INTRA AND INTER VARIETAL VARIABILITY ANALYSES IN CARDAMOM

(*Elettaria cardamomum Maton*)

By

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THESIS

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1987

DECLARATION

I hereby declare that this thesis entitled "Intra and Inter Varietal Variability Analysés in Cardamom (*Elettaria cardamomum* Maton)" 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.

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CERTIFICATE

Certified that this thesis entitled "Intra and Inter Varietal Variability Analysès in Cardamom (*Elettaria cardamomum* Maton)" is a record of research work done independently by Gopal Radhakrishnan 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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INTRODUCTION

INTRODUCTION

Cardamom (*Elettaria cardamomum* Maton,) is one of the oldest known spices. It is mentioned in early Sanskrit writing as 'Eta' from which most of the Indian names of the spice have been derived. Popularly known as 'The Queen of Spices' it is by far the most important spice in trade and commerce, having earned about sixty crores of rupees as foreign exchange in 1985-86 alone. The commercially important product of this plant is the dried capsule which may be used for flavouring beverages or the seeds may be extracted and powdered for use in curry powder, cakes, biscuits and other baked foods; in desserts, puddings and a whole variety of other traditional and modern culinary items. Indian cardamom is used in the preparation of medicines, too. It is a powerful aromatic, carminative, stomachic and diuretic and checks nausea and vomiting. Some even believe it to be a potent aphrodisiac.

In India; Kerala, Karnataka and Tamil Nadu account for the majority of the area under this crop with 58,769 ha, 29,260 ha. and 8,108 ha. respectively. These three states share in the order of 61.12 per cent, 30.44 per cent and 8.43 per cent of the total area (Cherian, 1986) under cultivation of cardamom. The present day production of cardamom in India is estimated at an average of about 4700 metric tonnes with the bulk of the produce being exported to the countries in the Middle East. Although India holds a prime position among

the cardamom producing countries of the world, her productivity at 50 to 75 kg per hectare is very low and is not in any way near the Guatemalan average of 250 kg per hectare.

Strong competition from other cardamom producing countries such as Guatemala, Tanzania and Srilanka together with production constraints on account of cultivation of poor genetic material, high incidence of pests and diseases and increased cost of production are major threats to the cardamom industry in India. Hence high productivity and superior quality of produce is warranted to tackle these problems.

Breeding of better types with higher production potential and resistance is an important method of achieving this objective. The information on the type of variability available in the genetic stock and the part played by the environment on the expression of characters is a prerequisite for any crop improvement programme. The present study is therefore undertaken to obtain information on the magnitude of genetic variability in the population and the extent to which the desirable characters are heritable. To explore the genetic variability, phenotypic and genotypic coefficients of variation, heritability and genetic advance of different characters were determined. Attempts have also been made to study the correlations between yield and its components and the direct and indirect effects of these components on yield.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Cardamom is a cross-pollinated crop which shows a lot of variation in the natural population (Purseglove, 1975 Gopimony, 1976 and Shankar et al, 1981). However studies on the magnitude of genetic variability and the extent to which the desirable characters are heritable, which are prerequisites for any crop improvement programme, are areas where only limited research has been done so far. Hence the literature pertaining to the present investigation is restricted to a review of the work done in closely related and other crops under the following headings:

1. Studies on genetic variability and the estimation of genetic parameters
2. Correlation and path coefficient analysis

1. Studies on genetic variability and the estimation of genetic parameters

a) Intravarietal variability:

Most of the variations within a variety for quantitative characters are reported to be due to the effects of environment. Reports on these lines were published by Rieman et al. as early as in 1950. They recorded significant differences in the

yielding capacity of the potato variety 'Chippewa'. They concluded that these variations were heritable and their occasional appearance was the rule and not the exception in asexual propagation.

Davidson and Lawley (1953) reported that high and low yielding clones appeared in 'King Edward' and probably in other varieties of potato.

Gross and Simmonds (1954) tried to identify mutations in 'Dwarf Cavendish' group of banana with the help of differences in leaf ratios. They suggested that rather than height, leaf ratios serve better to identify the varieties. In potato Cockerham and Macarthur (1956) showed that there was significant difference in yield and disease resistance among the sub-clones of the variety 'Majestic'. A study conducted by Shepherd (1957) reinforced the views of Gross and Simmonds (1954). He opined that the leaf ratio seemed to be a character least affected by environment and therefore would be of great use for detection of intra varietal variation.

Nayar (1958) suggested that the occurrence of somatic mutations in banana offers greater scope for selection of desirable types. Simmonds (1959) had observed that although banana offered little scope for detection of such subtle changes as were detected in potatoes, there was still reason to believe that they were no less subjected to such changes.

Harris et al.(1967) studied the effects of three different environments on a clone of potato and found evidence to suggest that the different environments altered the relative expression of growth and yield parameters. Clonal variation in potato was also reported by Terry et al.(1970), though they could not find significant differences with regard to clone x location interactions, the clone x year x location interaction was significant for plant height and yield.

Compton et al.(1965) estimated genetic variances from intra varietal families in open pollinated varieties of corn and found that the genetic variances of intra varietal families tended to be lower than those from inter varietal families. The ratio between these genetic variances was less than one for the characters studied, suggesting that additive gene action with no more than partial to complete dominance was the primary cause of genetic variation in open pollinated progenies.

In mango distinct clonal variations were observed when grown in different areas (Singh, 1971). This difference was often met with in 'Desheri' and 'Alphonso'.Root stock, soil and climatic factors as well as indiscriminate multiplication were attributed as the reasons.

Exploitation of natural variability in cardamom has led to the evolution of "Hema" series one to twelve at Mudigere,

seven selections at Pampadumpara and five selections at Appangala (Nambiar, 1972).

Chandrasekharan and Parthasarathy (1975) reported that in genetically complex, vegetatively propagated plants like apple, dahlia, chrysanthemum and potato, conditions favourable for occurence of variations exsist. It was pointed out that the variations in yield observed in the sub clones were largely due to environment.

Milutinovic et al.(1981) after studying the clones of the sour cherry variety 'Oblacinska' suggested that there was a possibility of improving the characteristics of this variety by clonal selection.

Based on the results of clonal selection in the apricot 'Velkopavilovickal', Vachun (1981) observed that the variability was high for yield but low for vigour and fruit quality.

Pattanshetti, et al.(1981) found that there was much greater variation in yield among clones than among seedling progeny families in a study on sixty seedling progeny families and eighty provisionally selected clones of cardamom. Twenty per cent of the clones were found to have cumulative average yields/ clump of more than 500 g. They concluded that rapid improvement could be effected through clonal selection.

Rajeevan et al . (1984) studied the variability in ratoon crop of banana variety Palayankodan and observed that significant variation exsists for all characters studied. Finger number/bunch, finger weight and height and circumference of the pseudostem at flowering gave high values for heritability and genetic advance.

b) Inter varietal variability:

Kamalam et al .(1977) conducted a study in ten varieties of sweet potato and estimated phenotypic and genotypic coefficients of variation, heritability and genetic advance, for six characters. Genotypic coefficient of variation was lower than the phenotypic one for all the characters studied. Length of vine and number of tubers showed very high degree of phenotypic and genotypic coefficients of variation associated with high heritability estimates and genetic advance.

Balasundaram et al .(1978) estimated genetic variability and heritability in sugarcane and revealed that stalk yield and its components, number of stalks per row suitable for milling, single stalk weight and amount of sugar produced per row were highly heritable in the broad sense and showed high genetic variability.

Jones et al .(1978) studied variability and heritability for fibre content, cracking and sprouting in sweet potato and

suggested that heritability estimates for the above characters were sufficiently independent to allow selection of one or any combination simultaneously without adversely effecting the others.

Biradar et al.(1978) conducted detailed investigations with twelve varieties of cassava to estimate genetic variability for seven quantitative characters and reported that phenotypic coefficient of variation was higher than that of genotypic for all the characters studied. Phenotypic and genotypic coefficients of variation, heritability and genetic advance estimates were high for number of nodes and root yield per plant indicating considerable scope for improvement of economic traits like tuber yield.

Kaminski (1978) examined eleven characters in 120 varieties of potato for three years. He found that the more variable and the least heritable characters were tuber number per plant and mean tuber weight. Morphological characteristics of the aerial parts displayed low variability and differed in heritability.

In a study of variability and heritability of fourteen characters in ginger, Mohanty et al.(1979) reported that the genotypic coefficient of variation, expected genetic advance and heritability estimates were high for number of secondary rhizome fingers and total root weight and leaf breadth.

Dandin et al.(1981) presented the varietal description based on data collected from 180 accessions which was considered to represent the known genetic variability in cardamom.

Sulikeri et al.(1981) suggested that the habit of the prostrate type of cardamom is better suited to dry conditions than the erect type. Average yield of green capsules per clump at the end of the third year after planting was significantly higher for the prostrate type than for the erect type.

George et al.(1981) opined that panicle characters were the most variable among the twelve characters measured in 180 accessions of wild and cultivated cardamom and twelve ecotypes were indentified.

Pattanshetti (1981) studied variability in the yield of cardamom raised from seeds collected throughout Karnataka. Yield was highly variable. A yield of over 500 g was obtained from 40% of the population. Pattanshetti (1981) reported that high variability in yield (88.8%) and a high percentage (44.23%) of low yielding clones were the major factors responsible for low yield in cardamom.

Gurusinghe et al.(1985) reported that, of the six introductions of Elettaria Cardamomum, evaluated under artificial shade condition at an altitude of 500 m, Indian bulk clone 37, Malabar and Local bulk showed good performance.

2. Correlation and path coefficient analysis

Galton (1889) conceived the idea of correlation of variables for the first time and Fisher (1918, 1954) developed the method of applying the theory of correlation of variables, in the understanding of their influence in biological systems.

Snedecor and Cochran (1967) improvised the mathematical computation of the coefficient of correlation in biological system.

The expression of inherited characters is often influenced by the genotype, the environment and the genotypic environmental interaction. Burton (1952) introduced a convenient procedure for the calculation of the phenotypic and genotypic coefficients of correlation.

Jones (1959) reported that the yield of tuber in tapioca was associated positively with relatively large leaves, duration and higher values for the leaf area index. Magoon (1972) reported that the number of tubers per plant in Tapioca was significantly and positively correlated with tuber yield per plant. Further the yield was significantly and directly correlated with tuber length, tuber circumference, plant height and rind thickness. Length of tuber was, however positively associated with girth.

Muthukrishnan et al.(1973) reported that tuber yield in tapioca is positively and significantly correlated with number

of nodes per plant and negatively with leaf breadth. Accordingly tuber yield could be predicted on the basis of number of nodes, plant height, length and breadth of leaves and length and girth of individual tubers. William and Gazali (1974) found that tuber size is the major component of yield in cassava.

Wilson (1976) while conducting detailed studies on the effect of different components on yield in cassava, obtained significant values for correlation among node number, leaf number, leaf area and dry matter production.

Meister and Thompson (1976) studied the phenotypic correlations among the yield components of potato such as number, size, specific gravity of tubers and number of leaves. A model for yield formation as affected by the above components was proposed and analysed by the path coefficient method and the effects of genotypic and environmental correlations were seperated.

Maity and Chatterjee (1977) in a study with fifty varieties of potato for five characters, found that yield was positively correlated with height and number of tubers per plant. There was significant partial correlation between yield and leaflet size. Multiple correlations indicated that leaflet size had the greatest influence on yield followed by tubers per plant and height.

Kawano et al.(1977) stated that varietal variation in yield and harvest index were sufficient for making efficient visual selection in cassava. He observed that harvest index is highly associated with root yield. The correlation between harvest index and root yield was significant. It was concluded that in the selection for root yield harvest index is a better criterion to be relied upon.

Ribeiro (1977) suggested that root production was related to plant height, stem diameter, number of shoots and number of leaves. He recommended that the relationship root fresh weight/dry weight of plant, could be considered as a valid criterion in the selection of cultivars for high productivity in tapioca.

Kamalam et al.(1978) conducted correlation studies in seventy one selfed progeny lines of cassava for tuber yield and it's five components, viz. harvest index, number of tubers, number of nodes, weight of vegetative part and plant height. The tuber yield was positively and significantly associated with all the above characters.

Sequra moreno and Puentecrindad (1978) while estimating the phenotypic correlations in potato cultivars found that plant height and tuber number had the maximum direct influence on yield. Average leaf length was of importance in inter specific crosses. In some of the cultivars stem number and average number of leaves were also of importance.

Challaiah and Kulkarni (1978) in a study on the growth and yield attributes in potato found that fresh weight of top and tubers had significant association with the tuber yield. Total tuber weight had significant association with the tuber yield while average and gradewise specific gravity had no significant correlation with yield.

Mohanty et al.(1979) reported that in ginger rhizome yield was positively and significantly correlated with number of stems, leaves, secondary rhizome fingers, tertiary rhizome fingers and total rhizome fingers. Plant height, leaf breadth, girth of secondary rhizome fingers and number and weight of adventitious roots were also positively correlated with yield.

Sreekumar et al.(1980) in studies on quantitative and qualitative attributes of ginger cultivars found that there was significant positive correlation between plant height, tiller number, leaf number and rhizome weight. The dry ginger percentage had a significant negative correlation with crude fibre content.

Radhakrishnan and Gopakumar (1984) while studying the correlation between yield and its components in tapioca, found that a high value for harvest index was indicative of a correspondingly high tuber yield. Harvest index was inversely influenced by the number of leaves which abscised during the fourth

month after planting. An increase in stem length had a negative influence on yield while an increase in tuber girth had a positive influence.

Dayal et al.(1984) reported that positive phenotypic and genotypic correlations were found between thousand seed weight and total tuber yield/plant in potato. Number of leaves on the main shoot, number of shoots per plant and harvest index were also positively correlated with yield. They suggested that thousand seed weight could be used as a valid criterion in selection for yield in F_1 seedlings of potato.

Wei et al.(1985) found that there was positive genotypic and phenotypic correlations between weight per bunch and height in banana. Hands per bunch was also positively correlated with girth of the plant and fingers per bunch. It was established that plant height and plant girth were the two most important characters for selection.

Since the correlated variables exert their influence, both directly and indirectly through other variables and since the residual factor also gets involved, for the proper understanding of the role of causation on the ultimate effect, a different procedure of analysis has to be depended upon. Wright (1921, 1923, 1934) introduced the path coefficient analysis and

the method has been found to be useful in solving the problems mentioned above. In this method the theory of causation and effect is made applicable. The ultimate dependent variable is referred to as the 'effect', and the components, which by themselves may or may not be dependent on other variables as the "causes".

Niles (1922, 1923) Tukey (1954) and Dewey and Lu (1959) recommended the application of the path coefficient analysis as a potent method for resolving the accurate and dependable criteria in selection procedures in the breeding of plants and animals.

Durate and Adams (1972) emphasised the identification and the classification of the components (causes) to different orders (first, second, third etc.) and the vital importance of the formulation of the causal scheme in path analysis studies. The recommendations too have been followed with success by various authors in different crop species. Tai (1975) during a study on yield and yield components in seven potato cultivars established a causal relationship between environmental resources, component traits and yield based on the concept that yield components were determined sequentially at different stages in the ontology of plants and the hypothesis that the environmental resources could be seperated into independent groups with each

contributing to the development of a component trait. These components were estimated using the method of path coefficient analysis based on the postulated causal relationship.

Thamburaj and Muthukrishnan (1976) in an investigation of association of metric traits by path analysis indicated that the weight of foliage, girth of tubers and number of tubers/vine contributed maximum direct effects on tuber yield indicating the importance of these characters for selection indices for sweet potato. The number of leaves, length of petiole and length of tuber had negative direct effects on tuber yield.

Simple and mutual correlations and path at the levels of the first and second order of components was studied by Pushkaran et al.(1976) in sweet potato and reported that an increase in the length of vine caused significant increase in tuber yield. But at the same time the overall area of leaf should not be allowed to increase because this character had negative relationship with yield.

Nambiar (1979) in an analysis of inter-correlations of coefficients among the morphological characters and yield in turmeric, revealed that the number of tillers, plant height and number of fingers had significant correlation with yield. Path coefficient analysis indicated that wherever significant positive correlations between yield and morphological characters

were established, it was mainly due to substantial positive contribution by plant height and number of fingers either directly or indirectly. He concluded that plant height in turmeric was a single important morphological character on which selection for yield could be made.

Sidhu et al.(1980) in trials with eighty one potato cultivars found that the greatest contribution to tuber yield/plant was made by the number of tubers/plant followed by tuber weight. Ratnambal et al. (1980) partitioned the phenotypic correlation between yield and the morphological characters into direct and indirect effects by the method of path coefficient analysis in ginger and revealed that the character plant height exhibited a high direct effect as well as high indirect effect in the establishment of correlation between yield and other morphological characters.

Pandita and Sidhu (1980) reported that the number of stems and average tuber weight had high positive direct effect on yield in potato but plant height and number of tubers per plant had negative effects. Vijayaraghava Kumar et al.(1984) in a comparative study of the contribution of biometric characters on yield in dessert varieties of banana revealed that hand weight made the highest direct contribution to yield while finger weight and number contributed indirectly.

Chaudary et al.(1984) in a study on path coefficient analysis in F_1C_2 generation of potato crosses, reported that height and foliage weight were positively and significantly correlated with yield and they could be recommended as selection criteria.

MATERIALS AND METHODS

MATERIALS AND METHODS

Experimental material

The present study was conducted at the Cardamom Research Station, Pampadumpara during the period 1985-86. Four popular cultivars of cardamom (Elettaria cardamomum Maton.) viz. Malabar, Mysore, Vazhukka and PV-1 (a promising selection from Malabar) planted at the above station were used for the investigation.

A short description of the varieties is given below:

(1) Malabar : Plants are of medium height, leaves 30 to 45 cms long, short petioled and the lower surface of leaves are pubescent. Panicles are prostrate and trail on the ground. Flowers have long pedicels, capsules are small, globose, rounded or ovoid and lightly ribbed. (PLATE : 1)

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

(3) Vazhukka : Plants are medium tall with non-pubescent leaves and semi-erect-panicles. This is an intermediate type between Malabar and Mysore. (PLATE : 3)

(4) PV-1 : It is of medium height, main characteristic feature is the shape of capsules which is thin and long. Panicles are semi-erect to prostrate. (PLATE : 4)

PLATE -I : MALABAR

PLATE - 2 : MYSORE

Experimental methods

Plants of two age groups (three and six years) from the above four varieties were selected for the study. One hundred sexual progenies of each variety in each age group were labelled separately and randomly divided into five replications (plots) consisting of twenty plants each. Observations on the following characters were recorded as described below.

(1) Number of productive tillers/plant

The total number of panicle bearing tillers were taken as productive tillers and their number per plant was counted and recorded.

(2) Height of tillers/plant

The height from the base to the tip of the pseudo-stem was measured and expressed in centimeters. The average of five tillers per plant was recorded.

(3) Number of leaves/tiller

The total number of leaves present on each tiller was counted and the average number of leaves on five tillers in each plant was recorded.

(4) Number of panicles/plant

The total number of panicles per plant was counted and the values were recorded.

(5) Length of panicle

The length of the panicle was measured from the point of its attachment to the pseudo-stem to the tip. The mean value of five panicles selected at random from each plant was recorded in centimeters.

(6) Number of nodes/panicle

The number of nodes (point of attachment of the raceme) present in each of the five selected panicles was counted and the average value was recorded for each plant.

(7) Internodal length in the panicle

The distance between the two successive nodes in the proximal, mid and distal portions of each panicle was measured and the mean value of five panicles per plant was taken as the length of the internode in the panicle and was expressed in centimeters.

(8) Number of capsules/panicle

The total number of capsules formed in each of the five selected panicles was counted and the average value was recorded for each plant.

(9) Hundred capsule weight/plant

One hundred capsules were counted out from each plant in

each variety at the time of harvest and the weight was recorded in grammes.

(10) Capsule volume

It was recorded by the water displacement method. Water was filled to a known level in a measuring cylinder, hundred capsules of uniform boldness were counted out and immersed completely in the measuring cylinder. The displacement in the level of water from the original to the final level was recorded in cubic centimeters and was taken to be a measure of the capsule volume.

(11) Number of seeds/capsule

Five capsules were selected at random from each plant at the time of harvest and the number of seeds was counted in each capsule and the mean value was recorded as the number of seeds/capsule/plant.

(12) Fresh weight of capsules/plant

The plants were harvested in five rounds at forty day intervals from September to February and the fresh weight of the capsules harvested at each round from each plant was recorded and the average value of the five harvests was taken to be the average fresh weight of the capsules per plant.

(13) Yield or Dry weight of capsules/plant

The capsules harvested at each round from each plant were dried separately in trays placed in smoke houses or curing houses where the room temperature is brought upto about 54-55 degrees celsius. This temperature is maintained for about three hours after which the ventilators of the smoke houses are opened out to allow for quick cooling of the heated capsules. After cooling, the temperature is again raised to about 44°C and maintained at this level for about 30 hours. Thereafter the temperature is raised further to about 54°C for three hours, by which time the whole process of drying is completed. The dried capsules were rubbed on wire mesh to remove the stalk, dried portions of the flower from the capsules and other foreign matter. This process is known as polishing. After polishing the weight of the dried capsules was recorded in grammes.

Statistical analyses

The data collected in respect of the different metric traits were tabulated and analysed statistically.

(1) Estimation of Intra-varietal variability :

The general mean (μ) and the standard deviation (σ) was determined for all the thirteen metric traits in both the age groups. The phenotypic expression of the traits were categorised

under three heads to study their frequency distribution. The categories include negative group (below $\mu-\sigma$), control or median group ($\mu-\sigma$ to $\mu+\sigma$), and positive group (above $\mu+\sigma$). The frequencies of phenotypes under these three categories were calculated and analysed statistically, using the Analysis of variance technique of Completely Randomised Design. The Error variance was taken to be an estimate of the variability within the variety and Bartlett's χ^2 test (1937) was applied to test the homogeneity of variance estimates. The significance of the observed value was tested against the appropriate tabular value.

The coefficient of variation of each character was also calculated to get a unit free measure of the variation within the variety.

(2) Inter varietal variability analysis

The data relating to the different parameters were analysed statistically by applying the technique of analysis of variance for factorial experiments in Completely Randomised Design (Cochran and Cox, 1957) and the significance of main effects and interaction effects was tested by the F test. The outline of the analysis of variance table showing the source

of variation and corresponding degrees of freedom is given below:

Source	degree of freedom
Treatments	7
Between age groups (A)	1
Between varieties (B)	3
A x B	3
Error	32
Total	39

(3) Estimation of genetic parameters

The phenotypic and genotypic variances, coefficients of variation, heritability in the broad sense, expected genetic advance and genetic gain were studied using the following methods.

Variance : The observed variability for each character was partitioned into genetic and environmental components. The components of variance for each character were worked out following Johnson et al.(1955).

Genotypic variance (V_g)

$$V_g = \frac{S^2V - S^2E}{r}$$

Where S^2V = Mean sum of squares due to varieties

S^2E = Mean sum of squares due to error

r = Number of replications

Environmental variance (V_e)

V_e = Mean sum of squares due to error

Phenotypic variance (V_p)

$V_p = V_g + V_e$ Where V_g = Genotypic variance

V_e = Environmental variance

Phenotypic coefficient of variation (Burton, 1952)

$$pcv = \frac{\sqrt{V_p} \times 100}{Mean}$$ Where pcv = Phenotypic coefficient of variation

V_p = Phenotypic variance

Genotypic coefficient of variation (Burton, 1952)

$$gcv = \frac{\sqrt{V_g} \times 100}{Mean}$$ Where gcv = Genotypic coefficient of variation

V_g = Genotypic variance

Heritability in the broad sense (Hanson et al., 1956)

$$h^2 = \frac{V_g \times 100}{V_p}$$ Where h^2 = heritability expressed in percentage

V_g = genotypic variance

V_p = phenotypic variance

The expected Genetic Advance under selection was estimated following (Lush, 1949 and Johnson et al., 1955)

$GA = K h^2 \sqrt{V_p}$ Where GA = Genetic advance

h^2 = heritability in the broad sense

K = selection differential which is 2.06 at 5% selection in large samples (Miller et al. 1958 and Allard, 1960)

V_p = Phenotypic variance

The expected genetic gain under selection was estimated using the formula proposed by (Johnson et al., 1955)

$$GG = \frac{GA \times 100}{\bar{X}}$$

Where GG = Genetic gain

$\bar{X}$ = General mean

GA = Genetic advance

(4) Correlation analysis

The inter-relationship of all the thirteen characters was analysed as follows:

Estimation of covariance - The genotypic, environmental and phenotypic covariances were computed using the method suggested by Snedecor, 1961.

$$Cov\ (g_1, g_2) = \frac{MSPV - MSPE}{r}$$

Where $Cov(g_1, g_2)$ = Genotypic covariance between X_1 and X_2

MSPV = Mean sum of products between varieties

MSPE = Mean sum of products error

r = Number of replications

$$Cov\ (e_1, e_2) = MSPE$$

Where $Cov(e_1, e_2)$ = Environmental covariance

$$Cov(p_1, p_2) = Cov\ (g_1, g_2) + Cov\ (e_1, e_2)$$

Where $Cov(p_1, p_2)$ = Phenotypic covariance

Genotypic correlation coefficient (Al-Jibouri et al., 1958)

$$r_g = \frac{Cov\ (g_1, g_2)}{\sqrt{V_{g1} \times V_{g2}}}$$

Where r_g = Genotypic correlation coefficient

V_{g1} = Genotypic variance of first character

V_{g2} = Genotypic variance of second character

(5) Path coefficient analysis :

Path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959) was utilised to partition the cause and effect relationship among the characters. Eight morphological characters showing high genotypic correlation with yield of capsules were subjected to path coefficient analysis in order to separate the cause and effect relationship among the characters into measures of direct and indirect effects on yield, by assuming a linear model $Y = a_1X_1 + a_2X_2 \ldots\ldots + a_8X_8$, where Y and Xi (i = 1,2.....8) are standardised variates corresponding to yield and its attributes respectively. The following set of simultaneous equations were formed and solved for estimating the various direct and indirect effects.

$$r_{iy} = \sum_{j=1}^{8} P_{jy}\, r_{ij};\ i = 1, \ldots\ldots 8,$$ where, r_{iy} denotes

Coefficient of correlation between independent character x_i and dependent character y, r_{ij} denotes the coefficient of correlation between i^{th} and j^{th} characters, P_{jy} denotes the direct effects of the j^{th} character on y.

The above equation can be written in a matrix form as shown below:

$$
\underset{A}{\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ r_{4y} \\ r_{5y} \\ r_{6y} \\ r_{7y} \\ r_{8y} \end{bmatrix}} = \underset{B}{\begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} & r_{17} & r_{18} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} & r_{26} & r_{27} & r_{28} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} & r_{36} & r_{37} & r_{38} \\ r_{41} & r_{42} & r_{43} & r_{44} & r_{45} & r_{46} & r_{47} & r_{48} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} & r_{56} & r_{57} & r_{58} \\ r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & r_{66} & r_{67} & r_{68} \\ r_{71} & r_{72} & r_{73} & r_{74} & r_{75} & r_{76} & r_{77} & r_{78} \\ r_{81} & r_{82} & r_{83} & r_{84} & r_{85} & r_{86} & r_{87} & r_{88} \end{bmatrix}} \underset{C}{\begin{bmatrix} p_{1y} \\ p_{2y} \\ p_{3y} \\ p_{4y} \\ p_{5y} \\ p_{6y} \\ p_{7y} \\ p_{8y} \end{bmatrix}}
$$

where,

$r_{ij} = r_{ji}$; $r_{ii} = 1$

ie. $A = BC$, hence $C = B^{-1}A$, Where B^{-1} is the inverse of B.

The residual effect which assumes the contribution of the rest of the characters not included in the causal scheme was obtained by the formula $(1 - R^2)^{\frac{1}{2}}$, where $R^2 = \sum_{i=1}^{8} P_{iy}\, r_{ij}$.

RESULTS

RESULTS

The data collected on the various morphological traits in cardamom in the four varieties of two age groups were statistically analysed and the results are presented under the following headings.

A. Intra varietal variability analysis

B. Inter varietal variability analysis

C. Estimation of genetic parameters

D. Correlation and path coefficient analysis

A. Intra varietal variability analysis

Number of productive tillers/plant

The range in mean values, frequency distribution of the different phenotypes, intra varietal variance and coefficient of variation of the four varieties at two different age groups for the number of productive tillers are presented in table: 1. Statistical analysis of the data to test the significance for intra-varietal variability for the four cultivars showed no significance in either of the age groups.

In the third year group the cultivars Mysore and PV-1 showed the same range in the number of productive tillers (1 to 5), which was very low compared to those of Malabar and Vazhukka where tiller number ranged from 2 to 21 and 1 to 15 respectively.

Table : 1 INTRA VARIETAL VARIABILITY FOR NUMBER OF PRODUCTIVE TILLERS/PLANT

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	2 to 21	7 to 50	-ve Group Median Group +ve Group	16% 40% 44%	4% 52% 44%	10.66	68.82	56.37%	43.57%
MYSORE	1 to 5	3 to 35	-ve Group Median Group +ve Group	84% 16% -	28% 32% 40%	1.36	86.36	49.41%	60.97%
VAZHUKKA	1 to 15	5 to 26	-ve Group Median Group +ve Group	48% 48% 4%	44% 48% 8%	7.48	22.96	71.97%	46.97%
PV-1	1 to 5	2 to 17	-ve Group Median Group +ve Group	8% 48% 44%	100% - -	1.54	13.68	48.92%	51.70%

$\chi^2(3)$ 3 YEAR = 1.35 NOT SIGNIFICANT

6 YEAR = 2.90 NOT SIGNIFICANT

The mean number of productive tillers per plant ranged from 7 to 50, 3 to 35, 5 to 26 and 2 to 17 in Malabar, Mysore, Vazhukka and PV-1 respectively in the sixth year group.

The frequency distribution of negative variants ranged from 8% in PV-1 to 84% in Mysore with Vazhukka and Malabar having 48% and 16% respectively in the third year group. The values for the median group was uniform for both Vazhukka and PV-1 (48%) while it was 40% and 16% for Malabar and Mysore respectively. The proportion of positive variants was nil for Mysore and 4% for Vazhukka in the third year group. Malabar and PV-1 showed a uniformly high frequency of positive variants (44%).

The frequency of negative variants in the sixth year group ranged from 4% in Malabar to 100% in PV-1 while it was 28% in Mysore and 44% in Vazhukka. The maximum frequency of median variants was in Malabar (52%) followed by Vazhukka (48%) and Mysore (32%). The variety PV-1 had no positive variants while it was 8% in Vazhukka, 44% in Malabar and 40% in Mysore.

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (71.97%) followed by 56.37%, 49.41% and 48.92% in Malabar, Mysore and PV-1 respectively. In the sixth year group the maximum value for the coefficient of variation was in the cultivar Mysore (60.97%) followed by PV-1, Vazhukka and Malabar with 51.70%, 46.97% and 43.57% respectively.

Height of tillers/plant

The range in mean values, frequency distribution of the different phenotypes, intra-varietal variance and coefficient of variation of the four varieties at two different age groups for the height of tillers/plant are presented in table : 2. Statistical analysis of the data to test the significance for intra-varietal variability for the four cultivars showed no significance in either of the age groups.

The height of tillers ranged from 181.60 to 296.60 cm in Malabar, 224.20 to 363.80 cm in Mysore, 132.80 to 296.20 cm in Vazhukka and 146.40 to 330.00 cm in PV-1 in the third year group and from 208.40 to 407.80, 194.00 to 391.80, 224.80 to 406.20, 162.00 to 342.00 centimeters in Malabar, Mysore, Vazhukka and PV-1 respectively in the sixth year group.

Under the third year group the frequency distribution of negative variants varied from zero percent in Mysore to a maximum of 60% in Vazhukka while it was 36% in Malabar and 44% in PV-1. The median group of phenotypes ranged from 28% in Mysore to 40% in Malabar, Vazhukka and PV-1 showed no variation for phenotypic frequency (32%).

In the sixth year group the frequency of negative variants ranged from 16% in Malabar to 56% in PV-1. Mysore and Vazhukka showed a frequency of 20% each. The maximum frequency for the

Table : 2 INTRA VARIETAL VARIABILITY FOR HEIGHT OF TILLERS/PLANT

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	181.60 to 296.60	208.40 to 407.80	-ve GROUP Median Group +ve Group	36% 40% 24%	16% 56% 28%	1014.36	2455.42	13.49%	15.86%
MYSORE	224.20 to 363.80	194.00 to 391.80	-ve Group Median Group +ve Group	- 28% 72%	20% 48% 32%	1520.38	2797.64	13.62%	17.03%
VAZHUKKA	132.80 to 296.20	224.80 to 406.20	-ve Group Median Group +ve Group	60% 32% 8%	20% 32% 48%	1547.65	3569.24	19.16%	18.53%
PV-1	146.40 to 330.00	162.00 to 342.00	-ve Group Median Group +ve Group	44% 32% 24%	56% 44% -	2707.90	2133.50	22.02%	17.92%

X^2 (3) 3 YEAR = 0.24 NOT SIGNIFICANT

6 YEAR = 0.09 NOT SIGNIFICANT

median class was noted in Malabar (56%) when it was 48%, 44% and 32% respectively in Mysore, PV-1 and Vazhukka. The frequency of positive variants varied from zero in PV-1 to 48% in Vazhukka. Malabar and Mysore showed 28% and 32% of positive variants respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar PV-1 (22.02%) followed by 19.16%, 13.62% and 13.49% in Vazhukka, Mysore and Malabar respectively. In the sixth year group the maximum value for the coefficient of variation was in the cultivar Vazhukka (18.53%) followed by PV-1, Mysore and Malabar with 17.92%, 17.03% and 15.86% respectively.

Number of leaves/tiller

The range in mean values, frequency distribution of the three class categories of phenotypes, intra-varietal variance and coefficient of variation of the four varieties at two different age groups for the number of leaves/tiller are presented in table :3. Statistical analysis of the data to test the significance for intra-varietal variability for the four cultivars showed no significance in either of the age groups.

The number of leaves/tiller ranged from 10 to 18 in Mysore and 8 to 18 in Vazhukka. Both Malabar and PV-1 recorded a range of 11 to 21 leaves/tiller in the third year group. The

Table : 3 INTRA VARIETAL VARIABILITY FOR NUMBER OF LEAVES/TILLER

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	11 to 21	11 to 21	-ve Group Median Group +ve Group	20% 56% 24%	16% 44% 40%	6.26	8.84	17.42%	18.17%
MYSORE	10 to 18	8 to 18	-ve Group Median Group +ve Group	20% 44% 36%	32% 40% 28%	6.28	9.94	16.97%	21.07%
VAZHUKKA	8 to 16	12 to 23	-ve Group Median Group +ve Group	64% 28% 8%	24% 36% 40%	4.95	7.70	18.54%	16.75%
PV-1	11 to 21	11 to 18	-ve Group Median Group +ve Group	28% 28% 44%	44% 52% 4%	7.81	5.10	35.78%	16.22%

$\chi^2(3)$ 3 YEAR = 0.05 NOT SIGNIFICANT

6 YEAR = 0.12 NOT SIGNIFICANT

number of leaves per tiller in Malabar, Mysore, Vazhukka and PV-1 ranged from 11 to 21, 8 to 18, 12 to 23 and 11 to 18 respectively in the sixth year group.

In the third year group the frequency of negative variants ranged from 20% in Malabar and Mysore to 64% in Vazhukka while it was 28% in PV-1. The maximum frequency of median class phenotypes was recorded in Malabar (56%) followed by Mysore (44%), Vazhukka and PV-1 gave a uniform value of 28%. The positive variants ranged from 8% in Vazhukka to 44% in PV-1 when it was 24% and 36% in Malabar and Mysore respectively.

In the sixth year group an entirely different trend in the distribution of phenotypic variants was noticed. The maximum negative variants were seen in PV-1 (44%) followed by Mysore (32%) Vazhukka (24%) and Malabar (16%). PV-1 showed the maximum frequency in the median class of 52%, while it was lowest in Vazhukka (36%). Malabar and Mysore recorded 44% and 40% of median phenotypes respectively. The frequency of positive variants was uniform in both Malabar and Vazhukka (40%) while it was only 4% in PV-1 and 28% in Mysore.

The highest value for the coefficient of variation in the third year group was in the cultivar PV-1 (35.78%) followed by 18.54%, 17.42% and 16.97% in Vazhukka, Malabar and Mysore respectively. In the sixth year group the maximum value for the

coefficient of variation was in the cultivar Mysore (21.07%) followed by Malabar, Vazhukka and PV-1 with 18.17%, 16.75% and 16.22% respectively.

Number of panicles/plant

The range in mean values, frequency distribution of the three class categories, intra-varietal variance and coefficient of variation for number of panicles/plant in the four varieties under the two age groups are presented in table:4. Statistical analysis of the data showed no significant variation within the variety in both the age groups.

In the third year group the number of panicles/plant ranged from 3 to 48 and 5 to 27 in Malabar and Mysore respectively. While the range was almost similar (1 to 22) in Vazhukka and PV-1. Malabar showed the maximum range of variability (22 to 145) for number of panicles in the sixth year group, followed by Vazhukka (15 to 112), Mysore (13 to 75) and PV-1 (3 to 35).

The frequency of negative variants ranged from 4% in Mysore to 60% in Vazhukka in the third year group while it was 16% in Malabar and 32% in PV-1 for the number of panicles per plant. The frequency of median class variants was maximum in Mysore (64%) which was closely followed by PV-1 (56%). Malabar

Table : 4 INTRA VARIETAL VARIABILITY FOR NUMBER OF PANICLES/PLANT

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	3.00 to 48.00	22.00 to 145.00	-ve Group Median Group +ve Group	16% 44% 40%	20% 24% 56%	146.16	1018.80	75.56%	54.80%
MYSORE	5.00 to 27.00	13.00 to 75.00	-ve Group Median Group +ve Group	4% 64% 32%	52% 24% 24%	41.32	337.34	49.29%	56.75%
VAZHUKKA	1.00 to 22.00	15.00 to 112.00	-ve Group Median Group +ve Group	60% 36% 4%	16% 32% 52%	16.28	667.30	70.53%	51.21%
PV-1	1.00 to 21.00	3.00 to 35.00	-ve Group Median Group +ve Group	32% 56% 12%	88% 12% -	34.16	75.38	65.76%	49.66%

$\chi^2(3)$ 3 YEAR = 1.28 NOT SIGNIFICANT

6 YEAR = 1.45 NOT SIGNIFICANT

and Vazhukka recorded 44% and 36% respactively. The frequency of positive variants was low in Vazhukka (4%), while it was highest in Malabar (40%). PV-1 and Mysore recorded 12% and 32% of positive variants.

In the sixth year group PV-1 recorded the maximum number of negative variants (88%) followed by Mysore (52%), Malabar (20%) and Vazhukka (16%). Malabar and Mysore were uniform with 24% of median class variants. Vazhukka recorded the maximum frequency of 32% and PV-1 the minimum frequency of 12% in the median group. There were no positive variants in PV-1 in the sixth year group while Malabar, Vazhukka and Mysore recorded 56%, 52% and 24% respectively.

Malabar recorded the highest value for the coefficient of variation in the third year group (75.56%), followed by Vazhukka (70.53%), PV-1 (65.76%) and Mysore (49.29%). In the sixth year group the maximum value for the coefficient of variation was in the cultivar Mysore (56.75%) followed by Malabar, Vazhukka and PV-1 with 54.80%, 51.21% and 49.66% respectively.

Length of panicle

The range in mean values, frequency distribution of the three class categories, intra varietal variance and coefficient of variation for the length of panicle in the four varieties of

Table : 5 INTRA VARIETAL VARIABILITY FOR LENGTH OF PANICLE

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	14.34 to 44.00	21.40 to 68.20	-ve Group Median Group +ve Group	4% 68% 28%	28% 40% 32%	55.20	226.91	28.66%	34.14%
MYSORE	19.00 to 39.00	29.80 to 61.60	-ve Group Median Group +ve Group	- 44% 56%	20% 56% 24%	38.23	65.16	21.82%	18.45%
VAZHUKKA	10.34 to 35.00	27.80 to 77.80	-ve Group Median Group +ve Group	52% 36% 12%	16% 28% 56%	46.33	199.69	34.95%	25.28%
PV-1	10.00 to 43.34	12.34 to 44.40	-ve Group Median Group +ve Group	32% 60% 8%	64% 36% -	53.48	106.17	34.09%	33.59%

$\chi^2(3)$ 3 YEAR = 0.04 NOT SIGNIFICANT

6 YEAR = 0.45 NOT SIGNIFICANT

cardamom under the two age groups are presented in table :5. Statistical analysis of the data showed no significance for variation within the variety at the two stages of growth.

The length of panicles ranged from 14.34 cm to 44.00, 19.00 to 39.00, 10.34 to 35.00 and 10.00 to 43.34 centimeters in Malabar, Mysore, Vazhukka and PV-1 respectively, in the third year group. The maximum range of variability in the sixth year group was seen in Vazhukka (27.80 to 77.80) followed by Malabar (21.40 to 68.20), PV-1 (12.34 to 44.40) and Mysore (29.80 to 61.60).

The frequency of the negative variants in the third year group varied from zero in Mysore to 52% in Vazhukka. The frequency of negative variants was 4% in Malabar when it was 32% in PV-1. The frequency of median class variants in Malabar and PV-1 were 68 and 60% respectively when it was 44% in Mysore and 36% in Vazhukka. The positive variants ranged from 8% in PV-1 to 56% in Mysore. Malabar and Vazhukka recorded 28 and 12% respectively.

In the sixth year group the frequency of negative variants ranged from 16% in Vazhukka to 64% in PV-1. In Malabar and Mysore it was 28% and 20% respectively. The maximum frequency for the median group variants was recorded in Mysore (56%) followed by Malabar (40%), PV-1 (36%) and Vazhukka (28%).

The frequency of positive variants was nil in PV-1 when it was 56% in Vazhukka, Malabar and Mysore recorded 32% and 24% of positive variants respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (34.95%), followed by PV-1 (34.09%), Malabar (28.66%) and Mysore (21.82%). In the sixth year group the maximum value for the coefficient of variation was in the cultivar Malabar (34.14%) followed by PV-1, Vazhukka and Mysore with 33.59%, 25.28% and 18.45%.

Number of nodes/panicle

Table : 6 represents the range in mean values, distribution of different phenotypes, intra-varietal variance and coefficient of variation of the number of nodes per panicle in the four cultivars under the two age groups of cardamom. Statistical analysis of the data showed no significance for intra-varietal variability for the four varieties under the two age groups. The mean values for the number of nodes per panicle ranged from 8 to 22, 13 to 20, 5 to 24 and 5 to 15 in the cultivars Malabar, Mysore, Vazhukka and PV-1 respectively, in the third year group. In the sixth year group the means ranged from 10 to 25 and 8 to 22 in Malabar and PV-1 respectively. In Vazhukka and Mysore it ranged from 13 to 25 and 13 to 24 respectively.

Table : 6 INTRA VARIETAL VARIABILITY FOR NUMBER OF NODES/PANICLE

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	8 to 22	10 to 25	-ve Group Median Group +ve Group	8% 40% 52%	20% 56% 24%	8.32	17.48	18.87%	23.59%
MYSORE	13 to 20	13 to 24	-ve Group Median Group +ve Group	- 76% 24%	16% 64% 20%	2.34	9.10	10.11%	17.13%
VAZHUKKA	5 to 24	13 to 25	-ve Group Median Group +ve Group	36% 44% 20%	8% 52% 40%	12.98	11.62	28.86%	18.34%
PV-1	5 to 15	8 to 22	-ve Group Median Group +ve Group	60% 40% -	36% 52% 12%	8.61	15.72	26.96%	25.15%

$\chi^2(3)$ 3 YEAR = 0.65 NOT SIGNIFICANT

6 YEAR = 0.12 NOT SIGNIFICANT

The frequency of negative variants in the third year group ranged from zero in Mysore to 60% in PV-1, Malabar and Vazhukka showed 8% and 36% respectively. Mysore gave the maximum frequency of median types (76%) followed by Vazhukka (44%). It was uniform for both Malabar and PV-1 (40%). No positive variants was noted in the cultivar PV-1 when Malabar gave a maximum frequency of 52%. Mysore and Vazhukka recorded 24 and 20 per cent of positive variants respectively.

In the sixth year group an entirely different trend in the frequency distribution of the three phenotypic variants was noticed in the different cultivars. The frequency of negative variants ranged from 8% in Vazhukka to 36% in PV-1, Mysore and Malabar gave 16% and 20% respectively. Mysore gave the maximum frequency of 64% in the median class followed by Malabar with a frequency of 56%. Vazhukka and PV-1 recorded a uniform value of 52% of median class variants. The frequency of positive variants ranged from 12% in PV-1 to 40% in Vazhukka. Under Malabar and Mysore the frequencies were 24% and 20% respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (28.86%), followed by PV-1 (26.96%), Malabar (18.87%) and Mysore (10.11%). In the sixth year group the maximum value for the coefficient of vari-

ation was in the cultivar PV-1 (25.15%), followed by Malabar, Vazhukka and Mysore with 23.59%, 18.34% and 17.13% respectively.

Internodal length in the panicle

The range in mean values, frequency distribution of the three class categories of the different phenotypes, intra-varietal variance and coefficient of variation for the internodal length in the panicle of the four varieties of cardamom under the two age groups are presented in table :7. Statistical analysis of the data showed no significant difference for intra varietal variability in the two age groups, for all the four cultivars studied.

The internodal length in the panicle ranged from 1.12 to 1.92, 1.20 to 2.14, 1.09 to 1.90 and 1.20 to 2.14 centimeters in Malabar, Mysore, Vazhukka and PV-1 respectively in the third year group. In the sixth year group it ranged from 1.25 to 2.48 cm in Malabar, 1.50 to 2.96 cm in Mysore, 1.50 to 2.60 cm in Vazhukka and 1.10 to 1.80 cm in PV-1.

In the third year group the frequency of negative variants ranged from 20% in Mysore to 80% in Vazhukka. Malabar and PV-1 recorded 52% and 24% of negative variants respectively. In the median group Malabar and Mysore recorded a frequency of 24% while it was 28% and 16% in PV-1 and Vazhukka respectively.

Table : 7 INTRA VARIETAL VARIABILITY FOR INTERNODAL LENGTH IN THE PANICLE

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	1.12 to 1.92	1.25 to 2.48	-ve Group Median Group +ve Group	52% 24% 24%	40% 32% 28%	0.22	0.12	34.03%	19.36%
MYSORE	1.20 to 2.14	1.50 to 2.96	-ve Group Median Group +ve Group	20% 24% 56%	8% 28% 64%	0.04	0.11	13.06%	15.89%
VAZHUKKA	1.09 to 1.90	1.50 to 2.60	-ve Group Median Group +ve Group	80% 16% 4%	16% 20% 64%	0.03	0.08	13.30%	13.65%
PV-1	1.20 to 2.10	1.10 to 1.80	-ve Group Median Group +ve Group	24% 28% 48%	92% 8% -	0.04	0.03	13.30%	12.67%

$\chi^2(3)$ 3 YEAR = 1.44 NOT SIGNIFICANT

6 YEAR = 0.54 NOT SIGNIFICANT

Mysore had the maximum number of positive variants (56%) followed by PV-1 (48%), Malabar (24%) and Vazhukka (4%).

In the sixth year group PV-1 showed the maximum frequency of negative variants (92%), while it was only 8% in Mysore and 16% in Vazhukka, Malabar had a frequency of 40%. PV-1 gave the minimum frequency of medium types (8%) while it was maximum in Malabar (32%). Mysore and Vazhukka had 28% and 20% of median variants respectively. There were no positive variants in the sixth year group for PV-1 while both Mysore and Vazhukka showed a uniformly high frequency of 64%, Malabar recorded a frequency of 28% in the positive group. The highest value for the coefficient of variation in the third year group was in the cultivar Malabar (34.03%), followed by Vazhukka and PV-1 with 13.30% and Mysore with 13.06%. In the sixth year group the maximum value for the coefficient of variation was in the cultivar Malabar (19.36%) followed by Mysore, Vazhukka and PV-1 with 15.89%, 13.65% and 12.67% respectively.

Number of capsules/panicle

The range in mean values frequency distribution of the phenotypes intra-varietal variances and coefficient of variation of the four varieties under the two age groups are presented in table : 8. Statistical analysis of the data showed

Table : 8 INTRA VARIETAL VARIABILITY FOR NUMBER OF CAPSULES/PANICLE

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	6 to 48	24 to 72	-ve Group Median Group +ve Group	16% 48% 36%	12% 28% 60%	124.88	206.50	43.36%	28.19%
MYSORE	8 to 48	16 to 66	-ve Group Median Group +ve Group	24% 48% 28%	56% 36% 8%	134.00	167.24	47.13%	39.57%
VAZHUKKA	4 to 36	18 to 85	-ve Group Median Group +ve Group	68% 16% 16%	20% 36% 44%	58.84	281.48	51.27%	35.15%
PV-1	4 to 42	12 to 56	-ve Group Median Group +ve Group	16% 64% 20%	76% 20% 4%	83.74	84.56	40.49%	32.93%

$\chi^2(3)$ 3 YEAR = 0.20 NOT SIGNIFICANT

6 YEAR = 0.34 NOT SIGNIFICANT

no significant variation within the variety for the two age groups.

In the third year group the range in the number of capsules per panicle in all the varieties were almost similar, 6 to 48 in Malabar, 8 to 48 in Mysore, 4 to 36 in Vazhukka and 4 to 42 in PV-1. But the trend was different in the sixth year group with the values ranging from 24 to 72 in Malabar, 16 to 66 in Mysore, 18 to 85 in Vazhukka and 12 to 56 in PV-1.

The frequency of negative variants in the third year group was the same in both Malabar and PV-1 (16%) while it was highest in Vazhukka (68%) and only 24% in Mysore. The maximum frequency of median types was in PV-1 (64%) followed by Mysore and Malabar with (48%). It was only 16% in Vazhukka. In Malabar 36% of the phenotypes were in the positive group, while it was 16,28 and 20 per cent respectively in Vazhukka, Mysore and PV-1.

In the sixth year group the highest frequency for negative variants was in the cultivar PV-1 (76%) followed by Mysore (56%), Vazhukka (20%) and Malabar (12%). In the median group Mysore and Vazhukka gave the same frequency of 36%, while it was 28% and 20% in Malabar and PV-1 respectively. The positive variants ranged from 4% in PV-1 to 60% in Malabar with Vazhukka and Mysore having 44% and 8% respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (51.27%), followed by Mysore (47.13%), Malabar (43.38%) and PV-1 (40.49%). In the sixth year group the maximum value was in the cultivar Mysore (39.57%), followed by Vazhukka, PV-1 and Malabar with 35.15%, 32.93% and 28.19% respectively.

Hundred capsule weight/plant

The data presented in table :9, represents the range in mean values, frequency distribution of the different phenotypes, intra-varietal variance and coefficient of variation for the hundred capsule weight of the four varieties of cardamom under the two age groups. Statistical analysis of the data showed that the intravarietal variability for all the four cultivars was not significant in both the age groups.

In the third year group the range was maximum in Malabar (50 to 130) followed by Vazhukka (20 to 82), PV-1 (56 to 105) and Mysore (44 to 72). In the sixth year group the range in mean values were 49 to 92, 74 to 134, 57 to 127 and 54 to 88 in Malabar, Mysore, Vazhukka and PV-1 respectively.

In the third year group the frequency of negative variants ranged from 8% in Malabar and PV-1 to 80% in Vazhukka. Mysore showed a frequency of 60% of negative variants. The frequency of median group were 32% and 36% for Malabar and Mysore while

Table : 9 INTRA VARIETAL VARIABILITY FOR HUNDRED CAPSULE WEIGHT/PLANT

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	50 to 130	49 to 92	-ve Group Median Group +ve Group	8% 32% 60%	60% 32% 8%	3.34	124.66	22.28%	16.71%
MYSORE	44 to 72	74 to134	-ve Group Median Group +ve Group	60% 36% 4%	- 28% 72%	86.98	201.98	16.18%	15.32%
VAZHUKKA	20 to 82	57 to127	-ve Group Median Group +ve Group	80% 8% 12%	40% 16% 44%	184.38	266.92	31.22%	20.48%
PV-1	56 to 105	54 to 88	-ve Group Median Group +ve Group	8% 8% 84%	44% 52% 4%	189.80	94.74	19.67%	14.14%

$\chi^2(3)$ 3 YEAR = 0.4645 NOT SIGNIFICANT

6 YEAR = 0.3136 NOT SIGNIFICANT

it was 8% for both Vazhukka and PV-1. In the positive group PV-1 gave a very high frequency of 84% followed by Malabar (60%), Mysore (4%) and Vazhukka (12%) respectively.

In the sixth year group the frequency of negative variants ranged from zero in Mysore to 60% in Malabar, Vazhukka and PV-1 gave a frequency of 40% and 44% respectively. The maximum frequency in the median group was in PV-1 (52%) followed by Malabar (32%). Mysore and Vazhukka gave frequencies of 28 and 16% respectively. The maximum value in the positive group was registered in Mysore (72%) followed by Vazhukka (44%), Malabar (8%) and PV-1 (4%).

The maximum value for the coefficient of variation in the third year group was in the cultivar Vazhukka (31.22%), followed by 22.28% in Malabar, 19.67% in PV-1 and 16.18% in Mysore. In the sixth year group the highest value for the coefficient of variation was in Vazhukka (20.48%), followed by Malabar, Mysore and PV-1 with 16.71%, 15.32% and 14.14% respectively.

Capsule Volume

The range in mean values, frequency distribution of the phenotypes, intra-varietal variance and coefficient of variation for the four varieties under the two age groups in relation to capsule volume are presented in table :10. Statistical analysis

Table : 10 INTRA VARIETAL VARIABILITY FOR CAPSULE VOLUME

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	40 to 106	53 to 100	-ve Group Median Group +ve Group	20% 52% 28%	28% 48% 24%	217.02	174.18	17.29%	16.51%
MYSORE	41 to 92	68 to 123	-ve Group Median Group +ve Group	60% 20% 20%	8% 48% 44%	193.82	148.82	25.52%	13.77%
VAZHUKKA	32 to 88	49 to 105	-ve Group Median Group +ve Group	72% 8% 20%	56% 24% 20%	143.56	420.65	19.91%	27.89%
PV-1	43 to 99	62 to 112	-ve Group Median Group +ve Group	8% 8% 84%	20% 56% 24%	169.66	143.66	18.35%	14.71%

$\chi^2(3)$ 3 YEAR = 0.04 NOT SIGNIFICANT

6 YEAR = 0.43 NOT SIGNIFICANT

of the data showed no significant variation for intra-varietal variability in both the age groups.

The capsule volume in the third year group ranged from 40 to 106, 41 to 92, 32 to 88 and 43 to 99 cubic centimeters in Malabar, Mysore, Vazhukka and PV-1 respectively. In the sixth year group the range in mean values were from 53 to 100, 68 to 123, 49 to 105 and 62 to 112 cubic centimeters, in Malabar, Mysore, Vazhukka and PV-1 respectively.

The frequency of negative variants in the third year group ranged from 8% in PV-1 to 72% in Vazhukka. The frequency of negative variants in Mysore and Malabar were 60% and 20% respectively. In the median group PV-1 and Vazhukka gave a uniform value of 8%, while Mysore recorded a frequency of 20% and Malabar 52%. The maximum frequency of positive variants was registered by PV-1 (84%) while both Mysore and Vazhukka showed a uniform frequency of 20%. Malabar had a frequency of 28% in the positive group.

The maximum frequency of negative variants in the sixth year group was in Vazhukka (56%). Mysore, PV-1 and Malabar had values of 8, 20 and 28 per cent respectively. The maximum value in the median group was for the cultivar PV-1 (56%) while Malabar and Mysore were uniform with 48%. Vazhukka gave a frequency of 24% in the median group. In the positive group Malabar

and PV-1 gave uniform frequencies of 24% while Mysore and Vazhukka recorded 44% and 20% respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar Mysore (25.52%), followed by Vazhukka, PV-1 and Malabar with 19.91%, 18.35% and 17.29% respectively. In the sixth year group the maximum value was in the cultivar Vazhukka (27.89%) followed by Malabar (16.51%), PV-1 (14.71%) and Mysore (13.77%).

Number of seeds/capsule

The range in mean values, frequency distribution of the three class categories, intra-varietal variance and coefficient of variation under the two age groups in relation to number of seeds/capsule of the four varieties are presented in table: 11. Statistical analysis of the data showed no significant variation for intra-varietal variability for both the age groups.

The number of seeds per capsule in the third year ranged from 8 to 17, 7 to 13, 6 to 13 and 7 to 17 in Malabar, Mysore, Vazhukka and PV-1 respectively. In the sixth year group it ranged from 11 to 18, 13 to 18, 11 to 19 and 7 to 16 in Malabar, Mysore, Vazhukka and PV-1 respectively.

The frequency of negative variants in the third year group ranged from 16% in Malabar to 40% in Vazhukka. Mysore and PV-1 gave values of 36% and 20% respectively. Vazhukka recorded the

Table : 11 INTRA VARIETAL VARIABILITY FOR NUMBER OF SEEDS/CAPSULE

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	8 to 17	11 to 18	-ve Group Median Group +ve Group	16% 48% 36%	44% 20% 36%	7.94	4.42	22.79%	14.68%
MYSORE	7 to 18	13 to 18	-ve Group Median Group +ve Group	36% 40% 24%	12% 32% 56%	9.58	2.58	27.34%	10.32%
VAZHUKKA	6 to 18	11 to 19	-ve Group Median Group +ve Group	40% 56% 4%	20% 28% 52%	6.20	5.40	24.41%	15.12%
PV-1	7 to 17	7 to 16	-ve Group Median Group +ve Group	20% 44% 36%	52% 40% 8%	8.14	4.72	23.61%	16.97%

$\chi^2(3)$ 3 YEAR = 0.04 NOT SIGNIFICANT

6 YEAR = 0.14 NOT SIGNIFICANT

maximum number of median types (56%) followed by Malabar (48%), PV-1 (44%) and Mysore (40%). In the positive group Malabar and PV-1 were uniform (36%) while Mysore and Vazhukka recorded values of 24% and 4% respectively.

In the sixth year group the frequency of negative variants ranged from 12% in Mysore to 52% in PV-1. Malabar and Vazhukka gave frequencies of 44% and 20% respectively. The percentage values of the median class in the four varieties were 20% in Malabar, 32% in Mysore, 28% in Vazhukka and 40% in PV-1. The positive variants were maximum in Mysore and Vazhukka (56 and 52% respectively). PV-1 recorded the lowest value of 8%, while Malabar gave a frequency of 36% in the positive group.

The highest value for the coefficient of variation in the third year group was in the cultivar Mysore (27.34%) followed by Vazhukka, PV-1 and Malabar with 24.41, 23.61 and 22.79% respectively. In the sixth year group the highest value for the coefficient of variation was in the cultivar PV-1 (16.97%), followed by Vazhukka (15.12%) Malabar (14.68%) and Mysore (10.32%).

Fresh weight of capsules/plant

The range in mean values, frequency distribution of the different phenotypes, intra varietal variance and coefficient of variation under the two age groups for the four varieties of

cardamom with respect to fresh weight of capsules is presented in table: 12. Statistical analysis of the data showed no significant variation in intra-varietal variability under the two age groups.

The fresh weight of capsules/plant (wet yield) ranged from 27 to 1973, 47 to 743, 3 to 408 and 20 to 416 grammes in Malabar, Mysore, Vazhukka and PV-1 respectively in the third year group and from 232 to 3370, 115 to 2053, 170 to 3340 and 61 to 1050 grammes in the sixth year group.

In the third year group the frequency of negative variants ranged from 8% in Malabar to 68% in Vazhukka while it was 20% in Mysore and 24% in PV-1. The maximum frequency for the median group was in PV-1 (72%) followed by Mysore (60%) Malabar (52%) and Vazhukka (28%). Vazhukka and PV-1 had a very low frequency of positive variants (4%), while it was 40% and 20% in Malabar and Mysore respectively.

In the sixth year group the frequencies of negative variants ranged from 20% in Malabar to 68% in PV-1. In Mysore and Vazhukka the frequency of negative variants were 56% and 28% respectively. In the median group the cultivar Malabar, Vazhukka and PV-1 were uniform in percentage frequency (32%) while Mysore gave only 28%. The frequency of positive variants in PV-1 was zero while it was 48% in Malabar, 40% in Vazhukka and 16% in Mysore.

Table : 12 INTRA VARIETAL VARIABILITY FOR FRESH WEIGHT OF CAPSULES/PLANT

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	27 to 1973	232 to 3370	-ve Group Median Group +ve Group	8% 52% 40%	20% 32% 48%	239201.60	912978.00	115.21%	70.41%
MYSORE	47 to 743	115 to 2053	-ve Group Median Group +ve Group	20% 60% 20%	56% 28% 16%	49702.54	275754.50	91.35%	79.33%
VAZHUKKA	3 to 408	170 to 408	-ve Group Median Group +ve Group	68% 28% 4%	28% 32% 40%	8839.98	692317.60	139.78%	71.09%
PV-1	20 to 416	61 to 1050	-ve Group Median Group +ve Group	24% 72% 4%	68% 32% -	17704.70	55500.85	82.33%	52.67%

$\chi^2(3)$ 3 YEAR = 2.97 NOT SIGNIFICANT

6 YEAR = 1.70 NOT SIGNIFICANT

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (139.78%), followed by Malabar (115.21%), Mysore (91.35%) and PV-1 (82.33%). In the sixth year Mysore had the highest value (79.33%) followed by Vazhukka, Malabar and PV-1 with 71.09%, 70.41% and 52.67% respectively.

Dry weight of capsules/plant (Yield)

The results presented in table : 13 shows the range in mean values, frequency distribution of the three class categories of the phenotypes, intra-varietal variance and coefficients of variation under the two age groups of the four varieties for dry weight of capsules per plant (yield). Statistical analysis of the data showed no significance for intra-varietal variance for the four varieties under the two age groups.

In the third year group the dry weight ranged from 6 to 415, 10 to 129, 1 to 82 and 5 to 83 grammes in Malabar, Mysore, Vazhukka and PV-1 respectively. In the sixth year group the dry weight of capsules ranged from 42 to 783, 26 to 421, 46 to 757 and 22 to 212 in Malabar, Mysore, Vazhukka and PV-1 respectively.

The frequency of negative variants in the third year group ranged from 8% in Malabar to 68% in Vazhukka. PV-1 and Mysore recorded 24% and 12% of negative variants respectively.

Table : 13 INTRA VARIETAL VARIABILITY FOR DRY WEIGHT OF CAPSULES/PLANT (YIELD)

VARIETIES	RANGE IN MEAN VALUES		FREQUENCY OF DIFFERENT PHENOTYPES			VARIANCE		COEFFICIENT OF VARIATION	
	3 YEAR	6 YEAR	CLASSES	3 YEAR	6 YEAR	3 YEAR	6 YEAR	3 YEAR	6 YEAR
MALABAR	6 to 415	42 to 783	-ve Group Median Group +ve Group	8% 48% 44%	24% 28% 48%	10992.62	41389.18	116.23%	69.58%
MYSORE	10 to 129	26 to 421	-ve Group Median Group +ve Group	12% 68% 20%	48% 32% 20%	1852.10	13486.10	86.90%	69.85%
VAZHUKKA	1 to 82	46 to 757	-ve Group Median Group +ve Group	68% 28% 4%	28% 32% 40%	398.96	30749.62	138.70%	67.38%
PV-1	5 to 83	22 to 212	-ve Group Median Group +ve Group	24% 72% 4%	68% 32% -	705.74	2374.66	79.25%	49.08%

$\chi^2(3)$ 3 YEAR = 3.18 NOT SIGNIFICANT

6 YEAR = 1.71 NOT SIGNIFICANT

In the median group PV-1 gave the highest frequency (72%) followed by Mysore (68%), Malabar (48%) and Vazhukka (28%). Both Vazhukka and PV-1 gave only very low frequency (4%) of positive variants. While Malabar showed a maximum frequency of 44%, Mysore recorded only (20%).

In the sixth year group the frequencies of negative variants ranged from 24% in Malabar to 68% in PV-1. Mysore and Vazhukka gave 48% and 28% respectively. The frequency of median types was uniform for Mysore, Vazhukka and PV-1 (32%) while Malabar gave 28% of median type variants. There were no positive variants in the cultivar PV-1. When Malabar gave the highest frequency of positive variants (48%) Mysore and Vazhukka gave 20 and 40 per cent respectively.

The highest value for the coefficient of variation in the third year group was in the cultivar Vazhukka (138.70%), followed by Malabar (116.23%), Mysore (86.90%) and PV-1 (79.25%). In the sixth year group the maximum value for the coefficient of variation was in Mysore and Malabar with 69.83% and 69.58% respectively followed by 67.38% in Vazhukka and 49.08% in PV-1.

B. Inter varietal variability analysis

The variability for thirteen characters in the four varieties, viz. Malabar, Mysore, Vazhukka and PV-1 was studied and the results are presented below.

Number of productive tillers/plant

The mean number of productive tillers in the two age

groups of the four varieties of cardamom is presented in table : 14. (FIG:1) Statistical analysis of the data showed significant variation among the varieties, between the age groups and in their interactions.

In the third year group the number of productive tillers/plant ranged from the minimum of 2.34 in Mysore to the maximum of 7.56 in PV-1. The variety PV-1 which was on par with Malabar showed significant superiority over Vazhukka and Mysore. The varieties Vazhukka and Mysore were statisticaly on par.

In the sixth year group the number of productive tillers/plant ranged from the minimum of 2.40 in PV-1 to the maximum of 19.04 in Malabar. Malabar was significantly superior to Mysore, Vazhukka and PV-1 respectively.

All the varieties, except PV-1, showed a significant increase in the number of productive tillers with increase in age. The difference in the number of productive tillers between the sixth and third year stages was 12.86 in Mysore, 11.80 in Malabar, 6.41 in Vazhukka and -5.16 in PV-1.

Height of tillers/plant

The mean height of tillers in the two age groups of the four varieties is presented in table : 15. (FIG:2) Significant variation was observed among the varieties, between the age groups and in their interactions.

Table : 14 INTER VARIETAL VARIABILITY FOR NUMBER OF PRODUCTIVE TILLERS/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	7.24	2.34	3.79	7.56	5.23
6 Year	19.04	15.20	10.20	2.40	11.71
Mean	13.14	8.77	6.96	4.98	

CD (0.05)	For varietal means	= 1.52	Significant
CD (0.05)	For Age group means	= 2.17	Significant
CD (0.05)	For Variety x Age group interaction	= 3.07	Significant

Table : 15 INTER VARIETAL VARIABILITY FOR HEIGHT OF TILLERS/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	236.04	286.10	205.29	236.31	240.93
6 year	312.40	310.52	322.27	257.62	300.70
Mean	274.22	298.31	263.78	246.97	

CD (0.05)	For varietal means	= 17.01	Significant
CD (0.05)	For Age group means	= 24.06	Significant
CD (0.05)	For Variety x Age group interaction	= 34.02	Significant

In the third year group the height of tillers ranged from the minimum of 205.29 cm, recorded by Vazhukka to a maximum of 286.10 cm, recorded by Mysore. PV-1, Malabar and Vazhukka were statistically on par, while Mysore was significantly superior to all of them.

In the sixth year group the maximum height of tillers was recorded by Vazhukka (322.27 cm) followed by Malabar, Mysore and PV-1 with 312.40, 322.27 and 257.62 centimeters respectively. Malabar, Mysore and Vazhukka were statistically on par but significantly superior to PV-1.

All the varieties showed significant increase in the height of tillers with increase in age. The difference between the two groups was 116.98 cm in Vazhukka, 76.36 cm in Malabar, 24.30 cm in Mysore and 23.31 cm in PV-1.

Number of leaves/tiller

The data regarding mean number of leaves per tiller in the two age groups of the four varieties of cardamom are presented in table: 16. (Fig:3) Statistical analysis of the data showed significant differences between the age groups and in the variety x age group interaction. But there was no significant difference among the varieties.

In the third year group the number of leaves/tiller ranged from the minimum of 12.00 in Vazhukka to the maximum of 14.96 in

Table : 16 INTER VARIETAL VARIABILITY FOR NUMBER OF LEAVES/TILLER

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	14.36	14.96	12.00	14.64	13.99
6 year	16.36	14.96	16.56	13.92	15.45
Mean	15.36	14.96	14.28	14.28	

CD (0.05)	For varietal means	= 0.93	Not Significant
CD (0.05)	For Age group means	= 1.31	Significant
CD (0.05)	For Variety x Age group interaction	= 1.86	Significant

Table : 17 INTER VARIETAL VARIABILITY FOR NUMBER OF PANICLES/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	15.99	13.04	5.89	8.87	10.95
6 year	58.24	32.36	50.44	17.48	39.63
Mean	37.11	22.70	28.16	13.18	

CD (0.05)	For Varietal means	= 4.99	Significant
CD (0.05)	For Age group means	= 7.06	Significant
CD (0.05)	For Variety x Age group interaction	= 9.98	Significant

Mysore. The cultivars Mysore, PV-1 and Malabar were statistically on par but significantly superior to Vazhukka.

In the sixth year group the number of leaves per tiller ranged from a minimum of 13.92 in PV-1 to a maximum of 16.56 in Vazhukka. The cultivars Vazhukka and Malabar were significantly superior to PV-1, and on par with Mysore. There was no significant difference between Mysore and PV-1.

The varieties Malabar and Vazhukka showed an increase in the number of leaves per tiller with increase in age while Mysore gave the same value in both the age groups. PV-1 showed a decrease in the number of leaves per tiller with increase in age. The difference in the number of leaves produced per tiller between the sixth and the third year group was highest in Vazhukka (4.56) followed by Malabar (2.00) and PV-1 (-0.72).

Number of panicles/plant

The mean number of panicles per plant in the two age groups of the four varieties of cardamom is presented in table:17. (Fig. 4) Statistical analysis of the data showed significant variation among the varieties, between the age groups and in their interactions.

In the third year group the mean number of panicles per plant ranged from 5.89 in Vazhukka to 15.99 in Malabar. Mysore and PV-1 recorded values of 13.04 and 8.87 respectively. Malabar

is significantly superior to Vazhukka but on par with Mysore and PV-1. The cultivars Mysore, Vazhukka and PV-1 are also statistically on par.

In the sixth year group the mean number of panicles per plant ranged from 17.48 in PV-1 to 58.24 in Malabar. Mysore and Vazhukka gave values of 32.36 and 50.44 respectively. The cultivar Malabar is significantly superior to Mysore and PV-1 but statistically on par with Vazhukka. Mysore is significantly superior to PV-1.

All the cultivars showed a significant increase in the number of panicles produced per plant with increase in age. When the difference in the number of panicles produced between the sixth and third year group was highest in Vazhukka (44.55), it was only 42.25 in Malabar, 19.32 in Mysore and 8.61 in PV-1.

Length of panicle

The data regarding the mean length of panicle in the two age groups of the four varieties of cardamom are presented in table:18.(Fig:5) Statistical analysis of the data showed significant variation between the age groups and in the variety x age group interaction. But the variation among the varieties was not statistically significant.

In the third year group Mysore had the maximum length of panicle 28.34 cm followed by Malabar, PV-1 and Vazhukka with

Table : 18 INTER VARIETAL VARIABILITY FOR LENGTH OF PANICLE

Age Group/varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	25.91	28.34	19.47	21.46	23.79
6 year	44.11	43.73	52.18	30.67	42.67
Mean	35.01	36.03	35.83	26.07	

CD (0.05)	For varietal means	= 3.49	Not significant
CD (0.05)	For Age group means	= 4.94	Significant
CD (0.05)	For Variety x Age group interaction	= 6.98	Significant

Table : 19 INTER VARIETAL VARIABILITY FOR NUMBER OF NODES/PANICLE

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	15.31	15.12	12.50	10.86	13.45
6 year	17.72	17.60	19.64	15.76	17.68
Mean	16.51	16.36	16.07	13.31	

CD (0.05)	For Varietal means	= 1.24	Not significant
CD (0.05)	For Age group means	= 1.75	Significant
CD (0.05)	For Variety x Age group interaction	= 2.48	Significant

25.91, 21.46 and 19.47 centimeters respectively. Mysore is significantly superior to Vazhukka and on par with Malabar and PV-1. The cultivars Malabar, PV-1 and Vazhukka are also statistically on par.

In the sixth year group Vazhukka gave the maximum value of 52.18 cm followed by Malabar, Mysore and PV-1 with 44.11, 43.73 and 30.67 centimeters respectively. The cultivar Vazhukka is significantly superior to Malabar, Mysore and PV-1. There was no significant difference between Malabar and Mysore but they were both significantly superior to PV-1.

All the cultivars tested showed a significant increase in the length of panicle with increase in age. The difference in the two age groups was highest in Vazhukka (32.71), followed by Malabar (18.20), Mysore (15.39) and PV-1 (9.21) respectively.

Number of nodes/panicle

The mean number of nodes per panicle in the two age groups of the four varieties of cardamom is presented in table: 19. (Fig:6) Statistical analysis of the data showed significant variation between the age groups and in the variety x age group interaction, but the difference among the varieties was not statistically significant.

In the third year group the mean number of nodes per panicle was 15.31 in Malabar, followed by Mysore, Vazhukka and PV-1,

with 15.12, 12.50 and 10.86 respectively. Malabar is statistically superior to Vazhukka and PV-1 but on par with Mysore. Vazhukka and PV-1 are also statistically on par.

In the sixth year group Vazhukka had the maximum value of 19.64, followed by Malabar, Mysore and PV-1, with 17.72, 17.60 and 15.76 respectively. Vazhukka was significantly superior to PV-1 and statistically on par with Malabar and Mysore. The cultivars Malabar, Mysore and PV-1 were also statistically on par.

All the cultivars tested showed a significant increase in the number of nodes per panicle with increase in age. The difference in the number of nodes produced per panicle between the two age groups was highest in Vazhukka (7.14), followed by 4.90 in PV-1, 2.48 in Mysore and 2.41 in Malabar.

Internodal length in the panicle

The data regarding the mean internodal length in the panicle in the two age groups of the four varieties of cardamom are presented in table : 20. (FIG:7) Statistical analysis of the data showed significant differences among the varieties, between the age groups and in their interactions.

In the third year group the internodal length in the panicle ranged from 1.28 cm in Vazhukka to 1.53 cm in Mysore. Malabar and PV-1. gave values of 1.37 and 1.50 centimeters respectively.

Table : 20 INTER VARIETAL VARIABILITY FOR INTERNODAL LENGTH IN THE PANICLE

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	1.37	1.53	1.28	1.50	1.42
6 year	1.78	2.08	2.06	1.36	1.82
Mean	1.57	1.80	1.67	1.43	

CD (0.05)	For Varietal means	= 0.01	Significant
CD (0.05)	For Age Group means	= 0.11	Significant
CD (0.05)	For Variety x Age group interaction	= 0.16	Significant

Table : 21 INTER VARIETAL VARIABILITY FOR NUMBER OF CAPSULES/PANICLE

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	25.80	24.56	16.96	22.84	22.54
6 year	50.96	32.68	47.72	27.92	39.82
Mean	38.38	28.62	32.34	25.38	

CD (0.05)	For Varietal means	= 4.40	Significant
CD (0.05)	For Age Group means	= 6.23	Significant
CD (0.05)	For Variety x Age Group interaction	= 8.81	Significant

Mysore was significantly superior to Vazhukka but on par with PV-1 and Malabar. Malabar and Vazhukka were statistically on par.

In the sixth year group the internodal length in the panicle ranged from the minimum of 1.36 cm recorded in PV-1 to a maximum of 2.08 cm recorded in Mysore. The cultivar Mysore was significantly superior to Malabar and PV-1 but statistically on par with Vazhukka. Malabar was also significantly superior to PV-1.

All the varieties except PV-1 showed an increase in internodal length with increase in age. The difference in internodal length in the panicle between the two age groups was 0.78 in Vazhukka, 0.55 in Mysore, 0.41 in Malabar and -0.13 in PV-1.

Number of capsules/panicle

The mean number of capsules per panicle in the two age groups of the four varieties of cardamom is presented in table:21. (Fig:8) Statistical analysis of the data showed significant variation among the varieties, between the age groups and in their interactions.

In the third year group the number of capsules/panicle ranged from 16.96 in Vazhukka to 25.80 in Malabar. Mysore and PV-1 gave values of 24.56 and 22.84 respectively. The cultivar Malabar was significantly superior to Vazhukka and statistically

on par with Mysore and PV-1. There was no significant difference between Mysore, Vazhukka and PV-1.

In the sixth year group the number of capsules/panicle ranged from the minimum of 27.92 recorded in PV-1 to the maximum of 50.96 recorded in Malabar. Vazhukka and Mysore recorded values of 47.72 and 32.68 respectively. Malabar was significantly superior to Mysore and PV-1 and statistically on par with Vazhukka. Mysore and PV-1 were also statistically on par.

All the cultivars showed significant increase in the number of capsules/panicle with increase in age. When the difference in the number of capsules/panicle between the two age groups was 30.76 in Vazhukka it was only 25.16 in Malabar, 8.12 in Mysore and 5.08 in PV-1.

Hundred capsule weight

The data on the mean weight of hundred capsules in the two age groups of the four varieties of cardamom are presented in table: 22.(FIG:9) Statistical analysis of the data showed significant difference between the age groups and in the variety x age group interaction, while the variation among the varieties was not significant.

In the third year group hundred capsule weight ranged from the minimum of 43.49 g in Vazhukka to the maximum of 87.89 g in PV-1. The cultivar PV-1 was significantly superior to Mysore

Table : 22 INTER VARIETAL VARIABILITY FOR HUNDRED CAPSULE WEIGHT/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	81.90	57.64	43.49	87.89	67.73
6 year	66.80	92.76	79.76	68.80	77.03
Mean	74.35	75.20	61.62	78.34	

CD (0.05)	For varietal means	= 4.76	Not significant
CD (0.05)	For Age group means	= 6.74	Significant
CD (0.05)	For Variety x Age group interaction	= 9.53	Significant

Table : 23 INTER VARIETAL VARIABILITY FOR CAPSULE VOLUME

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	70.98	60.76	53.14	85.15	67.50
6 year	79.92	88.56	73.51	81.44	80.85
Mean	75.45	74.66	63.32	83.39	

CD (0.05)	For varietal means	= 4.96	Significant
CD (0.05)	For age group means	= 7.02	Significant
CD (0.05)	For Variety x Age group interaction	= 9.93	Significant

and Vazhukka and statistically on par with Malabar. Malabar was significantly superior to Mysore and Vazhukka.

In the sixth year group hundred capsule weight ranged from 66.80 g in Malabar to 92.76 g in Mysore. Vazhukka and PV-1 recorded values of 79.76 g and 68.80 g respectively. Mysore is significantly superior to Vazhukka and statistically on par with PV-1 and Malabar. There was no significant difference between the cultivars PV-1, Malabar and Vazhukka.

Mysore and Vazhukka showed significant increase in hundred capsule weight with increase in age, but a reverse trend was noticed in Malabar and PV-1. The difference in the capsule weight between the sixth and third year was 36.27 g in Vazhukka, 35.12 g in Mysore, -15.10 g in Malabar and -19.09 g in PV-1.

Capsule Volume

The data on the mean capsule volume in the two age groups of the four varieties of cardamom are presented in table : 23. (FIG: 10) Statistical analysis of the data showed significant difference among the varieties, between the age groups and in their interactions.

In the third year group the cultivar PV-1 recorded the maximum value of 85.15 cc, followed by Malabar, Mysore and Vazhukka with 70.98, 60.76 and 53.14 cubic centimeters respectively. PV-1

was significantly superior to Malabar, Mysore and Vazhukka. The cultivars Mysore and Vazhukka were statistically on par.

In the sixth year group the cultivar Mysore gave the highest value of 88.56 cc, followed by PV-1, Malabar and Vazhukka with 81.44 cc, 79.92 cc and 73.51 cc respectively. Mysore was statistically superior to Vazhukka but on par with PV-1 and Malabar. There was no significant difference between the cultivars Malabar, PV-1 and Vazhukka.

All the cultivars except PV-1 showed a significant increase in capsule volume with increase in age. The difference in the capsule volume between the sixth and third year groups were 27.80 cc in Mysore, 20.37 cc in Vazhukka, 8.94 cc in Malabar and -3.71 cc in PV-1.

Number of seeds/capsule

The mean number of seeds per capsule in the two age groups of the four varieties of cardamom is presented in table: 24. (Fig: 11) Statistical analysis of the data showed significant variation among the age groups and in the variety x age group interaction. But the difference between the varietal means were not significant.

In the third year group the number of seeds/capsule ranged from the minimum of 10.34 in Vazhukka to the maximum of 12.36 in Malabar. Mysore and PV-1 recorded values of 11.32 and 12.08 resperctively. Malabar was significantly superior to Vazhukka but

Table : 24 INTER VARIETAL VARIABILITY FOR NUMBER OF SEEDS/CAPSULE

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	12.36	11.32	10.34	12.08	11.52
6 year	14.32	15.56	15.36	12.80	14.51
Mean	13.34	13.44	12.85	12.44	

CD (0.05)	For varietal means	= 0.86 Not significant
CD (0.05)	For Age group means	= 1.22 Significant
CD (0.05)	For Variety x Age group interaction	= 1.73 Significant

Table : 25 INTER VARIETAL VARIABILITY FOR FRESH WEIGHT OF CAPSULES/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	424.46	244.04	67.35	161.60	224.36
6 year	1356.38	661.88	1170.60	447.28	909.16

CD (0.05)	For varietal means	= 173.53 Significant
CD (0.05)	For Age group means	= 245.41 Significant
CD (0.05)	For Variety x Age group interaction	= 347.06 Significant

on par with PV-1 and Mysore. There was no significant difference between the cultivars Mysore and Vazhukka.

In the sixth year group the number of seeds/capsule ranged from the minimum of 12.80 in PV-1 to the maximum of 15.56 in Mysore. Malabar and Vazhukka recorded values of 14.32 and 15.36 respectively. Mysore was significantly superior to PV-1 and on par with Vazhukka and Malabar. There was no significant difference between the cultivars Malabar and PV-1.

All the cultivars tested showed an increase in number of seeds/capsule with increase in age. The differences in the number of seeds/capsule between the sixth and third year groups were 5.02 in Vazhukka, 4.24 in Mysore, 1.96 in Malabar and 0.72 in PV-1.

Fresh weight of capsules/plant

The mean fresh weight of capsules in the two age groups of the four varieties of cardamom is presented in table: 25. (FIG:12) Statistical analysis of the data showed significant variation among the varieties between the age groups and in their interactions.

In the third year group Malabar gave the highest value of 424.46 g followed by Mysore, PV-1 and Vazhukka with 244.04, 161.60 and 67.35 grammes respectively. Malabar was significantly superior to Vazhukka and on par with Mysore, and PV-1. There was

no significant difference between the cultivars Mysore, Vazhukka and PV-1.

In the sixth year group Malabar recorded the maximum value for the fresh weight of capsules with 1356.88 g, followed by Vazhukka, Mysore and PV-1 with 1170.60, 661.88 and 447.28 grammes respectively. Malabar was significantly superior to Mysore and PV-1 but on par with Vazhukka. There was no significant difference between the cultivars Mysore and PV-1.

All the varieties showed a significant increase in the fresh weight of capsules with increase in age. The cultivar Vazhukka recorded the greatest difference in fresh weight of capsules (1103.23 g) between the two age groups followed by 932.42 g in Malabar, 417.84 g in Mysore and 285.68 g in PV-1.

Dry weight of capsules/plant (Yield)

The data on the mean dry weight of capsules/plant (yield) in the two age groups of the four varieties of cardamom are presented in table: 26. (FIG:13) Statistical analysis of the data showed a significant variation among the varieties, between the age groups and in their interactions.

In the third year group the dry weight of capsules ranged from the minimum of 14.39 g recorded in Vazhukka to the maximum of 90.92 g recorded in Malabar. Mysore and PV-1 recorded values of 49.52 g and 33.54 g respectively. Malabar was significantly

Table : 26 INTER VARIETAL VARIABILITY FOR DRY WEIGHT OF CAPSULES/PLANT

Age Group/Varieties	Malabar	Mysore	Vazhukka	PV-1	Mean
3 year	90.92	49.52	14.39	38.54	47.09
6 year	292.36	166.24	260.24	99.28	204.53
Mean	191.64	107.88	137.31	66.41	

CD (0.05)	For varietal means	= 36.81	Significant
CD (0.05)	For Age group means	= 52.06	Significant
CD (0.05)	For Variety x Age group interaction	= 73.62	Significant

FIG: 1 NUMBER OF PRODUCTIVE TILLERS

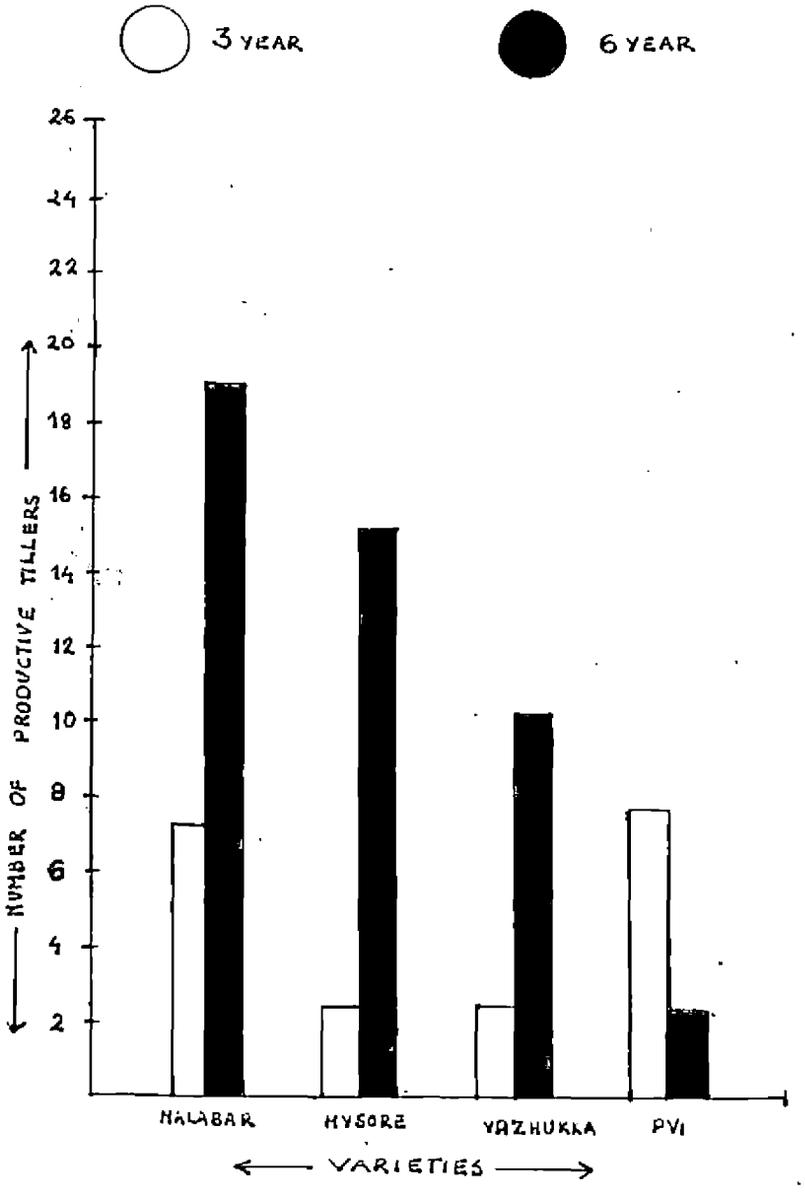


FIG: 2 HEIGHT OF TILLERS

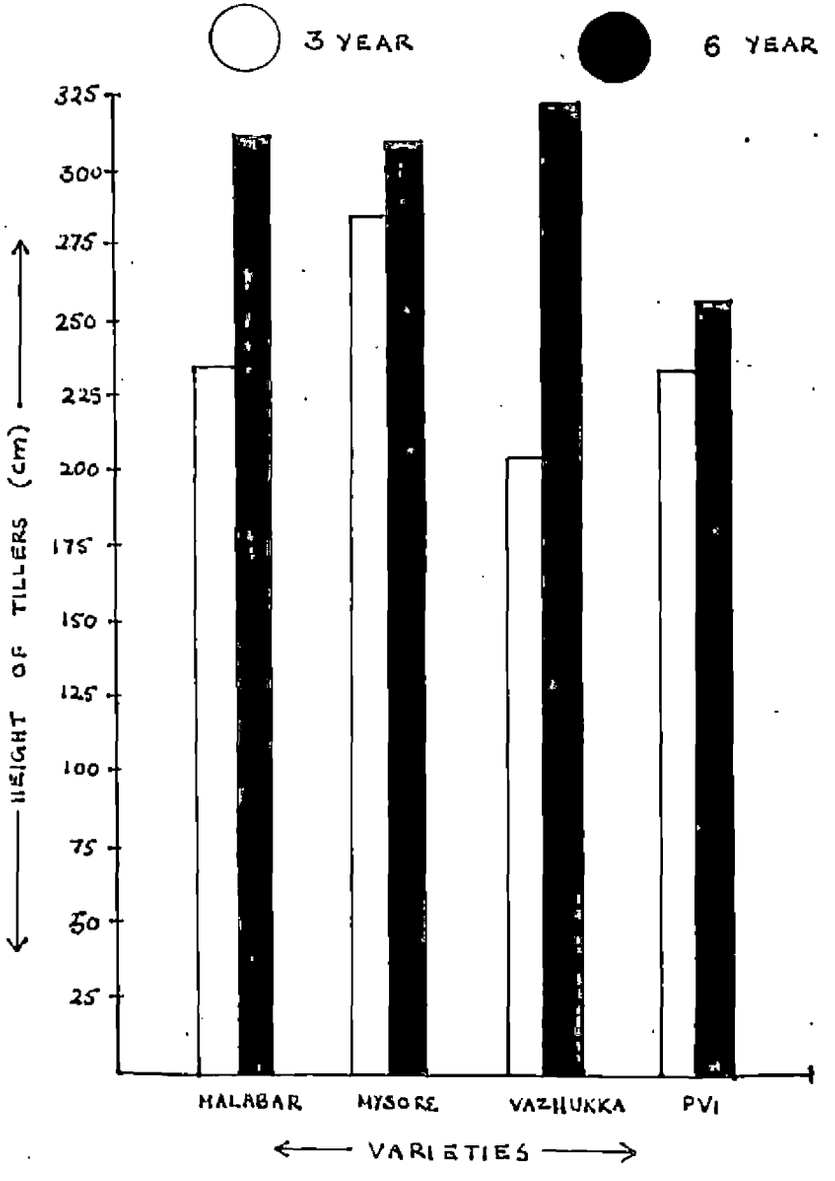


FIG: 9 HUNDRED CAPSULE WEIGHT

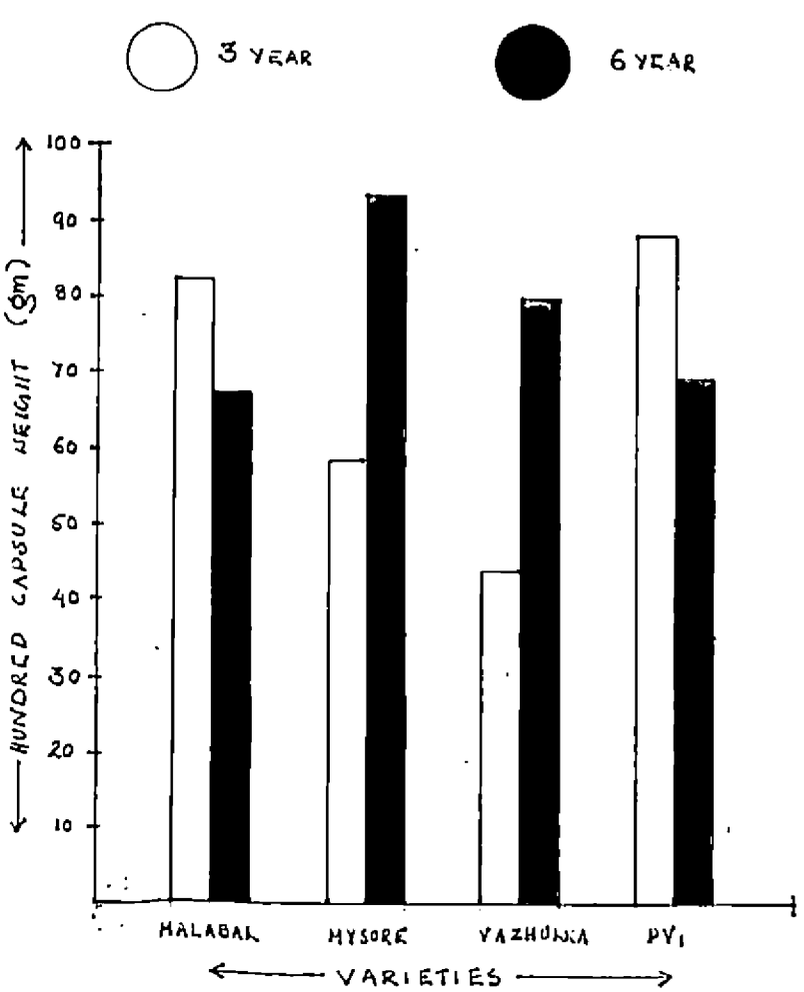


FIG: 10 CAPSULE VOLUME

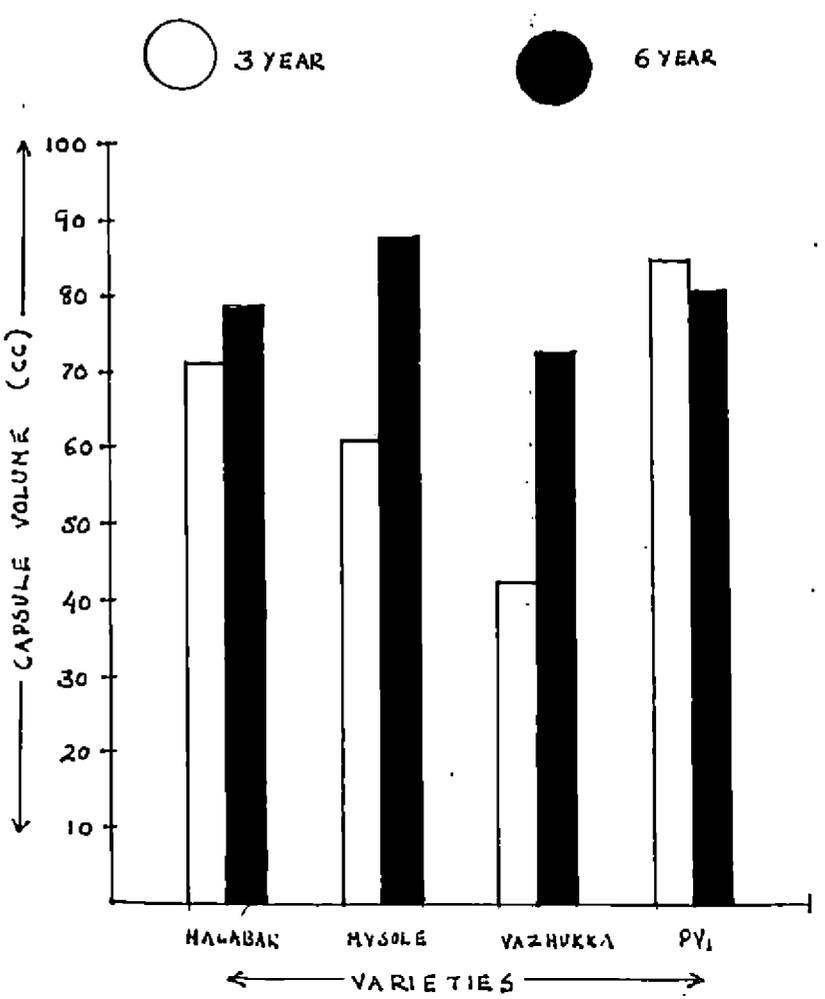


FIG: 11 NUMBER OF SEEDS/CAPSULE

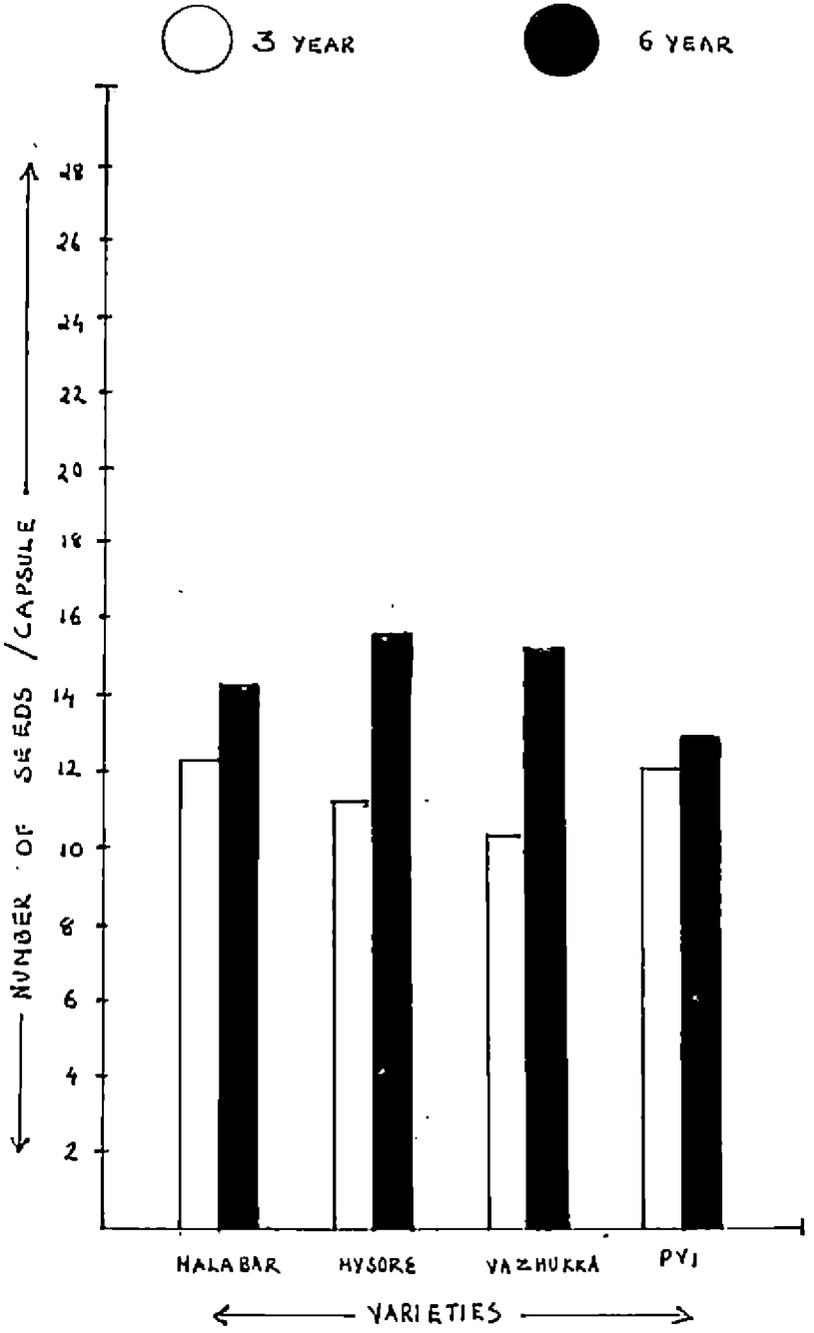


FIG: 12 FRESH WEIGHT OF CAPSULES

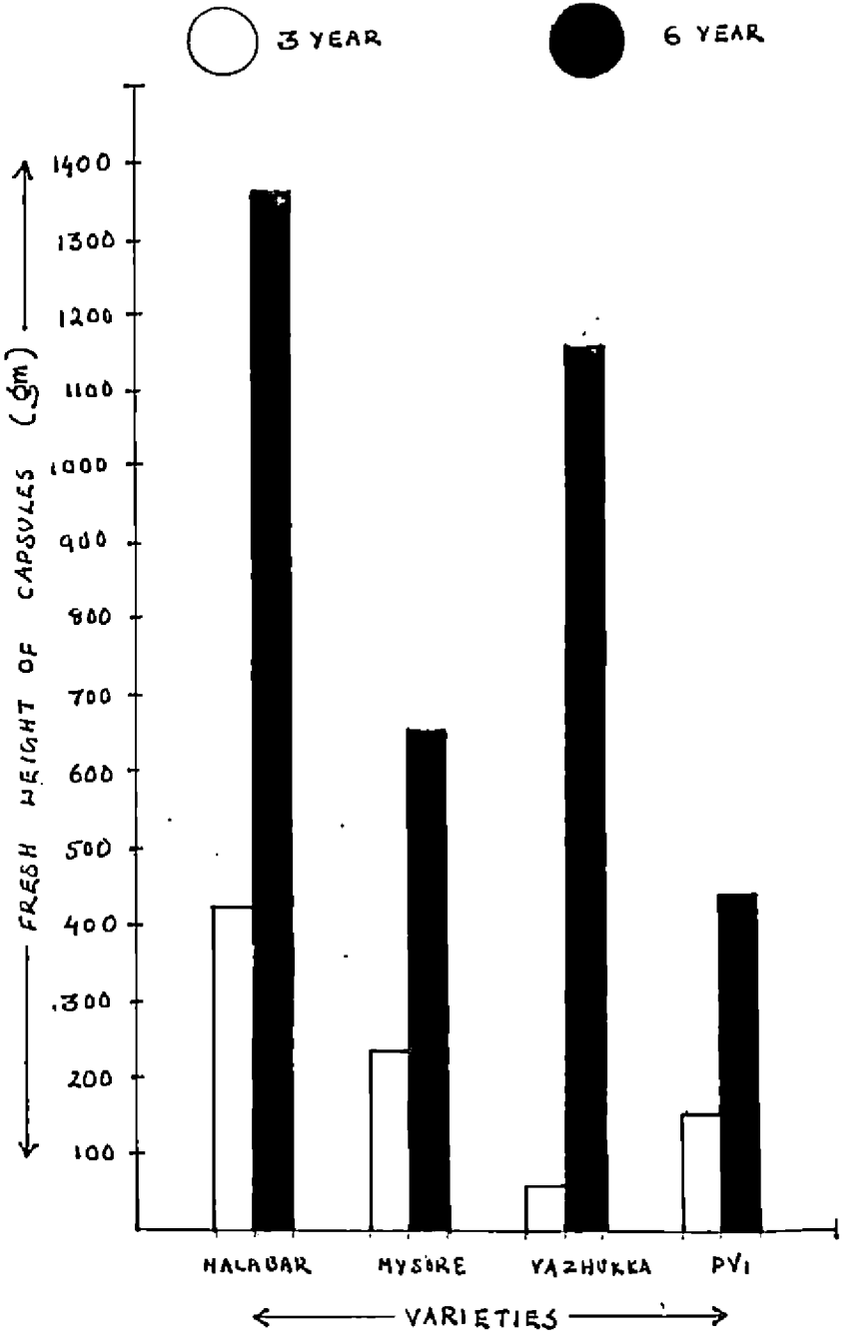


FIG: 11 NUMBER OF SEEDS/CAPSULE

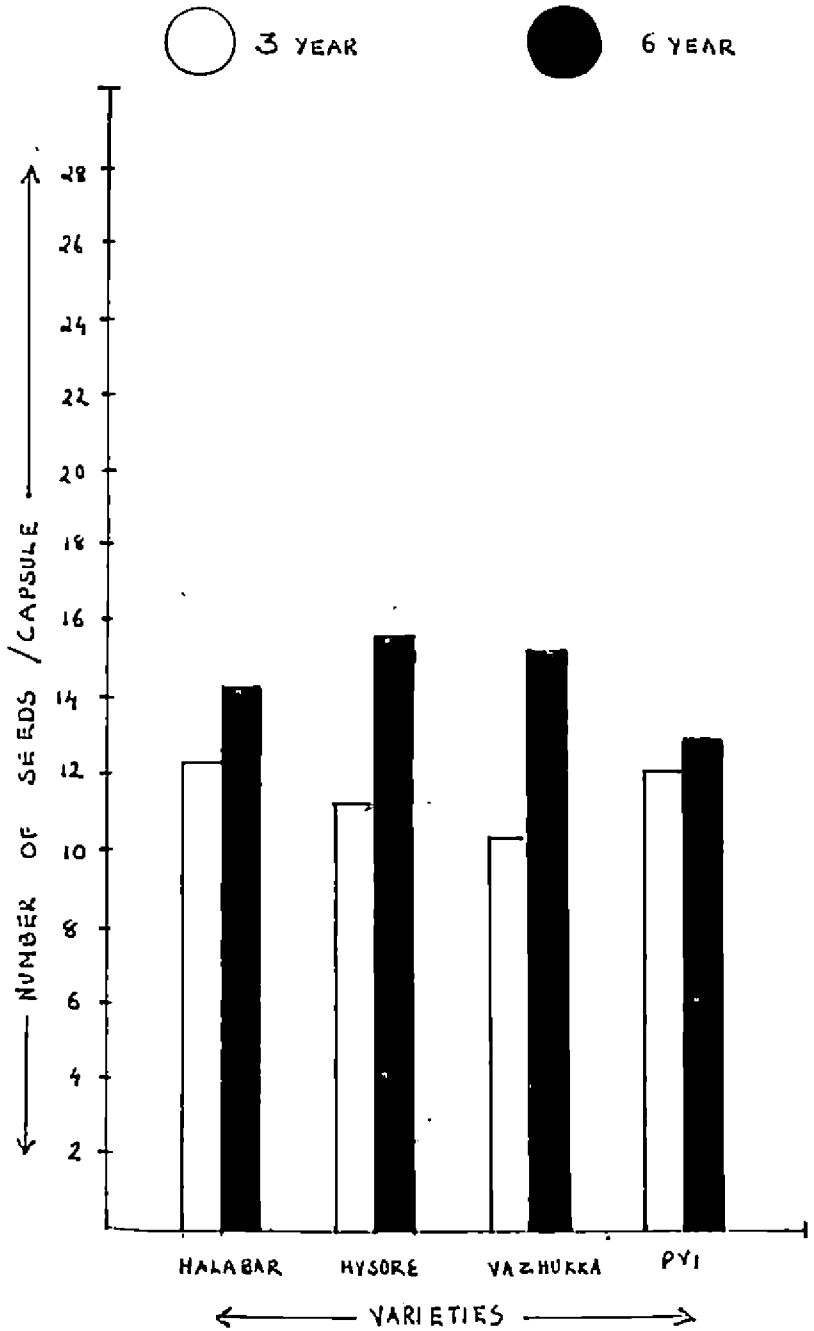


FIG: 12 FRESH WEIGHT OF CAPSULES

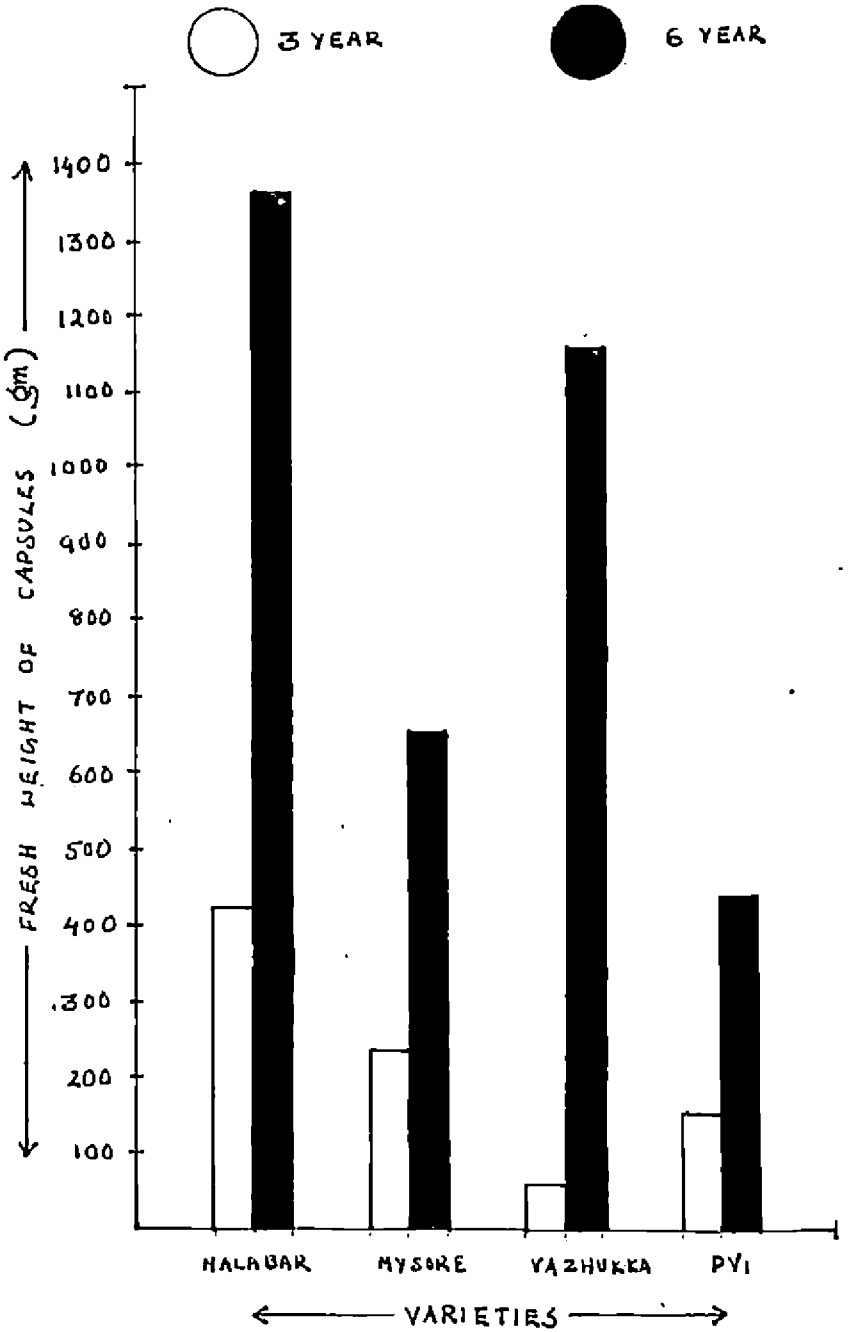


FIG: 9 HUNDRED CAPSULE WEIGHT

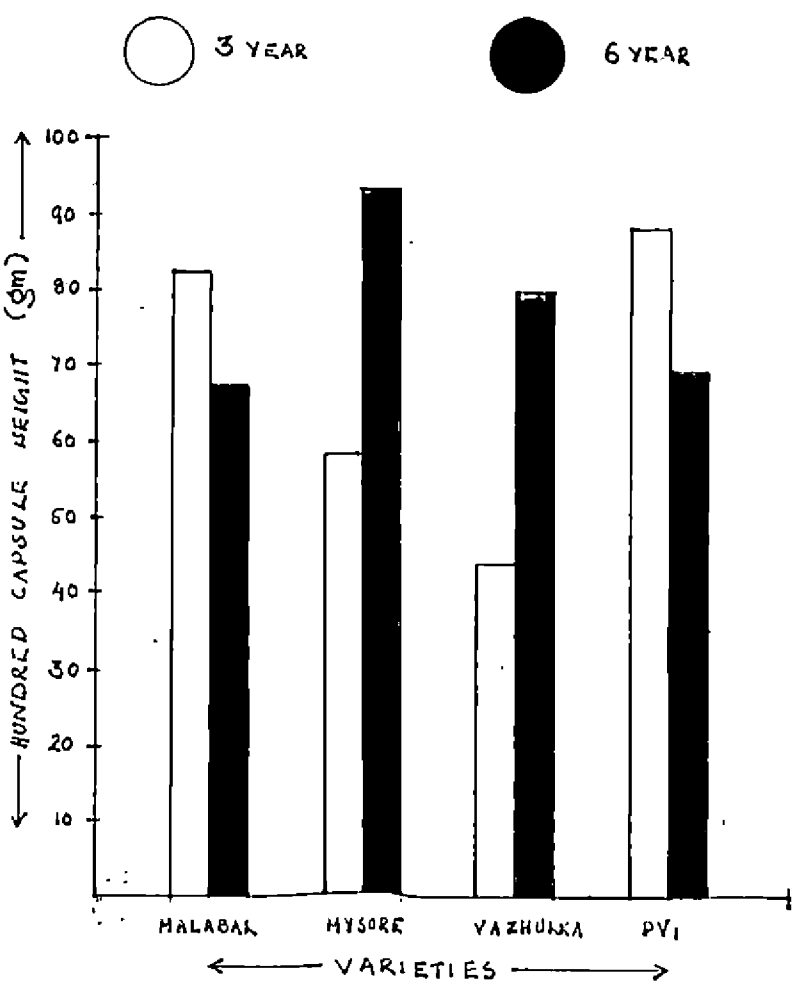


FIG: 10 CAPSULE VOLUME

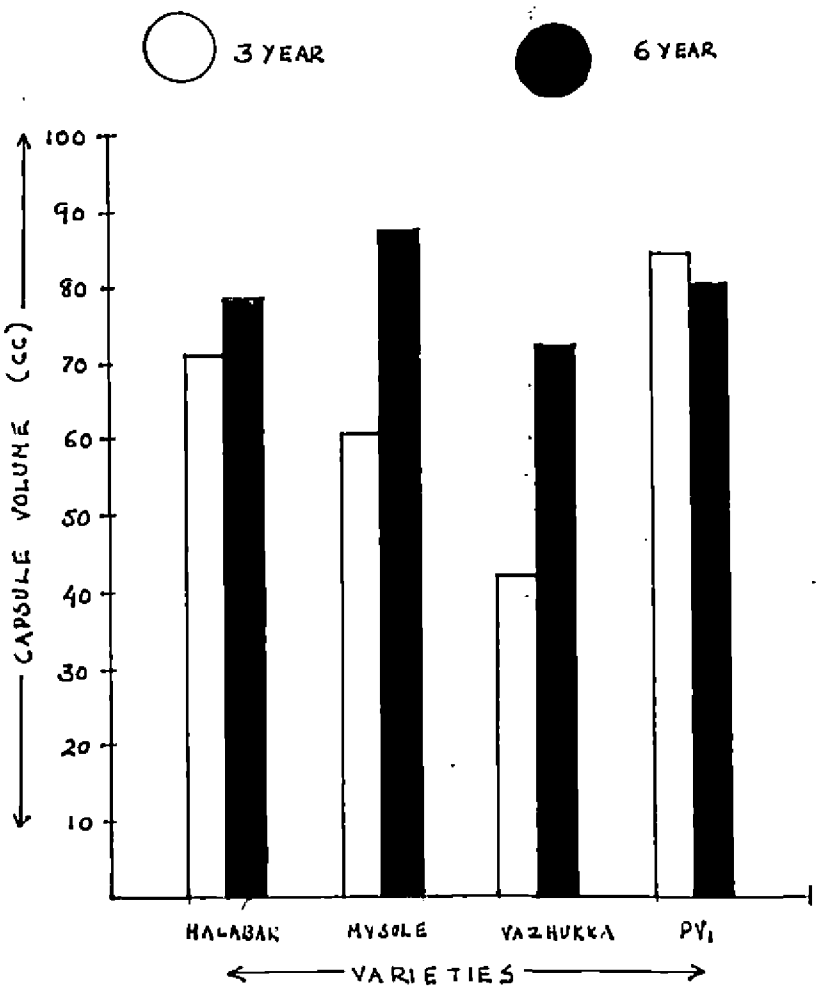


FIG: 1 NUMBER OF PRODUCTIVE TILLERS

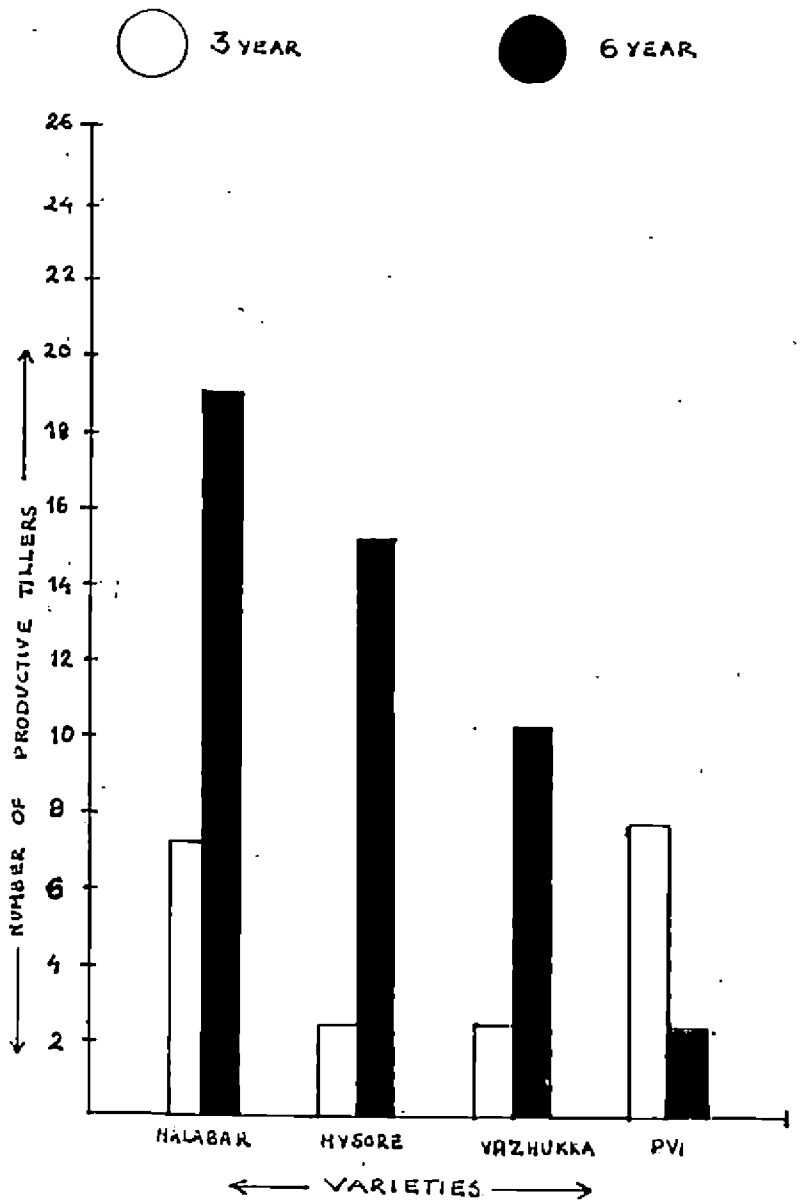


FIG: 2 HEIGHT OF TILLERS

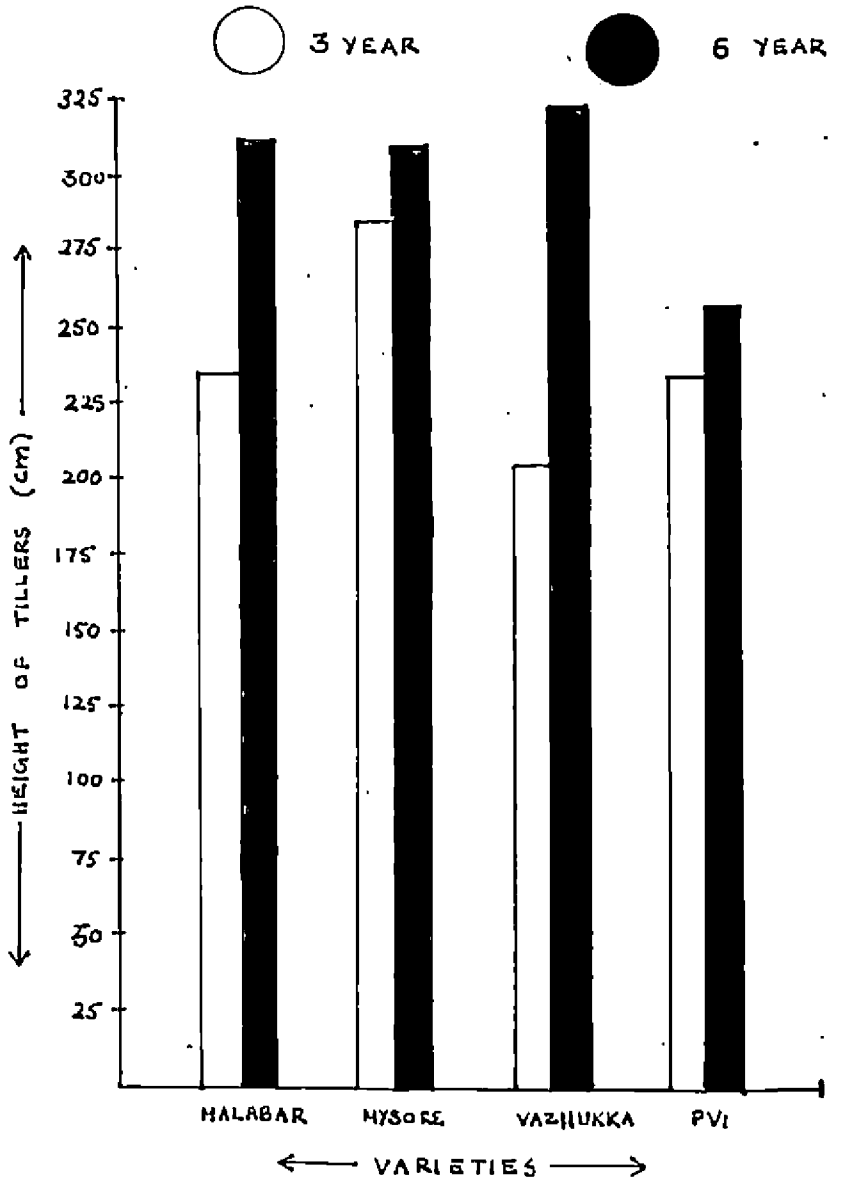


FIG: 3 NUMBER OF LEAVES/TILLER

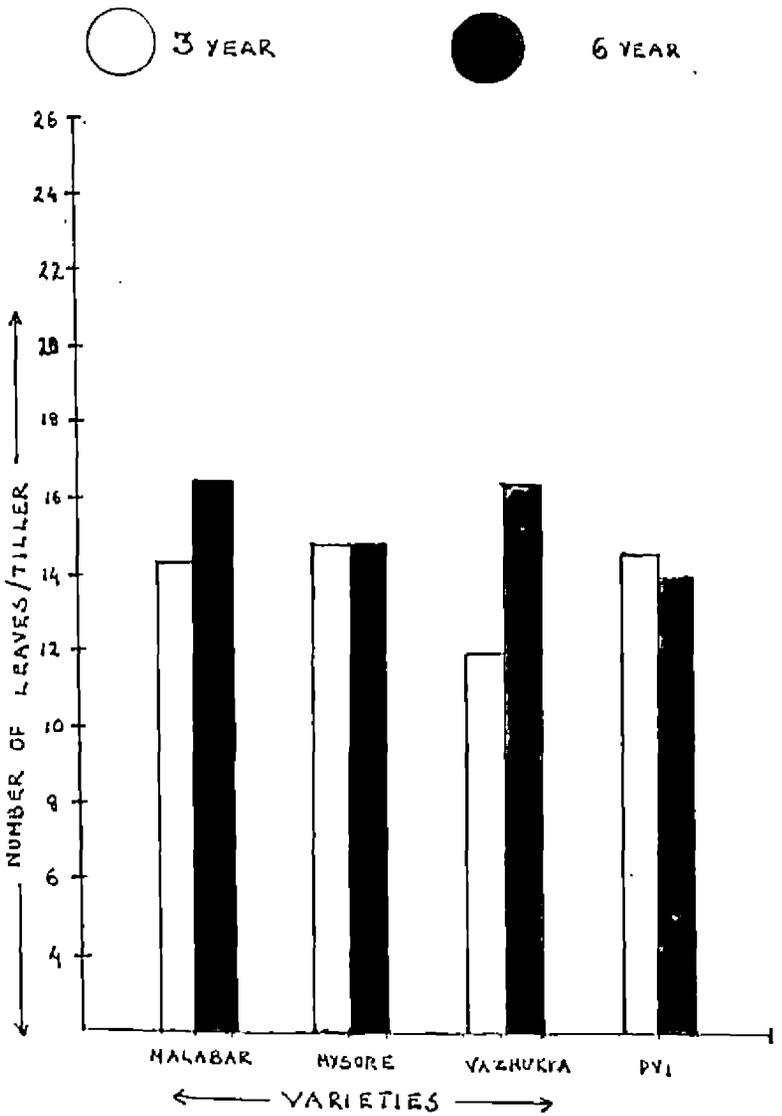


FIG: 4 NUMBER OF PANICLES/PLANT.

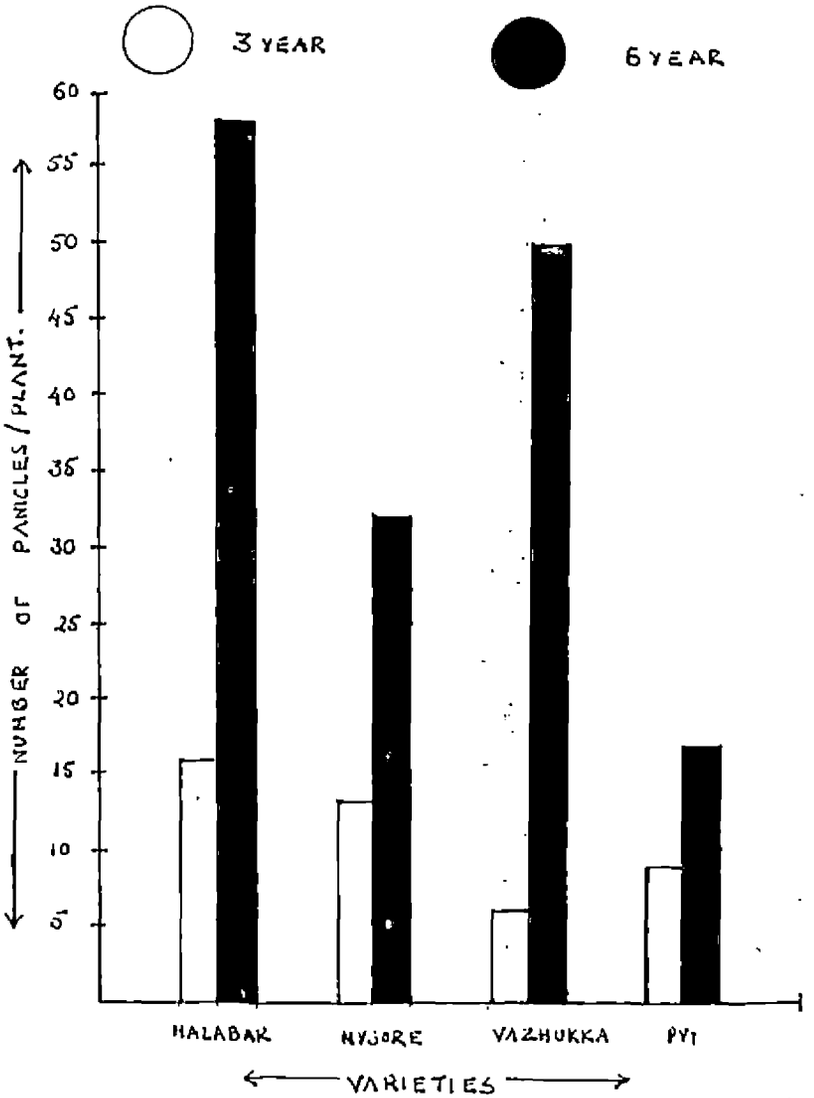


FIG: 5 LENGTH OF PANICLE

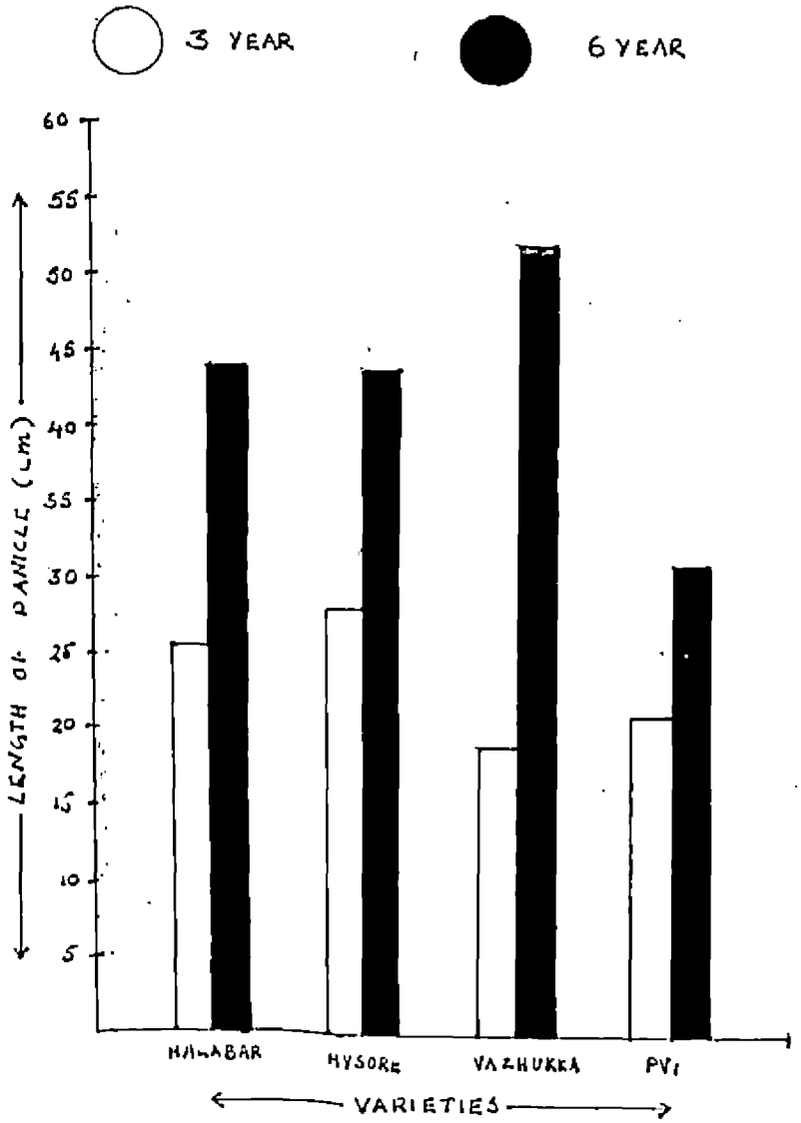


FIG: 6 NUMBER OF NODES/PANICLE

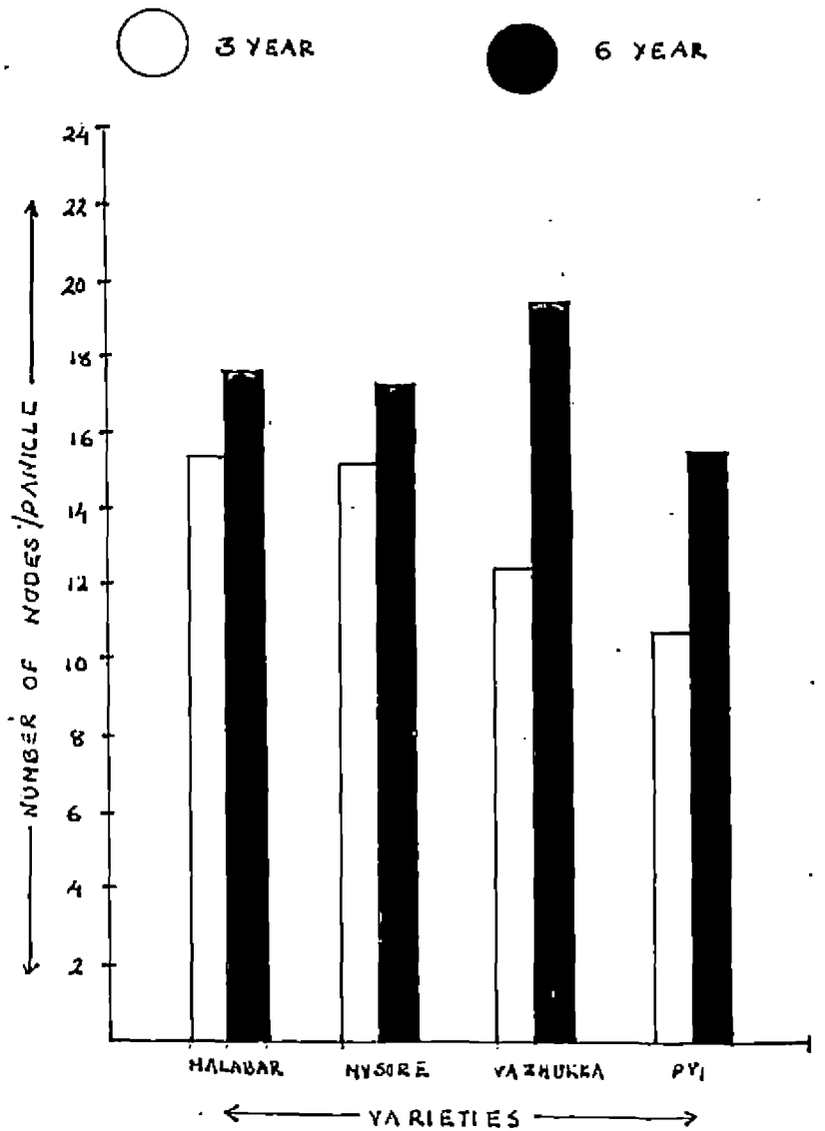


FIG: 7 INTERNODAL LENGTH IN THE PANICLE

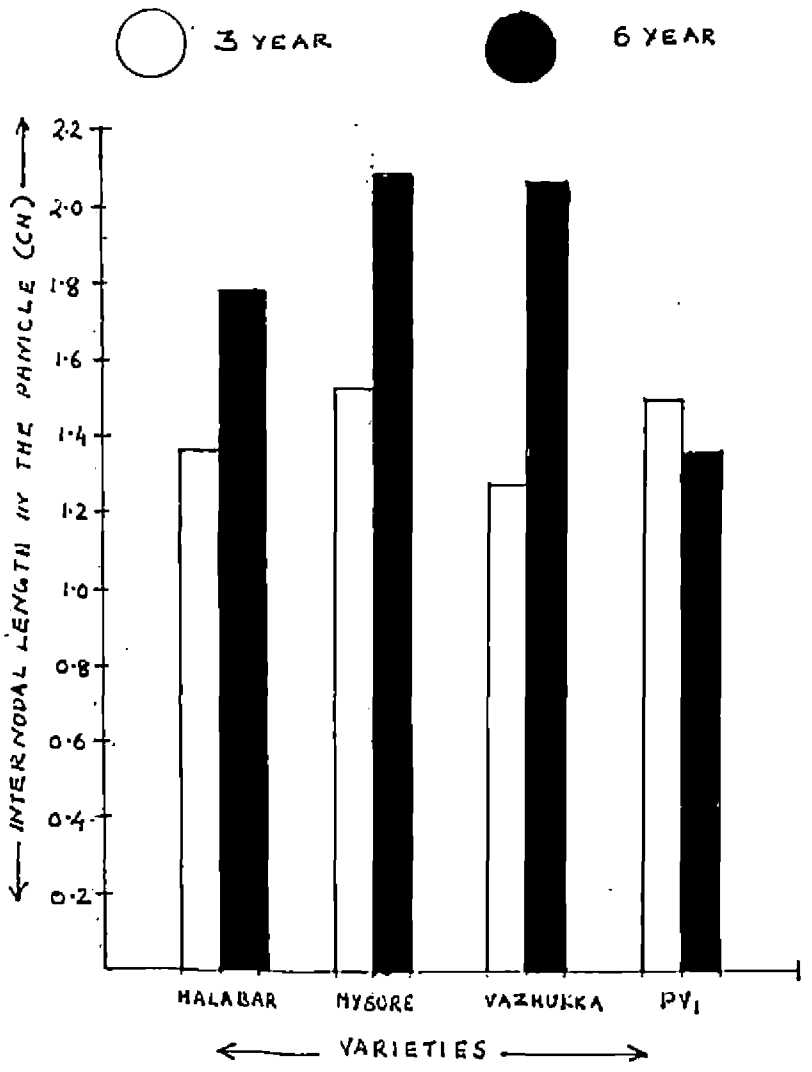
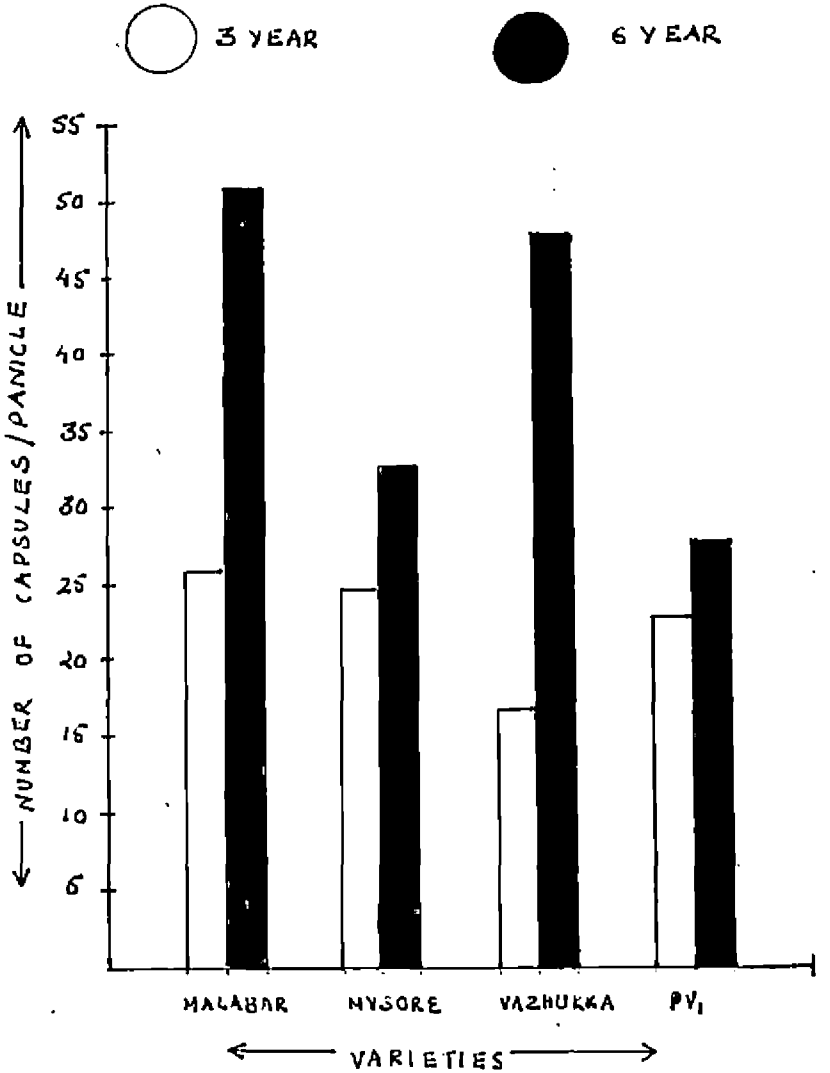


FIG: 8 NUMBER OF CAPSULES / PANICLE



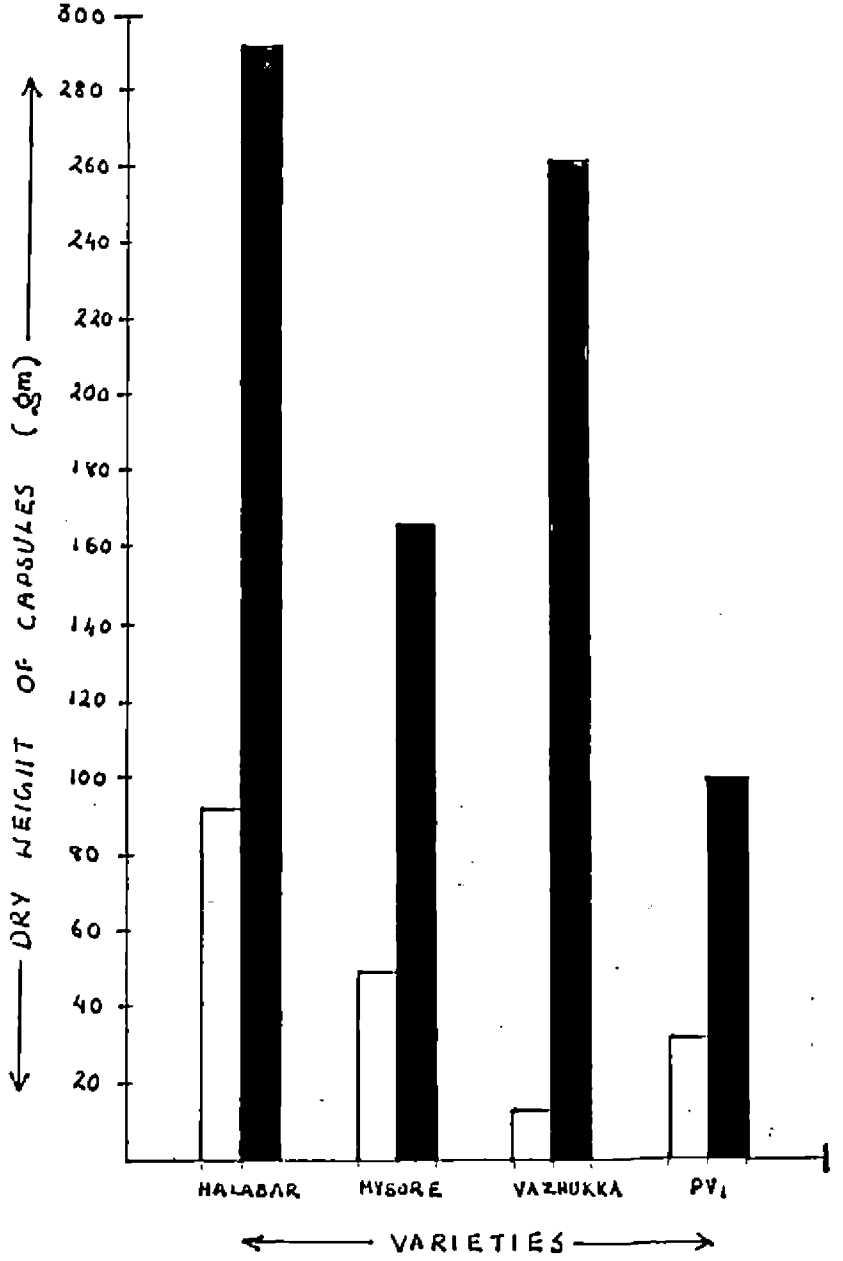


FIG: 13 DRY WEIGHT OF CAPSULES

3 YEAR

6 YEAR

superior to Vazhukka and statistically on par with Mysore and PV-1. There was no significant difference between the cultivars Mysore, Vazhukka and PV-1.

In the sixth year group the dry weight of capsules ranged from the minimum of 99.28 recorded in PV-1 to the maximum of 292.36 g recorded in Malabar. Mysore and Vazhukka gave values of 166.24 g and 260.24 g respectively. Malabar was significantly superior to PV-1 and Mysore and was on par with Vazhukka. There was no significant difference between the cultivars Mysore and PV-1.

All the cultivars showed significant increase in the dry weight of capsules with increase in age. The cultivar Vazhukka recorded the maximum difference of 245.85 g in the dry weight of capsules between the two age groups while it was only 65.74 g in PV-1. Malabar and Mysore showed a difference of 201.44 and 116.72 grammes respectively.

C. Estimation of Genetic parameters

Data on phenotypic and genotypic variances, Phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain of the thirteen characters at the third year stage are presented in table: 27.

The phenotypic variance ranged from the minimum of 0.01 recorded for internodal length in the panicle to the maximum of

Table : 27 ESTIMATION OF GENETIC PARAMETERS IN CARDAMOM (3 YEAR)

Character	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability	Genetic advance	Genetic gain
Height of tillers (cm)	1479.61	1028.30	15.96	13.30	0.69	55.06	22.85
No. of productive tillers/plant	8.69	6.12	56.35	47.28	0.70	4.27	81.72
No. of leaves/tiller	2.94	1.53	12.27	8.86	0.52	1.84	13.18
No. of panicles/plant	36.84	15.63	55.42	36.11	0.42	5.30	48.39
No. of capsules/panicle	54.08	16.16	33.36	18.24	0.29	4.52	20.54
Fresh weight of capsules/plant (g)	45777.19	17310.62	95.36	58.64	0.37	166.66	74.28
Dry weight of capsules/plant (g)	2099.30	822.61	95.18	60.90	0.40	37.80	80.26
100 capsules weight (g)	475.72	421.31	32.20	30.30	0.88	39.79	58.74
Capsules volume (cc)	238.21	180.14	22.86	19.88	0.75	24.04	35.61
No. of seeds/capsules	3.19	0.21	15.50	4.04	0.06	0.25	2.16
Length of panicle (cm)	31.59	12.59	23.62	14.91	0.39	4.61	19.37
No. of nodes/panicle	6.84	4.10	19.22	15.05	0.61	3.26	24.24
Internodal length in the panicle (cm)	0.01	0.01	9.11	9.91	0.71	0.19	13.35

45777.19 recorded for fresh weight of capsules. Genotypic variance ranged from the minimum of 0.01 recorded for internodal length in the panicle to the maximum of 17310.62 recorded for fresh weight of capsules/plant.

The phenotypic coefficient of variation ranged from 9.11 recorded for internodal length of panicle to 95.36 recorded for fresh weight of capsules. The genotypic coefficient of variation ranged from 4.04 recorded for number of seeds/capsule to the maximum of 60.90 recorded for dry weight of capsules per plant.

Characters like fresh weight of capsules/plant, dry weight of capsules/plant and number of productive tillers/plant showed a high genotypic coefficient of variation while characters like number of leaves/tiller, number of seeds/capsule and internodal length in the panicle recorded very low values.

Heritability values of the different characters ranged from 0.06 recorded for number of seeds/capsule to 0.88 recorded for 100 capsule weight. The heritability values were low for number of capsules/panicle and number of seeds/capsule.

Number of leaves/tiller, number of panicles/plant, fresh weight of capsules/plant, dry weight of capsules/plant and length of panicle recorded medium heritability. Height of tillers, number of productive tillers, 100 capsule weight, capsule volume, number of nodes/panicle and internodal length in

the panicle recorded high heritability. But among these, number of productive tillers/plant, fresh weight of capsules/plant, dry weight of capsules/plant and 100 capsule weight recorded high values for genetic gain. Maximum genetic advance (166.66) was recorded for fresh weight of capsules/plant and the lowest value of 0.19 was recorded for the internodal length in the panicle.

Eventhough heritability estimates were high for height of tillers, number of nodes/panicle, and internodal length in the panicle, the estimates of genetic gain were low for the above characters.

Data on phenotypic and genotypic variance, phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain of the thirteen characters at the sixth year stage are presented in table: 28

The phenotypic variance ranged from the minimum of 0.13 recorded for internodal length in the panicle to the maximum of 273387.90 recorded for fresh weight of capsules/plant. Genotypic variance ranged from the minimum of 0.10 recorded for internodal length in the panicle to the maximum of 157978.00 recorded for fresh weight of capsules/plant.

Phenotypic coefficient of variation ranged from 9.93 recorded for number of seeds/capsule to a maximum of 65.37 recorded

Table : 28 ESTIMATION OF GENETIC PARAMETERS IN CARDAMOM (6 YEAR)

Character	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation	Genotypic co-efficient of variation	Herita-bility	Genetic advance	Genetic gain
Height of tillers (cm)	1596.26	665.048	13.28	8.57	0.41	34.29	11.40
No. of productive tillers/plant	58.59	49.87	65.37	60.31	0.85	13.42	14.60
No. of leaves/tiller	3.73	0.99	12.52	6.47	0.26	1.06	6.86
No. of panicles/plant	413.90	315.96	51.34	44.85	0.76	31.99	80.72
No. of capsules/panicle	164.89	116.73	32.13	27.13	0.70	18.72	47.00
Fresh weight of capsules/plant (g)	273387.90	157978.00	57.51	43.72	0.57	622.40	68.46
Dry weight of capsules/plant (g)	12016.29	6729.83	53.60	40.10	0.56	126.46	61.82
100 Capsules weight (g)	185.56	131.63	17.68	14.89	0.70	19.90	25.83
Capsule volume (cc)	85.90	26.18	11.46	6.32	0.30	5.81	7.19
No. of seeds/capsule	2.07	1.47	9.93	8.36	0.71	2.10	14.47
Length of panicle (cm)	110.67	71.34	24.65	19.79	0.64	13.96	32.71
No. of nodes/panicle	6.32	1.56	14.22	7.06	0.24	1.24	7.01
Internodal length in the panicle (cm)	0.13	0.10	20.15	18.00	0.79	0.60	32.87

for number of productive tillers. Genotypic coefficient of variation ranged from 6.32 recorded for capsule volume to a maximum of 60.31 recorded for number of productive tillers/ plant.

Characters like fresh weight of capsules/plant, dry weight of capsules/plant, number of panicles/plant and number of productive tillers/plant showed high phenotypic and genotypic coefficients of variation.

Heritability values ranged from the minimum of 0.24 recorded for number of nodes/panicle to the maximum of 0.85 recorded for number of productive tillers/plant. Number of nodes/ panicle, capsule volume and number of leaves/tiller recorded low heritability. Height of tillers, fresh weight of capsules/ plant and capsule volume recorded medium heritability. Number of productive tillers/plant, number of panicles/plant, number of capsules/panicle, 100 capsule weight, number of seeds/capsule, length of panicle and internodal length in the panicle showed high heritability. High values for genetic gain were recorded for fresh weight of capsules, dry weight of capsules, number of capsules/panicle and number of panicles/plant, Maximum genetic advance (622.40) was recorded for fresh weight of capsules. Characters like number of seeds/capsule and internodal length in the panicle recorded very low values for genetic advance inspite of their high heritability estimates.

D. Correlation and path coefficient analysis

Analysis of co-variance was done for all the possible pairs of characters. The genotypic and phenotypic co-variance components were computed in a similar manner as for the corresponding variance components and from these, the genotypic correlation coefficients were estimated.

The inter-relationship of all the thirteen character combinations were analysed and the results are presented in tables: 29 (third year group) and 30 (sixth year group).

In the third year group positive correlation with yield was recorded in all the characters studied, out of which nine characters viz. Number of productive tillers/plant, number of leaves/tiller, number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant hundred capsule weight, number of seeds/capsule length of panicle and number of nodes per panicle registered very high values of 0.9161, 0.5438, 0.9828, 0.9247, 1.0000, 0.5765, 1.5638, 0.7345, 0.8167 respectively. All the other characters although positive recorded very low values.

In the sixth year group strong positive correlation was noticed for eleven character combinations. Dry weight of capsules/plant had high positive correlation with height of tillers, number of productive tillers/plant, number of leaves/tiller,

Table : 29 GENOTYPIC CORRELATION COEFFICIENTS AMONG YIELD AND COMPONENT CHARACTERS (3 YEAR)

Character	Height of tillers	Number of productive tillers per plant	Number of leaves per tiller	Number of panicles per plant	Number of capsules per panicle	Fresh weight of capsules per plant	Dry weight of capsules per plant	Hundred capsules weight	Capsule volume	Number of seeds per capsule	Length of panicle	Number of nodes per panicle	Internodal length in the panicle
Height of tillers	1.0000	0.1866	0.8282	0.6076	0.7569	0.3525	0.3092	0.0986	0.0814	0.3609	0.9850	0.5426	0.8929
Number of productive tillers		1.0000	0.7124	0.8352	0.9712	0.9189	0.9161	0.9332	0.7890	1.9934	0.4723	0.2811	0.3236
Number of leaves per tiller			1.0000	0.7550	1.0618	0.5733	0.5438	0.6898	0.6587	1.4545	0.8178	0.2680	0.9658
Number of panicles per plant				1.0000	1.1074	1.0022	0.9828	0.4957	0.2696	1.4209	0.9890	0.9477	0.3384
Number of capsules per panicle					1.0000	0.9442	0.9247	0.8314	0.6973	1.6966	0.9679	0.6034	0.8243
Fresh weight of capsules						1.0000	1.0000	0.5795	0.3236	1.5861	0.7695	0.8390	0.1520
Dry weight of capsules							1.0000	0.5765	0.3184	1.5638	0.7345	0.8167	0.1147
Hundred capsule weight								1.0000	0.9689	1.7993	0.1724	-0.1738	0.4522
Capsule volume									1.0000	1.6497	-0.0041	-0.4670	0.5603
Seeds per capsule										1.0000	0.6422	0.0796	0.8594
Length of panicle											1.0000	0.8559	0.6234
Nodes per panicle												1.0000	0.0073
Internodal length in panicle													1.0000

Table : 30 GENOTYPIC CORRELATION COEFFICIENTS AMONG YIELD AND COMPONENT CHARACTERS (6 YEAR)

Character	Height of tillers	Number of productive tillers per plant	Number of leaves per tiller	Number of panicles per plant	Number of capsules per panicle	Fresh weight of capsules per plant	Dry weight of capsules per plant	Hundred capsules weight	Capsule volume	Number of seeds per capsule	Length of panicle	Number of nodes per panicle	Internodal length in the panicle
Height of tillers	1.0000	0.8740	0.9014	0.9002	0.8193	0.8017	0.8782	0.3870	-0.4223	1.0248	0.9980	0.9976	0.9992
Number of productive tillers		1.0000	0.7573	0.7768	0.7026	0.7210	0.7762	0.2079	0.2616	0.6501	0.6444	0.6318	0.6617
Number of leaves per tiller			1.0000	0.9997	0.9992	0.9978	1.0000	-0.1866	-1.0084	0.7190	0.9996	0.9998	0.8096
Number of panicles per plant				1.0000	0.9989	0.9998	0.9980	-0.1722	-0.5946	0.5411	0.8518	0.9629	0.6008
Number of capsules per panicle					1.0000	0.9997	0.9978	-0.3130	-0.8066	0.4216	0.7881	0.9399	0.4621
Fresh weight of capsules						1.0000	0.9939	-0.3493	-0.7762	0.4314	0.8053	0.8873	0.5282
Dry weight of capsules							1.0000	-0.2301	-0.7020	0.5413	0.8718	0.9606	0.6346
Hundred capsule weight								1.0000	0.4524	0.8247	0.4211	0.3853	0.7742
Capsule volume									1.0000	0.0965	-0.5364	-0.8274	-0.0716
Seeds per capsule										1.0000	-0.9219	0.9515	1.0695
Length of panicle											1.0000	0.9989	0.9722
Nodes per panicle												1.0000	0.9998
Internodal length in panicle													1.0000

number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant, length of panicle, number of nodes/ panicle and internodal length in the panicle with values of 0.8782, 0.7762, 1.0000, 0.9980, 0.9978, 0.9939, 0.8718, 0.9606 and 0.6346 respectively. The characters, number of leaves/ tiller, number of panicles/plant and number of capsules/panicle gave very near perfect correlation with yield. Hundred capsule weight and capsule volume showed a negative correlation with yield in the sixth year group.

The cause effect relationship of the different attributes to yield was analysed and the data were presented in tables: 31 (third year group) and 32 (sixth year group). (Fig: 14 & 15)

Only the characters showing high positive correlation with yield were chosen for estimation of direct and indirect components in path coefficient analysis.

In the third year group the maximum direct effect on yield was recorded by the fresh weight of capsules/plant (1.02247) followed by number of productive tillers/plant (0.06684) and number of nodes/panicle (0.03027). The highest indirect effect of all the characters on yield was through the fresh weight of capsules/plant.

In the sixth year group the maximum direct effect on yield was recorded by the number of panicles per plant (1.36976)

Table : 31 PATH COEFFICIENT VALUES - DIRECT AND INDIRECT GENOTYPIC EFFECTS ON YIELD THROUGH VARIOUS YIELD COMPONENTS (3 YEAR)

Number of productive tillers per plant	Number of leaves per tiller	Number of panicles per plant	Number of capsules per panicle	Fresh weight of capsules per plant	Hundred capsule weight	Length of panicle	Number of nodes per panicle	Genotypic correlation with yield
0.06684	-0.01808	-0.07807	0.01229	0.93904	-0.01024	-0.00418	0.00851	r=0.9161
0.04762	-0.02538	-0.07058	0.01265	0.58618	-0.00757	-0.00724	0.00811	r=0.5438
0.05582	-0.01916	-0.09348	0.01265	1.02247	-0.00544	-0.00876	0.02869	r=0.9828
0.06491	-0.02538	-0.09348	0.01265	0.96542	-0.00912	-0.00857	0.01827	r=0.9247
0.06138	-0.01455	-0.09348	0.01195	1.02247	-0.00636	-0.00681	0.02540	r=1.0000
0.06237	-0.01751	-0.04634	0.01052	0.59252	-0.01097	0.00004	-0.01414	r=0.5765
0.03157	-0.02075	-0.09245	0.01225	0.78679	0.00004	-0.00886	0.02591	r=0.7345
0.01879	-0.00680	-0.08859	0.00764	0.85785	0.00512	-0.00758	0.03027	r=0.8167

RESIDUE = 0.00068

UNDERLINED NUMBERS INDICATE DIRECT EFFECTS

ALL OTHERS ARE THE INDIRECT EFFECTS

Table : 32 PATH COEFFICIENT VALUES - DIRECT AND INDIRECT GENOTYPIC EFFECTS ON YIELD THROUGH VARIOUS YIELD COMPONENTS (6 YEAR)

Height of tillers	Number of productive tillers per plant	Number of panicles per plant	Number of capsules per panicle	Fresh weight of capsules per plant	Length of panicle	Number of nodes per plant	Internodal length in the panicle	Genotypic correlation with yield
-0.02661	-0.11058	1.23306	-1.03806	0.99049	-0.92468	0.31968	0.43487	r=0.8781
-0.02325	-0.12653	1.06403	-0.89020	0.89078	-0.59706	0.17042	0.28798	r=0.7761
-0.02395	-0.09829	1.36976	-1.26562	1.23523	-0.78922	0.30856	0.26148	r=0.9979
-0.02180	-0.08890	1.36825	-1.26701	1.23511	-0.73020	0.30119	0.20111	r=0.9977
-0.02133	-0.09122	1.36949	-1.26663	1.23548	-0.74613	0.28434	0.22988	r=0.9939
-0.02655	-0.08153	1.16676	-0.99853	0.99493	-0.92653	0.32010	0.42312	r=0.8717
-0.02654	-0.06729	1.31894	-1.19087	1.09624	-0.92551	0.32045	0.43513	r=0.9605
-0.02659	-0.08372	0.82295	-0.58549	0.65258	-0.90077	0.32039	0.43522	r=0.6345

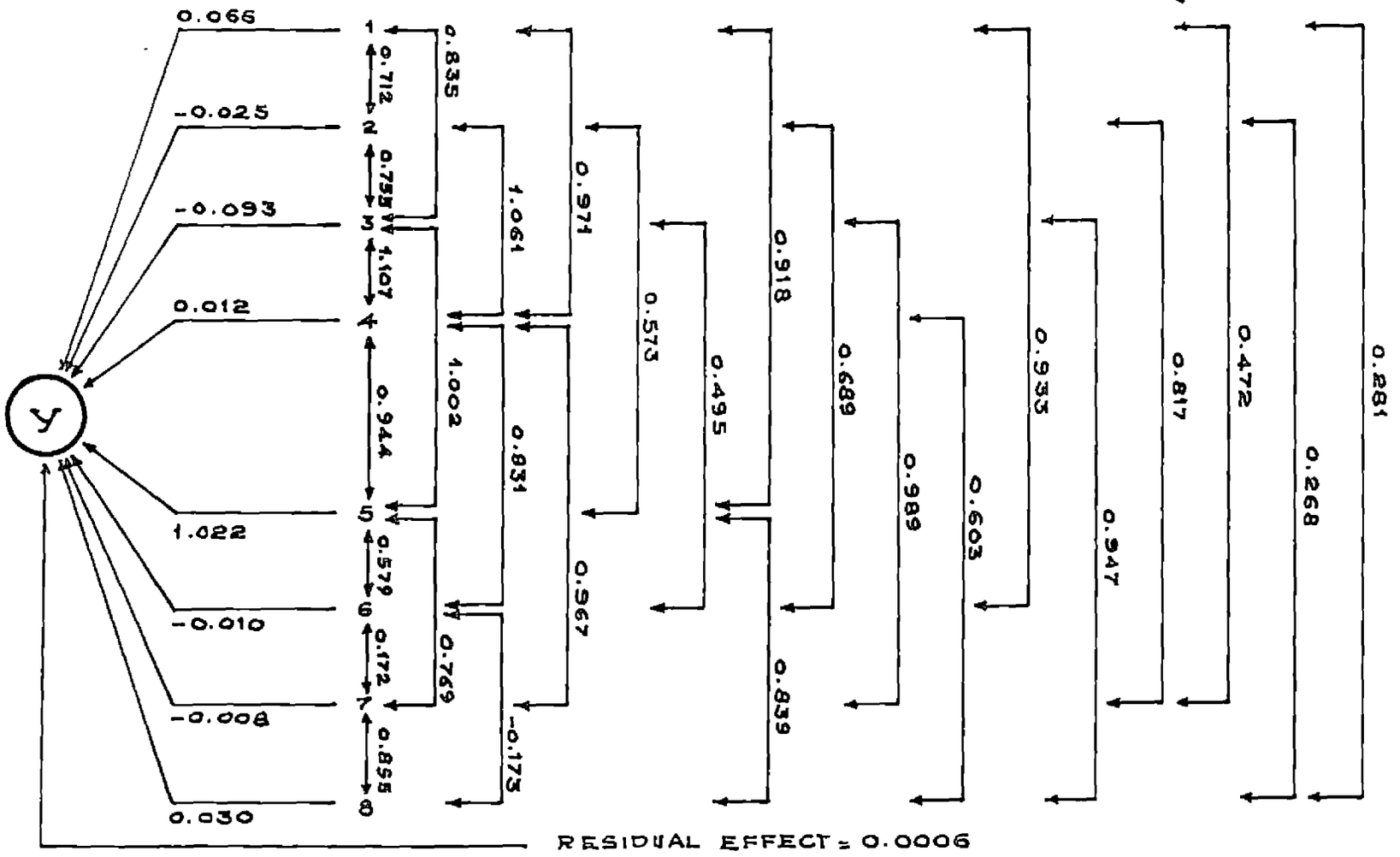
RESIDUE = 0.12090

UNDERLINED NUMBERS INDICATE DIRECT EFFECTS

ALL OTHERS ARE THE INDIRECT EFFECTS

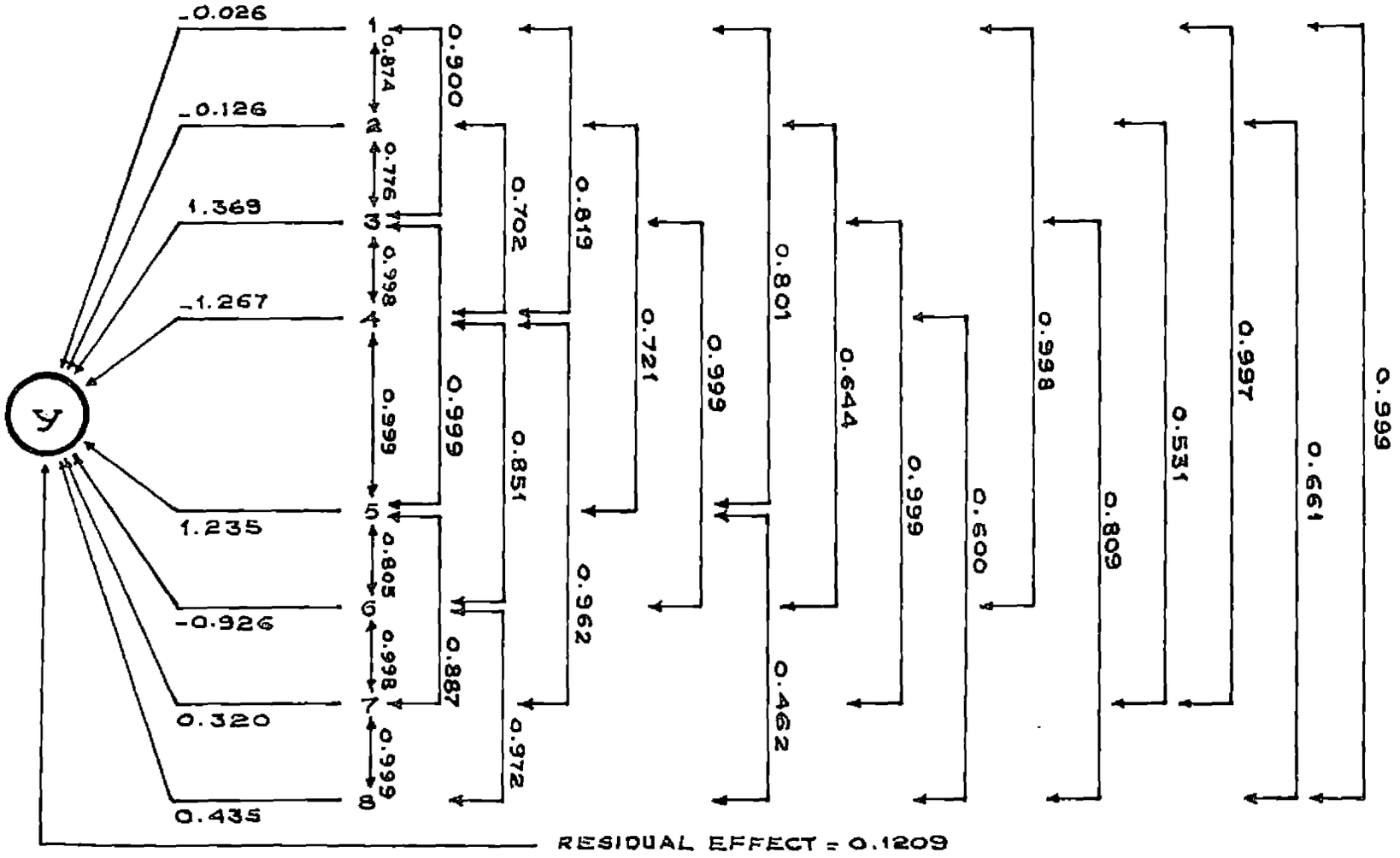
followed by fresh weight of capsules/plant (1.23548). The direct effects of number of capsules/panicle and length of panicle on yield were also high but negative, the values being -1.26701 and -0.92653 respectively. The highest indirect effect of the height of tillers, number of productive tillers, number of capsules/panicle, fresh weight of capsules/plant, length of panicle, number of nodes per panicle and internodal length in the panicle, on yield was through the number of panicles per plant.

FIG: 14. PATH DIAGRAM SHOWING THE DIRECT EFFECTS AND INTER-RELATIONSHIPS BETWEEN YIELD AND EIGHT SELECTED YIELD COMPONENTS IN CARDAMOM (THIRD YEAR)



Y = YIELD.
1 = NUMBER OF PRODUCTIVE TILLERS.
2 = NUMBER OF LEAVES PER TILLER.
3 = NUMBER OF PANICLES/PLANT.
4 = NUMBER OF CAPSULES/PANICLE.
5 = FRESH WEIGHT.
6 = HUNDRED CAPSULE WEIGHT.
7 = LENGTH OF PANICLE.
8 = NUMBER OF NODES/PANICLE.

FIG: 15. PATH DIAGRAM SHOWING THE DIRECT EFFECTS AND INTER-RELATIONSHIPS BETWEEN YIELD AND EIGHT SELECTED YIELD COMPONENTS IN CARDAMOM (SIXTH YEAR)



Y = YIELD.
1 = HEIGHT OF TILLERS.
2 = NUMBER OF PRODUCTIVE TILLERS.
3 = NUMBER OF PANICLES PER PLANT.
4 = NUMBER OF CAPSULES/PANICLE.
5 = FRESH WEIGHT.
6 = LENGTH OF PANICLE.
7 = NUMBER OF NODES/PANICLE.
8 = INTERNODAL LENGTH IN THE PANICLE.

DISCUSSION

DISCUSSION

The present investigation seems to be the first of its kind in this particular dollar yielding crop. Biometrical analysis on intra and inter varietal variations in cardamom revealed the existence of natural variability in the population for a positive selection response. The main objective of this study was to select out the better yielding clones in each variety and to fix the characters which will show a good response for selection and further improvement. The results of the study are discussed henceforth along with the reports of similar studies in related crops.

Intra varietal variability:

Analysis on intra varietal variation showed no significant variation for any of the traits. However, the cultivar Malabar showed the maximum range in mean values for the characters number of leaves/tiller, number of capsules/panicle and hundred capsule weight at the third year stage and for the height of tillers and number of nodes/panicle at the sixth year stage. In general the maximum range in mean values for a majority of yield attributing characters like number of productive tillers/plant, number of panicles/plant, fresh weight of capsules/plant and dry weight of capsules/plant was in Malabar at both the stages of growth.

In Vazhukka, the maximum range in mean values at the third year stage were recorded for number of nodes/panicle and number of seeds per capsule while at the sixth year stage maximum range in mean values were recorded for number of leaves/tiller, number of capsules/panicle, hundred capsule weight, capsule volume, fresh weight of capsules/plant and dry weight of capsules/plant. The minimum range in mean values for most of the characters studied at both the stages of growth were in the cultivars Mysore and PV-1 when compared to Malabar and Vazhukka. Except for internodal length in the panicle in Mysore and height of tillers and length of panicle in PV-1 at the third year stage, all other characters showed minimum range in mean values. At the sixth year stage both Mysore and PV-1 showed the minimum range in variability for a majority of the characters studied.

Analysis on the frequency distribution of the different phenotypes clearly demonstrated that the maximum frequency of positive variants for yield and its attributes were in the cultivars Malabar and Vazhukka at the sixth year stage and in Mysore and PV-1 at the third year stage. In the sixth year group the maximum frequency of positive variants in majority of the yield attributing characters like number of leaves/tiller, number of panicles/plant, length of panicle, internodal length in the panicle, number of capsules per panicle, and fresh

weight of capsules/plant were observed in Malabar followed by Vazhukka. The general trend in the number of positive variants in the third year stage was quite different from that in the sixth year stage, with the cultivars Mysore and PV-1 showing a higher frequency of positive variants.

Maximum positive variants for a majority of the yield attributing characters like height of tillers, number of leaves/tiller, number of panicles/plant, length of panicle, number of nodes/panicle and number of capsules/panicle were seen in the cultivar Mysore at the third year stage. For fresh weight of capsules/plant and dry weight of capsules/plant positive variants appeared in almost equal frequency at both the stages of growth. For PV-1, positive variants were observed at almost equal frequencies for fresh weight of capsules/plant and dry weight of capsules/plant at both the stages of growth. For number of nodes/panicle maximum positive variants were found at the sixth year stage. In all the other remaining ten characters the frequency of positive variants was maximum at the third year stage.

The estimates of coefficient of variation were high in Malabar, Vazhukka and Mysore while it was low in the cultivar PV-1. So in the light of the evidence on the studies of intra varietal variability and the frequency distribution of positive

variants it is indicated that the cultivars Malabar and Vazhukka may be more suitable for selection and further improvement at the sixth year stage since they show a greater range in variability and a higher frequency of positive variants. In Mysore and PV-1 the results indicated that the range of variability was narrow at both the stages of growth, more so in the sixth year stage. The frequency of positive variants was more at the third year stage thereby indicating that there is probably greater scope for selection and improvement at an earlier stage in both Mysore and PV-1.

Intra varietal variations in yield and its components were also reported in potato by Rieman et al.(1950) in the variety 'Chippewa', Davidson and Lawley (1953) in the variety 'King Edward' and Cockerham and Macarthur (1956) in the variety 'Majestic'. Harris et al.(1967) found evidence to suggest that the different environments altered the relative expression of growth and yield parameters in potato, clonal variation in potato was also reported by Terry et al.(1970). Distinct clonal variation was also reported in Mango in the varieties 'Alphonso' and 'Desheri' (Singh, 1971) in apricot 'Velkopavilovickal' (Vachun, 1981) and in sour cherry 'Oblacinska' (Milutinovic et al. 1981). Pattanshetti (1982) reported high variability in yield in cardamom. Rajeevan (1984) reported intraclonal variations for yield and its components in banana.

Inter varietal variability :

The present investigation clearly demonstrated the existence of appreciable amount of variability among the varieties tested. Out of the thirteen quantitative characters studied, eight characters showed significant variations. These characters were number of productive tillers/plant, height of tillers, number of panicles/plant, internodal length in the panicle, number of capsules/panicle, capsule volume, fresh weight of capsules/plant and dry weight of capsules/plant. Wide range of variability was exhibited by height of tillers, fresh weight of capsules and dry weight of capsules. Number of productive tillers/plant, number of panicles/plant, internodal length in the panicle, number of capsules/panicle and capsule volume showed narrow range of variability.

There was also significant variation between the age groups for all the thirteen characters studied and for the variety x age group interactions. The varieties Malabar, Mysore and Vazhukka recorded higher mean values at the sixth year stage for all the characters compared to those at the third year stage. But PV-1 showed low mean values at the third year stage for number of productive tillers/plant, number of leaves/tiller, internodal length in the panicle, hundred capsule weight and capsule volume.

For almost all characters wide range of variability was observed among the varieties, Malabar and Vazhukka at the sixth year stage. In characters like 100 capsule weight, capsule volume, number of nodes/panicle and height of tillers wide variability was expressed at the third year stage in PV-1 and Mysore. This indicated that a steady stage in growth and other characters are attained by different varieties at different stages. In general it can be seen that the cultivar Malabar was superior to Vazhukka, Mysore and PV-1 with respect to yield and its attributes.

The phenotypic variability may be due to genetic or environmental factors or due to the interaction between the two. Hence partitioning of the total variability into heritable and non-heritable portions helps the breeder to assess the genetic value of the various genotypes and also the extent of improvement that can be achieved in a particular crop. To make a more valid comparison phenotypic and genotypic variability were computed in terms of the corresponding coefficients of variation Viz. phenotypic coefficient of variation (p.c.v.) and genotypic coefficient of variation (g.c.v). In the present study high g.c.v. values were observed for dry weight of capsules/plant, fresh weight of capsules/plant and number of productive tillers/plant in the third year group and for the number of productive

tillers/plant, number of panicles/plant, fresh and dry weight of capsules/plant in the sixth year group. This indicated that these characters are potentially variable. This was in accordance with the reports made by Biradar et al.(1978) in Cassava, where the phenotypic and genotypic coefficients of variation were high for tuber yield per plant. Mohanty et al.(1979) found that the genotypic coefficient of variation was high for number of secondary rhizome fingers and total root weight in ginger.

The difference between the phenotypic and genotypic coefficients of variation for the different traits indicated that it was least in the number of seeds per capsule, internodal length in the panicle and hundred capsule weight. This clearly suggested that these characters were least influenced by the environment and genetic factors play a dominant role in determining the expression of these traits. The large difference between the two coefficients of variability (p.c.v and g.c.v) observed in the case of fresh and dry weight of capsules/plant, number of nodes per panicle, number of leaves/tiller and number of panicles/plant indicated that external factors play an important role in determining their expression.

The estimates of heritability separate the genetic variability from phenotypic variability and indicate the possibility and extent to which improvement can be brought about through proper

selection. It also provides us with a clear picture of the average effect of genes transmitted from parents to offspring or ratio of additive genetic variance to total variance. Heritability along with genetic gain is usually more useful than heritability estimate alone in predicting the selection response (Johnson et al, 1955; Swarup and Chaugale, 1962). Heritability estimates in the broad sense will be reliable if accompanied by a high genetic advance (Ramanujam and Thirumalachar, 1967).

In the present investigation the third year data showed moderate to high heritability values followed by high genetic gain for the characters number of productive tillers/plant, huhdred capsule weight, fresh weight of capsules/plant and dry weight of capsules/plant. In the sixth year data, moderate to high heritability and high genetic gain were recorded for characters like number of panicles/plant, fresh and dry weight of capsules/plant and number of capsules/panicle.

The moderate to high heritability, and high genetic gain observed for the characters, fresh and dry weight of capsules/plant, at both the stages of growth suggests that these characters are mainly of the additive type and will show a high response for selection and improvement as reported by Panse (1957) Johnson et al.(1955) Wright (1935) in other crops.

In the case of number of productive tillers and internodal length in the panicle eventhough heritability estimates were high the values for genetic gain were low showing that high heritability of the above characters is probably due to non-additive (Dominance and epistatic) gene effects as reported by Panse (1957).

Correlation and path coefficient analysis :

Yield is an important polygenic character which has a highly complex system of inheritance and expression subjected to varying environmental fluctuations. For better understanding of the inter-relationship of yield and its components genotypic correlation coefficients have been calculated for the third and sixth year groups of the four most popular varieties of cardamom.

In the present investigation it was observed that the yield or dry weight of capsules/plant is positively and highly correlated with other eight polygenic characters. Yield or dry weight of capsules/plant in the third year group showed strong positive correlation with number of productive tillers/plant, number of leaves/tiller, number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant.

In the sixth year also generally the dry capsule yield/plant was strongly and positively correlated with height of

tillers, number of leaves/tiller, number of productive tillers/plant, number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant, length of panicle, number of nodes/panicle and internodal length in the panicle. Similar positive correlations of different morphological characters with yield were reported by Mohanty et al.(1979) and Sreekumar et al.(1980) in ginger, Magoan (1972), Muthukrishnan et al. (1973), Wilson (1976), Ribeiro (1977) and Radhakrishnan and Gopakumar (1984) in tapioca. Maity and Chatterjee (1977), Sequra et al.(1978), Challaiah and Kulkarni (1978) and Dayal et al. (1984) in potato. Wei et al.(1985) reported that height and weight/bunch were positively correlated in banana.

The path analysis method introduced by Wright (1921), further helps us not only in revealing in absolute terms the relationship between yield and its components, but also helps in estimating more or less accurately the direct effect of each of the causes and the indirect effect that each of them contribute through other components, in the final causation of the effect.

Among the eight characters which showed strong positive correlation with yield which were selected for the path coefficient analysis, only four characters namely number of productive tillers/plant, number of capsules/panicle, fresh weight of capsules/plant and number of nodes/panicle showed positive

direct effect with yield in the third year group. Number of leaves/tiller, number of panicles/plant, hundred capsule weight and length of panicle showed a negative direct effect. The fresh weight of capsules/plant showed the highest positive direct effect on yield and the indirect effects of all the other characters were low. In the case of number of productive tillers/plant, number of capsules/panicle and number of nodes/panicle, the positive direct effects were very low and the strong positive correlation seen with yield was more through the indirect effect of fresh weight of capsules/plant. The other four characters Viz. number of leaves/tiller, number of panicles/plant, hundred capsule weight and length of panicle which showed very low negative direct effects had positive correlation with yield through the strong indirect effect of fresh weight of capsules/plant.

In the sixth year group the path analysis revealed that the number of panicles/plant, fresh weight of capsules/plant, number of nodes/panicle and internodal length in the panicle had the highest positive direct effects on yield indicating the importance of these characters to be used in selection indices for cardamom. The height of tillers, number of productive tillers/plant, number of capsules per panicle and length of panicle showed negative direct effects on capsule yield/plant. Both the number of nodes/panicle and the internodal length in the panicle

showed low positive direct effects and the reason for their high correlation with yield was more through the high indirect effect of the number of panicles/plant and fresh weight of capsules/plant. Similarly the number of capsules/panicle and length of panicle which showed a high negative direct effect was positively correlated with yield because of the high indirect effect of number of panicles/plant and fresh weight of capsules/plant. The height of tillers and number of productive tillers recorded low negative direct effect though they showed high positive correlation with yield. This is also because of the strong indirect effects through the characters, number of panicles per plant and fresh weight of capsules/plant. Hence selection for plants with higher number of panicles and high fresh weight of capsules is essential for ultimate realisation of yield in cardamom.

SUMMARY

SUMMARY

The present investigation was carried out at the Cardamom Research Station, Pampadumpara during the period 1985-86. Four popular varieties of cardamom (Elettaria Cardamomum Maton) Viz. Malabar, Mysore, Vazhukka and PV-1 (a selection from Malabar) planted at the above station were used for the experiment.

Plants of two age groups (three years and six years) from the above four varieties were selected for the study. One hundred plants of each variety in each age group were labelled seperately and randomly divided into five replications consisting of twenty plants/replication. Observations on thirteen characters viz. number of productive tillers/plant, height of tillers, number of leaves/tiller, number of panicles/plant, length of panicle, number of nodes/panicle, internodal length in the panicle, number of capsules/panicle, hundred capsule weight, capsule volume, number of seeds/capsule, fresh weight of capsules/plant and dry weight of capsules/plant were recorded and analysed statistically to determine the amount of variability within and between varieties. Analysis on intra varietal variation revealed that, in general the maximum range in mean values for yield and its attributes was in the cultivar Malabar at both the stages of growth. The maximum frequency of positive

variants were in the cultivars, Malabar and Vazhukka at the sixth year stage and in Mysore and PV-1 at the third year stage, thereby indicating that there is probably greater scope for selection and improvement at an earlier age in both Mysore and PV-1 and at a later age in Malabar and Vazhukka. The values for the coefficient of variation was higher in Malabar, Vazhukka and Mysore while it was very low in PV-1.

Analysis of inter varietal variability showed significant differences between the four varieties tested, for eight characters viz. number of productive tillers/plant, height of tillers, number of panicles/plant, internodal length in the panicle, number of capsules/panicle, capsule volume, fresh weight of capsules/plant and dry weight of capsules/plant. It was also seen that all the varieties showed significant variation with increase in age, for all the thirteen characters studied.

The phenotypic coefficient of vatiation (p.c.v.) was higher than the genotypic coefficient of variation (g.c.v.) in all the characters analysed. The fresh and dry weight of capsules/plant recorded high values for p.c.v. and g.c.v. in the third year group, and the number of productive tillers/plant also had a moderately high value for the genotypic coefficient of variation at the third year stage. In the sixth year group the number of productive tillers/plant had the highest values

for p.c.v. and g.c.v. while the values were moderately high for both p.c.v. and g.c.v. in fresh weight of capsules/plant, dry weight of capsules/plant and number of panicles/plant. Analysis on the genetic parameters concerned with yield attributes in both the years indicated the scope for further improvement in yield potential in this crop through combination breeding programme.

Estimation of heritability (broad sense) revealed that hundred capsule weight had the highest value followed by capsule volume. Internodal length in the panicle height of tillers number of productive tillers/plant also showed high heritability values in the three year group. The estimates were low for number of capsules/panicle and number of seeds/capsule, the latter having the lowest heritability.

In the sixth year group the number of productive tillers/plant had the highest value for heritability in the broad sense followed by internodal length in the panicle. Number of panicles/plant, number of seeds/capsule, number of capsules/panicle and hundred capsule weight also showed moderately high values. The estimates were low for number of leaves/tiller and number of nodes/panicle, with the latter having the lowest heritability.

Moderate to high heritability together with high genetic gain was seen for number of productive tillers/plant, hundred

capsule weight, fresh and dry weight of capsules/plant; in the third year group suggesting that these characters are mainly of the additive type and will show a high response for selection. Similarly in the sixth year group the number of panicles/plant, fresh and dry weight of capsules, and number of capsules/panicle showed moderate to high heritability and high genetic gain and may be expected to show a high response for selection and further improvement.

Studies on the genotypic correlation coefficients revealed that the dry weight of capsules/plant (yield) is positively and highly correlated with number of productive tillers/plant, number of leaves/tiller, number of panicles/plant, number of capsules per panicle, fresh weight of capsules/plant, hundred capsule weight, length of panicle and number of nodes/panicle in the third year group. In the sixth year group yield was strongly and positively correlated with height of tillers, number of productive tillers/plant, number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant, length of panicle, number of nodes/panicle and internodal length in the panicle.

Path coefficient analysis at the genotypic level in the third year group showed that number of productive tillers/plant,

number of capsules/panicle, fresh weight of capsules/plant and number of nodes per panicle showed positive direct effect with yield with the fresh weight of capsules/plant showing the highest positive direct effect on yield. In the sixth year group, the number of panicles/plant showed the maximum direct effect on yield followed by fresh weight of capsules/plant, number of nodes/panicle and internodal length in the panicle. Both the number of nodes per panicle and the internodal length in the panicle showed low positive direct effect and the reason for their high correlation with yield was more through the high indirect effect of the number of panicles/plant and fresh weight of capsules. Based on the studies conducted it is suggested that a plant with higher number of panicles/plant and high fresh weight of capsules promises a positive response to increase the yield of cardamom/unit area.

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*Originals not seen

INTRA AND INTER VARIETAL VARIABILITY ANALYSES IN CARDAMOM

(*Elettaria cardamomum Maton*)

By

GOPAL RADHAKRISHNAN

ABSTRACT OF A THESIS

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ABSTRACT

The present investigation was conducted at the Cardamom Research Station, Pampadumpara to obtain information on the magnitude of genetic variability in the population and the extent to which the desirable characters are heritable.

Four popular cultivars *viz.* Malabar, Mysore, Vazhukka and PV-1 of two age groups three and six year old planted at the above station were used for the study. Observations were made on height of tillers, number of productive tillers/plant, number of leaves/tiller, number of panicles/plant, number of capsules/panicle, fresh weight of capsules/plant, dry weight of capsules/plant, hundred capsule weight, capsule volume, number of seeds/capsule, length of panicle, number of nodes/panicle and internodal length in the panicle. The data collected was subjected to studies on genetic variability, estimation of genetic parameters, correlation and path coefficient analysis.

Variability analysis revealed that significant differences exsisted among the varieties for eight of the thirteen morphological characters studied. They were number of productive tillers/plant, height of tillers, number of panicles/plant,

internodal length in the panicle, number of capsules/panicle, capsule volume, fresh and dry weight of capsules/plant. The variability within the varieties was not significant.

The phenotypic coefficient of variation (p.c.v.) was higher than the genotypic coefficient of variation (g.c.v.) in all the characters studied. The fresh and dry weight of capsules per plant recorded high values for p.c.v. and g.c.v. in the third year group, while the number of productive tillers/plant had the highest value for p.c.v. and g.c.v. in the sixth year group. Moderate to high heritability together with high genetic gain was seen for number of productive tillers/plant, hundred capsule weight, fresh and dry weight of capsules/plant in the third year group and for number of panicles/plant, fresh and dry weight of capsules/plant and number of capsules/panicle in the sixth year group.

Studies on the genotypic correlation of different characters revealed that yield was positively and highly correlated with number of productive tillers/plant, number of leaves/tiller, number of panicles/plant, number of capsules/panicle, length of panicle, number of nodes/panicle, hundred capsule weight and fresh weight of capsules/plant in the third

year group. And in the sixth year group yield was strongly and positively correlated with height of tillers, number of productive tillers/plant, number of panicles/plant, number of capsules/panicle, length of panicle, number of nodes/panicle, internodal length in the panicle and fresh weight of capsules/plant.

Path analysis revealed that the maximum direct contribution to yield was through fresh weight of capsules/plant in the third year group and number of panicles/plant and fresh weight of capsules/plant in the sixth year group. This suggests that selection for improvement of yield in cardamom should be based on fresh weight of capsules/plant and number of panicles/plant.