultivars.

The cultivars did not differ significantly with respect to general floral morphology such as colour and shape. They also did not differ in quantitative aspects such as length of flower and floral parts. The diameter of pollen grains in the cultivars was slightly different. The pollen grains were spherical to oval in shape with small spines on the exine. They appeared as a white sticky or powdery mass according to the environmental conditions.

The period of flowering was shortest with 50 days in 'Malabar' as compared to the protracted flowering of the other two cultivars with 85 days. The rate of flowering was almost uniform upto two-thirds of the flowering period and dropped later.

The mechanism of flower opening was similar in all the three cultivars. It consists of four stages.

(i) Splitting open of the two lateral lobes of the corolla (petals).

(ii) Unfurling of the labellum following its release by the ventral lobe of the corolla, which holds it in a hooked condition.

(iii) Opening of the labellum fully and straightening of anther along with style and stigma.

(iv) Dehiscence of the anther.

The first three stages of anthesis were completed in 'Mysore' slightly earlier than in 'Malabar' and 'Vazhukka'. But the key process of anthesis viz., the dehiscence of anther took place almost at the same time in all the three cultivars and was between 8.03 and 8.22 AM.

Pollen fertility as indicated by the acetocarmine staining technique ranged from 88.36 to 91.82 per cent in the three cultivars. There was no significant difference between the three cultivars in fertility of pollen. Pollen germinability increased gradually from 6 to 10 AM in 'Malabar' and upto 11 AM in 'Vazhukka' and 'Mysore' and thereafter decreased. 'Malabar' had comparatively high germinability than the other two cultivars. It was inferred that the acetocarmine staining technique is not a reliable method of estimating viability of pollen as all the grains stained in the acetocarmine technique did not germinate. The receptivity of stigma estimated by capsule setting percentage was found to increase from 6 AM onwards reaching a peak at 8 AM and decreasing thereafter, in 'Malabar' and 'Vazhukka'. In 'Mysore' stigma receptivity exhibited an irregular pattern. There was no difference in number of

seeds per capsule at the different hours of pollination in spite of differences in the percentage of capsule setting.

Cardamom was found to be predominantly cross pollinated and the chief agent involved was inferred as the honey bees. The morphological features of the pollen grains, the placement of stigma above the anther lobes and the placement of panicles near the ground level might have facilitated cross pollination. There is no parthenocarpy in the three cultivars. Self or cross incompatibility is absent since, artificial selfing and the different cross combinations gave high capsule setting. The seed setting was also found to be very much similar in the different treatments further confirming the absence of self sterility or cross incompatibility. However, the seed viability percentages corresponding to different treatments showed high variability. In all the three cultivars the 'open pollinated' seeds showed high germinability while the seeds from assisted self pollination in 'Malabar' and 'Mysore' and those of the cross 'Vazhukka x Malabar' showed comparatively low germination. This observation needs further detailed investigation.

The present study has revealed that the three cultivars of cardamom though similar in any morphological aspects, are different in respect of a few characters.

'Vazhukka' seems to possess panicle characteristics which favour a higher yield of capsule. Moreover, there is no appreciable difference in floral morphology, pollen fertility, viability and stigma receptivity. Anthesis occurs in the early hours of the day almost at the same time. The crop is predominantly cross pollinated and the agents are inferred to be honey bees. It was also inferred that there is neither self sterility nor parthenocarpy in these cultivars of cardamom.

References

REFERENCES

Aiyadurai, S.G. (1966). A review of research on spices and cashewnut in India. Indian Council of Agricultural Research, Ernakulam: 16-18, 61-84.

Anonymous (1954). Cardamom - Varietal Introduction and trials and evolution of varieties. Memoirs of the Department of Agriculture, Madras: 633-635.

Anonymous (1977). Annual Report of the Central Plantation Crops Res. Instt., Kasaragod 1979: 204.

*Anonymous (1978). New clone developed. Farmer's Friend, 3 (2): 4-5.

Anonymous (1979). Annual Report of the Central Plantation Crops Research Institute, Kasaragod 1977: 204.

Anonymous (1980). Economic varieties of cardamom - Alfred, Cardamom, 12 (4): 29-30.

Anonymous (1981 a). Package of Practices Recommendations, Kerala Agricultural University, Mannuthy: 108

Anonymous (1981 b). Progress Report of the All India Co-ordinated Spices and Cashewnut Improvement Project, 1978-79. CPCRI, Kasaragod: 32-34.

Anonymous (1982). Farm Guide. Farm Information Bureau, Government of Kerala: 2.

Bliss, C.I. (1967). Statistics in Biology (1). McGraw-Hill Book Co., NY., pp: 356.

Federer, W.T. (1955). Experimental Design, Theory and Application. Oxford and IBH Publishing Co., pp: 6-93.

*Gamble, J.S. and Fisher, C.S.C. (1935). Elettaria cardamomum Maton. In Flora of Madras Presidency, 3 (1967 reprint edition). Botanical Survey of India, Calcutta: 1041-1042.

George, V.A., Gopalakrishnan, M and Mathew, A.G. (1980). Commercial bleaching of cardamom. Cardamom 12 (4): 15.

Gopimony, R. (1976). Cardamom varieties and crop improvement. Special lecture in October 1976.

*Hooker, J.D. (1894). Elettaria cardamomum. In The Flora of British India, 6: L. Reeve and Company, London: 251.

Ilyas, M. (1978). The Spices of India - II. Economic Botany, 32 (3): 238-263.

John, K. (1977). Mini cardamom. Cardamom, 9 (1): 30.

Jose, J.K. (1980). Pollination - Most decisive factor in cardamom production. Cardamom, 12 (8): 3-9.

Khan, K. and Khader, J.B.M. (1967). Development of cardamom in Madras. Cardamom News, 1 (4): 4-6.

*Kololgi, S.D., Pattanshetty, H.V. and Prasad, A.B.N. (1973). Germination of cardamom seeds can be improved by treatment with nitric acid and sowing in plastic house. Current Research, 2 (1): 3.

*Madhusoodanan, K.J., George, K.V. and Shankar, B.D.(1981). Studies on pollination and fruit set in cardamom (Elettaria cardamomum). In abstract of IV Annual Symposium on Plantation Crops, Mysore, December, 1981: 24.

*Nambiar, M.C. (1972). Advances in Spices Research. Indian Farming, 22 (8): 9-12.

*Pai, R.M. (1965). The floral anatomy of Elettaria cardamomum Maton. Mysore Journal of Agricultural Sciences, 7 (2): 205-213.

Parameswar, N.S. (1973). Floral Biology of cardamom (Elettaria cardamomum Maton). Mysore Journal of Agricultural Sciences, 7 (2): 205-213.

Parameswar, N.S. (1974). Studies on pollen viability in cardamom. Journal of Plantation Crops, 2 (1): 5-6.

Parameswar, N.S. and Siddappaji, C. (1973). A case of terminal inflorescence in cardamom (Elettaria cardamomum Maton). Current Research, 2 (5): 32.

Parameswar, N.S. and Venugopal, R. (1974 a). Capsule setting studies in Elettaria cardamomum Maton. Current Research, 3 (5): 57-58.

Parameswar, N.S. and Venugopal, R. (1974 b). Evaluation of different methods of determining pollen viability in cardamom. Current Research, 3 (9): 108-109.

Parameswar, N.S. and Venugopal, R. (1974 c). Study of flowering and anthesis in cardamom (Elettaria cardamomum Maton). Mysore Journal of Agricultural Sciences, 8 (3): 356-361.

Parameswar, N.S. and Venugopal, R. (1975). Preliminary studies on pollen germination in cardamom. Mysore Journal of Agricultural Sciences, 9 (1): 59-65.

Parameswar, N.S., Haralappa, H.S. and Maheshgowda, H.P. (1978). Bee keeping in cardamom plantations. Cardamom, 10 (3): 7.

Pattanshetty, H.V. and Prasad, A.B.N. (1972). Blossom Biology Pollination and fruitset in cardamom (Elettaria cardamomum Maton). In Third International Symposium of Subtropical and tropical Horticulture. Today and Tomorrow's Printers and Publishers, New Delhi: 262-268.

*Pattanshetty, H.V. and Prasad, A.B.N. (1974). Exposing the cardamom panicles from a layer of leaf mulch to open pollination by bees and thereby improving the fruitset. Current Research, 3 (8): 90.

*Pattanshetty, H.V., Rafeeq, M. and Prasad, A.B.N. (1978). Influence of the length and type of storage on the germination of cardamom seeds. In Proceedings of the First Annual Symposium on Plantation Crops, Kottayam, Indian Society for Plantation Crops, CPCRI, Kasaragod: 267-274.

Prasad, A.B.N., Pattanshetty, H.V. and Kololgi, S.D.(1974). Seed treatment to improve and hasten the germination of cardamom seeds sown during winter. Cardamom News, 5 (8): 5-12.

Purseglove, J.W. (1972). General Agronomic aspects of Spice Crops. Proceedings of the Conference on Spices, 10 - 14 April, 1972. Foreign and Commonwealth Office, Tropical Products Institute, London: 85-90.

Purseglove, J.W. (1975). Cardamom. Tropical Crops - Monocotyledons. The English Language Book Society and Longman: 528-533.

Rangaswami, G. (1977). Cardamom in Tamil Nadu. Cardamom, 9 (1): 3-7.

*Rao, N.U. (1955). Research shows new ways to bigger cardamom yields. Indian Farming, 5 (3): 11-12.

*Reddy, S.B.G., Siddaramaiah, A.L. and Parameswar, N.S. (1973). Ten minutes presowing treatment of cardamom with 50% HCl ensures good germination. Current Research, 2 (4): 22.

*Sarma, M.S. and Viswaswara, S. (1969). Some suggestions for breeding cardamom. Cardamom News, 5 (7): 2-5.

Shankar, B.D. (1979). Male cardamom. Cardamom, 11 (10): 27.

Shankar, B.D. (1980 a). Compound Panicle in Cardamom. Cardamom, 12 (1): 25.

Shankar, B.D. (1980 b). Alfred clone. Cardamom, 12 (2): 39.

Shankar, B.D. and Kumaresan, D. (1979). Bee - a friend of queen. Cardamom, 11 (7): 3-6.

*Shankar, B.D., Madhusoodanan, K.J. and George, K.V.(1981). Sexual polymorphism and evolution of sex in cardamom (Elettaria cardamomum). In Abstract of IV Annual Symposium on Plantation Crops, Mysore, December, 1981: 28.

Subbarao, G. and Dubey, O.P. (1980). Bibliography on cardamom (Elettaria cardamomum (L.) Maton). ICAR, CPCRI, Kasaragod. pp: 97.

Subbarao, G. and Naidu, R. (1981). Breeding Cardamom for 'katte' disease resistance. Paper presented in IV Annual Symposium on Plantation Crops, Mysore, December, 1981.

*Sulikeri, G.S. and Kololgi, S.D. (1977). Seed viability in cardamom. Current Research, 6 (10): 163-164 (Edn. 3 ref.)

Venugopal, R. and Parameswar, N.S. (1974 a). Germination of Pollen in cardamom in vitro. Current Research, 3 (5): 58-59.

Venugopal, R. and Parameswar, N.S. (1974 b). Pollen studies in cardamom. Mysore Journal of Agricultural Sciences, 8 (2): 203-205.

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REPRODUCTIVE MECHANISM IN CARDAMOM

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ABSTRACT OF A THESIS

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ABSTRACT

The study on the reproductive mechanism in cardamom was undertaken at the Cardamom Research Station, Pampadumpara in three popular cultivars viz., Malabar, Mysore and Vazhukka. Laboratory studies were conducted at the College of Agriculture, Vellayani.

Different morphological characters of the panicle and flower, spread of flowering, time and mechanism of anthesis, pollen viability, stigma receptivity and self sterility were studied. The three cultivars were critically compared with respect to each of these characters.

The cultivars were found to have mostly similar panicle characters and floral morphology. There was no distinct peak in flowering in the cultivars. In 'Malabar', the period of flowering was shorter than in the other two cultivars. Anthesis in cardamom was found to occur in the early hours of morning. The mechanism of flower opening involved four distinct but overlapping stages beginning with the opening of petals and ending with dehiscence of anthers. The first three stages of anthesis in 'Mysore' was completed slightly earlier than in 'Malabar' and 'Vazhukka'. But anther dehiscence occurred almost at the

same time. Pollen fertility by acetocarmine technique was high. The germinability of pollen was high in the early hours of the day and decreased by noon. Stigma receptivity was also high in the early hours of the day and decreased by noon, in 'Malabar' and 'Vazhukka'. However, 'Mysore' showed an irregular pattern as regards stigma receptivity.

The crop was predominantly cross pollinated and the chief agent involved is inferred as the honey bee. The morphological features of the pollen grains, the placement of stigma above the anther lobes and the placement of the panicles near the ground might facilitate cross pollination. Self pollination was found to occur on a small scale with the help of crawling insects like ants and lice. The seed setting, however, was lower in self pollinated capsules. This might be due to the lack of sufficient pollen grains for effective fertilization of all the ovules.

The results indicated that there is no parthenocarpy in cardamom and that there is neither self sterility nor cross incompatibility. Seed setting was found to be very much similar in the different treatments such as open pollination, artificial self pollination and controlled self pollination. However, seed viability in the different self

and cross combinations showed differing trends. Incidences of 'facultative parthenogenesis' or 'hybrid inviability' can be suspected. However, this needs further more detailed investigation.