GENETIC VARIABILITY AND CORRELATION STUDIES IN COCOA (*Theobroma cacao L.*)

By

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THESIS

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the requirements for the degree of

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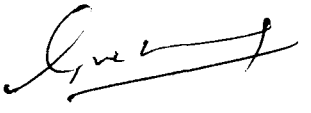
DECLARATION

I hereby declare that this thesis entitled "Genetic variability and correlation studies in cocoa (*Theobroma cacao* L.)" 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 any degree, diploma, associateship, fellowship or other similar title of any other University or Society.



Vellanikkara,
28-6-1983.

GREGORY ZACHARIAH

CERTIFICATE

Certified that this thesis entitled "Genetic variability and correlation studies in cocoa (*Theobroma cacao* L.)" is a record of research work done independently by Sri. Gregory Zachariah 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.

Vellanikkara,
28-6-1983.

Dr. K. Kumaran,
Professor, K.A.D.P.,
Chairman,
Advisory Committee.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Sri. Gregory Zachariah, a candidate for the degree of Master of Science in Agriculture agree that the thesis entitled "Genetic variability and correlation studies in cocoa (*Theobroma cacao* L.)" may be submitted by Sri. Gregory Zachariah, in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Cocoa (*Theobroma cacao*) is one of the most popular beverage crops extensively cultivated in the tropical situations in Africa, South America, West Indies and the Far East. In India, this crop was introduced into cultivation only recently. During the latter half of the 1970's, there was massive expansion of cocoa cultivation in India as a result of the attractive price that prevailed during early part of 1970's and the massive development programmes implemented by the State Department of Agriculture. Cocoa has become popular in Kerala mainly as an intercrop in coconut and arecanut gardens.

It is estimated that out of the total area of 20,000 ha under cocoa in India, Kerala accounts for about 15,000 ha followed by Karnataka with 4,400 ha and Tamil Nadu (600 ha). During 1980, India exported 1000 tonnes of cocoa products worth Rs.10 lakhs (Anon., 1981). The production of raw cocoa in India during 1981-82 was about 3080 tonnes; Kerala's contribution being 2500 tonnes. India's requirement of cocoa has been estimated to be around 5000 tonnes per year by 2000 AD (Ananthakrishnan *et al.*, 1979).

Forastero and Criollo are the two important varieties Experiences have shown that Forastero variety has better

adaptability and productivity under Kerala Conditions. Forastero provides the bulk of the commercial cocoa of the world. In order to boost cocoa production in the state, genetic improvement of the crop through selection from the existing sexually reproducing population offers considerable scope. Crop improvement through selection depends largely on the extent of genetic variation. Seedling populations of cocoa generally exhibit a great amount of heterogenity because of cross pollination which also results in the manifestation of a high level of variability in most of the plant characters. This variability can be attributed mainly to genetic factors or to a certain extent to environmental factors or to an interaction of both, the degree of each of these, however varies with the genetic structure of the particular population under consideration.

Attempts to gather information on the extent of genetic variability in respect of the economic attributes including yield, the nature of association between yield and yield contributing characters in the seedling population of Forastero under conditions prevailing in the state have not been undertaken so far. Such information is essential to undertake identification and selection of superior genotypes in the seedling population of cocoa, particularly the Forastero type, in order to achieve improvement in yield and other characters. These genotypes can after evaluation, be utilized as clones and as parents in hybridization programmes.

The present study in a well established population of Forastero trees, therefore, was undertaken with the objectives of:-

1. to study the extent of genetic variability existing in important plant, pod and bean characters of cocoa,

2. to find the interrelationship between yield and yield contributing characters, and

3. to identify superior genotypes which can be developed into clones for future studies.

Review of Literature

REVIEW OF LITERATURE

In cocoa, biometrical information like variability, correlation etc. is scanty. Available literature on the variability and correlation of different morphological characters including yield is briefly reviewed below.

A. Variability

Variability for some of the growth characters has been reported earlier. Greenwood and Posnette (1950) observed that overhead shade influences the growth of flushes of cocoa in Ghana. It was found that unshaded mature cocoa flushed more frequently and with greater intensity than shaded cocoa and that this difference was more marked during periods of low temperature. They also observed that the flushing of mature cocoa was suppressed when the weekly mean of the daily maximum temperature was below 85°F. Sale (1967) reported that at continuously high temperatures of 33°C (88°F) the hormone system of the tree was upset with the result that there is a loss of apical dominance and the leaves are smaller at higher temperatures.

Cocoa trees differ widely in their ability to produce flowers and to set fruits. Hewison and Ababio (1929) stated that only 0.2 to 1.5 per cent of the opened flowers developed into mature fruit. Purseglove (1974) as well as Cobley and Steele (1976) also recorded that only one in 500 flowers (0.2 per cent) matured to a fruit. Murray (1975) reported

that out of about ten thousand flowers produced by a full grown plant in a year only 10 to 50 developed as mature pods. Flowering has been found influenced by different weather conditions. Alvim (1966) reported that flowering was inhibited when the monthly mean temperature went below 23°C. Couprie (1972) recorded that flowering was greatest when the daily temperature variation was the least. Murray (1975) reported that cocoa is cauliflorus, the inflorescence arises in a leaf axil and is a very compressed dichasial cyme. Toxopeus and Jacob (1970) reported that inadequate fertilisation of the ovule of the cocoa flowers seemed to be the main cause of variability in the number of beans per pod.

Studies conducted in Trinidad by Pound (1932) showed that the thickness of the ridge and depth of the furrow of cocoa pods are very descriptive characters, but are partially affected by environment. He also reported that trees in Trinidad were variable in the number of pods they produced and the number of pods required to produce one pound of dry beans. This factor known as 'pod value' was found to vary from 6 to 22 pods per pound of dry cocoa. He also observed that Forastero variety produced 100 to 200 pods per year and the pod value was 10 to 12.

Pound (1933) observed that size of cocoa beans expressed in dry weight or wet weight was a variable character and was quantitative in nature. He also reported that seed

weight ranged from 0.5 g to 2.5 g. He observed variability of beans within a single pod itself. Stockdale (1928) studied the variability in width, length and thickness of seeds of 609 cacao trees in a Forastero population, pointing out great variability of these features. Paterson and Reed (1934) proposed a statistical method to classify cocoa beans by shape.

Enriques and Soria (1968) made an assessment of variability in wet weight, length, width, thickness of shell, pulp percentage and number of beans per pod in fresh samples from cocoa of different genetic origin. Interclonal differences in these characters were highly significant indicating that they are useful for clonal classification. The best sample size, according to these workers, was found to be three seeds of 20 pods per clone. They also opined that among other sample sizes, weighing five beans from each of 20 pods of one clone would give an adequate sample to evaluate its dry or wet weight.

Eskes et al. (1977) reported that dry bean production per pod was closely related to bean number than to average bean weight. They observed that in fruits with a relatively high number of beans, the average bean weight is of major importance.

Tollenaar (1958) reported a wide diversity of incidence of black pod infection from zero to 95 per cent. Incidence

of black pod disease causing enormous losses were estimated by Padwick (1959). Blencowe and Wharton (1961) found a significant positive correlation between the number of black pods and the total number of pods per acre in Ghana. Hislop and Park (1952) reported that the number of black pods per tree varied directly with the number of total pods per tree based on their studies in cocoa populations in Nigeria.

Burton (1952) suggested the estimation of genetic coefficient of variation along with the heritability estimates to determine the amount of heritable variation. Hanson et al. (1956) reported that heritability estimates are the true indications of the genetic potentiality of an individual which act as a tool in selection. According to Panse (1957) the magnitude of heritable variability is the most important aspect of the breeding material which has a close bearing on its response to selection. Studies of Gupta (1972) and Rangaswamy and Shanmughavelu (1980) showed that the genotypic coefficient of variation generally helps to measure the extent of genetic variability. Soria et al. (1974) observed high heritability for yield in hybrids of Trinitario and Criollo varieties. They also found moderately high heritability for pod and bean characters like pod length (55 per cent), pod diameter (63 per cent) and pod weight (57 per cent). Kumaran and Prasannakumari (1981) observed high heritability estimates for weight of bean and

weight of cotyledons and medium heritability for pod weight, pod length, pod diameter, pod husk thickness and weight of wet beans per pod in a study involving eight pod and bean characters in a random population of cocoa, variety Forastero.

B. Correlation

Pound (1932) and Bartley (1965) suggested that production of cocoa is better estimated by wet bean weight. Glendinning (1960) noted the relationship between growth and yield in cocoa was positively correlated with the rate of trunk diameter during early stages of growth. A difference of 1.2 centimetre per annum in the pre-bearing rate of trunk diameter increase seemed to be roughly equivalent to a difference in yielding capacity of 1,600 lbs. of dry cocoa per annum.

Vanderkmaap (1954) shewed that the beans from the middle of the pod were slightly heavier than those from either end. There was no relationship between bean weight and cotyledon colour. Alvardo and Bullard (1961) found a positive and significant correlation between bean size and fat content and a highly significant negative correlation between total size and shell percentage. Glendinning (1963) found a significant positive correlation between number of fruits produced and total wet weight of their seeds showing that in some populations number of fruits was a good estimate of yield. He also reported that size of seeds was

relatively constant for a tree, but it was influenced positively by the size of the pod and negatively by the number of seeds per pod.

Cheesman and Pound (1934) considered 'Pod value' and 'Seed index' as the main constants for the selection of individual trees. The basic methodology for selection of cocoa clones for yield was developed in Trinidad by them. They estimated the total capacity of yield in Trinitario population based on seed index, pod value, number of beans per pod and total number of pods per tree per year.

Multiple regression analysis, as suggested by Goulden (1952) has been used in many crops for formulating selection index. Anand and Terrie (1963) reported that the number of pods per plant and seeds per pod were more important than seed weight for predicting the yield in soyabean. Thamburaj (1973) carried out multiple regression analysis in ridge gourd and reported that the pod weight and number of seeds per pod had a significant effect on yield per plant.

Glendinning (1965) reported that correlations were found to exist between the rate of growth before bearing and the total yield upto 5 years. After bearing, vegetative growth slowed down and there was a high correlation between the reduction in growth rate and total yield. This suggests that an equation "Growth rate before bearing = growth rate while bearing + yield" may be used. A high yielding variety

will be thus the one making vigorous early growth which is later relatively greatly reduced. In the opinion of Pound (1933), in cocoa, yield of a tree can be estimated from the product of the number of pods it produced over a period of years and the average wet weight of cocoa per pod. The criteria for selection in Trinidad is 7.5 pods to a pound of dry cocoa or 150 g of wet cocoa per pod. Since high pod value and heavy bearing have been shown to exist in combination in some trees there is little danger that selecting for large pods will eliminate all the heavy bearers.

Relationship between girth of tree trunk and yield was established in crops like coconut, coffee, mango, etc. Patel (1938) reported that girth of the stem in coconut was influenced by variety, fertility and moisture condition of the soil and its management. The girth of the stem does not appreciably change with age, when once it has reached the maximum size.

Dhaliwal (1968) observed that yield was positively and significantly correlated with the circumference of the main stem at ground level in Coffea arabica. Yield also showed positive and significant correlation with height of tree. Girth of the trunk indicated the general vigour of the tree and tree vigour is considered as a criteria for yield in many trees as reported by Teotia et al. (1970) who could correlate the tree vigour to yield in mango. Thamburaj (1973) reported

that pod weight was significantly and positively correlated with yield in ridge gourd. He also reported that number of seeds per pod was also significantly and positively correlated with yield.

Materials and Methods

MATERIALS AND METHODS

The investigations were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period 1980-81 (July-August) on 10 year old trees available in the K.V.U. Estate, Alpara, Kannara in Trichur District. This garden is located at an altitude of 55-60 metres above mean sea level and is situated between 10.5 N latitude and 76.17 E longitude. The meteorological data for the season under experimentation are presented in Appendix I and II.

The Estate is typical of the cocoa gardens in the state, cocoa being intercropped in a 20 year old arecanut garden. In arecanut where the normal spacing is 2.7 m x 2.7 m, cocoa is planted in the centre of four areca palms. Both cocoa and arecanut were given cultural and manurial treatments as per the package of practices of the Kerala Agricultural University. Cocoa trees were regularly pruned of excess fan shoots and were sprayed with one per cent Bordeaux mixture, twice before and after the monsoons. The land is properly terraced and is highly fertile. The field is usually flood irrigated during December to April when drought conditions set in.

A. Experimental materials

The experimental material consisted of 135 ten-year old cocoa trees of the variety Forastero. The sample represented

about ten per cent of the total population of cocoa trees in the garden. The trees were originally raised from selected seedlings supplied by the Department of Agriculture, Kerala. The trees were yield-stabilized at the time of the studies and they in general, possessed characters typical of the variety Forastero. This variety is characterised by pods whitish or green ripening yellow, usually inconspicuously ridged and furrowed; surface smooth, ends rounded or very bluntly pointed; and by relatively thick pod husk with a woody layer inside which is difficult to cut, flattened, fresh cotyledons deeply pigmented and dark violet in cross section, usually giving astringent product. Trees are hardier, more vigorous and higher yielding than Criollo types (Pursoglove, 1974).

B. Experimental methods

The garden was divided into four contiguous blocks consisting of 288 trees in Block I, 288 trees in Block II, 396 trees in Block III and 400 trees in Block IV. Consulting random number table 30 trees from Block I, 30 trees from Block II, 40 trees from Block III and 35 trees from Block IV were selected at random. All the trees were given number in the serial order. During selection, trees of the non-Forastero type were eliminated based on their morphological features and appearance.

Observations on the following vegetative characters, pod and bean characters were recorded from each tree. Characters like jorquette height, girth of trunk and number of cushions per unit area were observed once, while for other characters, observations from representative samples were observed.

1. Vegetative characters

a. Jorquette height: Height of the first jorquette was measured in centimetres as the vertical distance from ground level upto the first jorquetting point, using a meter scale.

b. Girth of the trunk: Girth of the trunk at 15 cm above the ground level was measured in centimetres using a non-stretching cloth tape.

c. Intensity of flushing: New flushes formed in the four aspects namely, north, south, east and west of each tree were observed in an area of 0.25 sq.m. during the month of October-November. For this a square shaped wooden frame of 0.5 m was used. The number of fan branches with and without new flush was counted and the intensity of flushing was recorded using the following grades:

0, No flushing

1, 25 per cent flushing

2, 50 per cent flushing

3, 75 per cent flushing

4, 100 per cent flushing

d. Intensity of flowering

i) Flowering in the trunk: A distance of 50 cm starting from the first jorquetto downward was marked all around the trunk. Total number of cushions in this area was counted from all trees. Ten cushions were selected at random from among all cushions in the 50 cm space and the number of flowers per cushion was recorded.

ii) Flowering in main branch: One main branch on the right side from north aspect and emerging from the first jorquette of each of the trees was selected. A distance of 50 cm was marked on the branch 50 cm away from the jorquette. Number of cushions was counted and number of flowers per cushion from 10 of the selected cushions were recorded as in item d.i. Three grades for the intensity of flowering namely, profusely flowering or floriferous, medium flowering, and poor flowering were adopted to classify the trees. Mean number of flowers per cushion from a unit area in the trunk and in one main branch was also worked out.

e. Pollen fertility: Pollen fertility was found out using acetocarmine staining technique (Zirkle, 1937). Mature flower buds were collected in distilled water from the trees before the anther dehiscence.

Five flower buds were collected from each tree and two anthers from each flowerbud were crushed and slides were prepared in acetocarmine-glycerine mixture. The slides were kept for about 30 minutes for proper staining before examining under the microscope. Pollen fertility was calculated in percentage of a total number of about hundred pollen counted from five to ten microscopic fields.

2. Pod characters

a. Pod set per cushion: Number of pods (cherellae) set per cushion was counted from each of the ten randomly selected cushions and the percentage of pod set was worked out.

b. Pods per cushion: Number of pods developed in the selected ten cushions during the period of study was recorded and mean per cushion was worked out.

c. Pods per tree per year: Number of pods developed including diseased and otherwise damaged pods in two cropping seasons during July 1980-August 1981 was counted from all the trees. Counts of the pods were made at monthly intervals.

d. Potential yield per tree per year: Potential yield of wet beans per tree per year (kg) was worked out for each tree as the product of the mean wet weight of the beans per pod and the number of pods per tree.

From each tree five uniformly ripe pods were selected at a time and the following five characters were studied and their averages worked out.

e. Length of pod: Length of mature pod was measured in cm from pedicel end to apex.

f. Weight of pod: The fresh weight of the pod was recorded in gram.

g. Girth of pod: The girth at the middle portion of each of the pod was measured in centimetre.

h. Volume of pod: Volume of pod was recorded in cubic centimetre by the water displacement method.

i. Husk thickness: Husk thickness was measured in millimetre at the middle part of each pod using a vernier caliper.

j. Pod value and convertion ratio: Pod value can be defined as the number of pods required to produce one pound of dry beans.

$$\text{Convertion ratio} = \frac{\text{Dry weight of beans}}{\text{Wet weight of beans}} \times 100$$

As the number of ripe pods from each tree was not sufficient for curing and for working out actual convertion ratio, a general theoretical estimate of the convertion ratio of 40 as derived from preliminary observations was used to compare pod values for all the trees in the present study.

k. Black pod incidence: The extent of Phytophthora palmivora incidence during the period of study was observed for each tree and percentage of incidence in relation to the total number of pods developed was calculated.

3. Bean characters

A sample of five mature pods which were used for observing pod characters were broken and the beans were observed for the following eight characters of all the 135 trees.

a. Wet weight of beans per pod: Total wet weight (g) of all the beans in a pod was recorded per tree.

b. Beans per pod: Total number of fully developed beans in a pod was counted per tree.

c. Germinated beans per pod: Number of germinated beans in a pod was counted for five pods of each tree.

d. Flat beans per pod: Counts were made of the number of flat beans in a pod per tree.

e. Wet weight of one bean: Weight of ten beans, two each taken from all the five pods was recorded in gram. Mean weight of a bean was worked out.

f. Volume of one bean: Volume of ten beans drawn from five pods was recorded in cubic centimetre by the water displacement method. Mean volume of one bean was then estimated.

g. Seed index: This represents the mean weight of a dry bean. A sample of 20 beans from the five selected pods of each tree was cured by keeping them in sweat boxes containing bulk beans under fermentation following the mini box method of fermentation (Kumaran et al., 1980). The mean weight of a bean was worked out for all the trees.

h. Percentage of shell and cotyledon: Twenty cured beans were peeled and the weight of shell (testa) and cotyledons was taken. The percentage shell content and cotyledon content were worked out for all the trees.

C. Statistical analysis

The mean, range and standard error values for the various characters under study were worked out from the data collected. The details of the statistical analysis carried out are presented below:

1. Estimation of variability and heritability

Variability existing in yield and yield contributing characters was estimated as suggested by Burton (1952). The formulae used in the estimation of variability at genotypic and phenotypic levels are:

a) Genotypic coefficient of variation = (G.C.V.)

$$= \frac{\text{Genotypic standard deviation}}{\text{Mean of the character under study}} \times 100$$

b) Phenotypic coefficient of variation (P.C.V.)

$$= \frac{\text{Phenotypic standard deviation}}{\text{Mean of the character under study}} \times 100$$

c) Heritability: Heritability in the broad sense was estimated by the formula by Burton and Devane (1953).

$$h^2_{(b)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

2. Estimation of correlation

Correlations between yield and its components were calculated at genotypic and phenotypic levels following Searle (1961).

a) Genotypic correlation between characters x and y

$$r_{xy}(g) = \frac{Cov(xy)_g}{(Var(x)_g \times Var(y)_g)^{\frac{1}{2}}}$$

b) Phenotypic correlation between characters x and y

$$r_{xy}(p) = \frac{Cov(xy)_p}{(Var(x)_p \times Var(y)_p)^{\frac{1}{2}}}$$

Where, $Cov(xy)_g$ and $Cov(xy)_p$ denote genotypic and phenotypic covariances respectively between characters x and y. $Var(x)_g$, $Var(x)_p$ and $Var(y)_g$, $Var(y)_p$ denote genotypic and phenotypic variances respectively for character x and y. The phenotypic and genotypic correlation-coefficients were tested for significance.

3. Multiple regression analysis

The characters having high direct contribution towards yield were selected for the formulation of selection index according to the method given by Goulden (1952), by means of a multiple regression equation:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + \text{..etc.}$$

Results

RESULTS

Data collected from the experiments were subjected to statistical scrutiny and the results are presented in the following major heads:

A. Variability

1. Tree characters

Observations on 10 tree characters were made and data on the range, mean and standard error of the characters such as jorquetting height, girth, number of flushes, number of cushions on trunk, number of cushions on branches, number of flowers, number of cherelles per tree per year, number of pods per tree per year and yield per tree are presented in Table 1. Considerable variation was noticed in all the tree characters examined in the present study. Jorquetting height for all the 135 trees ranged from 0.53 m in tree No.133 to 2.90 m in tree No.79 with a SE of 0.43. The mean value was worked out to be 1.32 m. Girth of the trunk at 15 cm above ground level ranged from 14.1 cm to 49.3 cm with mean of 30.57 cm and SE 2.34. This attribute showed considerable variation; minimum in Tree No.76 and maximum in Tree No.13.

Number of flushes per plant from a unit area of 0.25 sq.m. varied from zero in Tree No.126 to 20 in Tree No.21

Table 1. Range, mean and standard error for 10 tree characters in 135 cocoa trees

Sl. No.	Characters	Range		Mean	SE
1	Jerquette height (m)	0.53	2.90	1.32	0.43
2	Trunk girth (cm)	14.1	49.3	30.57	2.34
3	Number of flushes per unit area	0	20	15.32	4.84
4	Number of cushions on trunk	5	32	17.38	3.73
5	Number of cushions on branch	0	24	11.87	4.34
6	Number of flowers per unit length on the trunk	93	904	258.04	20.53
7	Pollen fertility	71	88	79.50	2.33
8	Number of cherelles per unit length per year	6	23	13.58	1.84
9	Number of pods per tree per year	2	134	33.51	8.94
10	Yield per tree per year (Kg)	0.372	35.27	4.318	1.05

with a SE of 4.84. The mean value was worked out to be 15.32. Among the 135 trees, the range for number of cushions on trunk varied from 5 in Tree No.26 to 32 in Tree No.108. Trees exhibited variation for this character with a mean value of 17.38 and standard error 3.73. The number of cushions on trunk had a significant positive correlation with yield. The maximum number of cushions recorded in a length of 50 cm on the branch was 24 in Tree No.130 while the minimum number of cushions was zero in Tree No.126. Number of cushions on branches too manifested moderate variation among the 135 trees. It ranged from 0 to 24 with a mean of 11.87 and standard error 4.34.

Flower production per cushion showed considerable variation among all the selected trees. A floriferous cocoa tree located from the experimental plot is shown in Plate Ia. The number of flowers per tree from a length of 50 cm varied from 93 to 904 with a mean value of 258.04 and standard error 20.53. Tree No.73 had the lowest number of flowers, while the highest number was recorded in Tree No.101. Pollen fertility ranged from 71 per cent (Tree No.95) to 88 per cent (Tree No.19) with a mean of 79.50 and standard error of 2.33. Number of cherelles per tree per year from a unit length ranged from 6 to 23 in Tree No.26 and in Tree No.123 respectively with a mean value of 13.58 and standard error 1.84. Plate Ib shows a cocoa tree with good cherelle set. Number

PLATE 1

a. A floriferous cocoa tree

b. A Forastero tree with good cherelle set


101

of pods per tree per year during the period of study ranged from 2 to 134 with a mean value of 33.51 and standard error 8.94. Tree No.117 produced maximum number of pods per year and Tree No.42 produced minimum number of pods per year. The maximum yield in terms of wet beans per tree per year was estimated to be 35.27 kg in Tree No.117 while the minimum yield per tree was 0.372 kg in Tree No.26. The mean value for the population was 4.318 kg with a standard error of 1.05 kg.

2. Pod characters

Data on the range, mean and standard error of all the nine characters such as weight of pod, length of pod, diameter of pod, thickness of pod husk, wet weight of beans per pod, pod value, volume of pod, number of beans per pod and percentage of black pod incidence are presented in Table 2. Plate 2a shows the general trend in the variation of size and shape of pods in the population studied. A great extent of variation in terms of range and SE were observed in almost all characters studied. Mean weight of five pods per tree ranged from 162 g in Tree No.84 to 804 g in Tree No.110 with a mean value of 483 and SE 39.6. Length of pod varied from 10.3 cm to 18.3 cm and the mean value was 14.3 cm with a SE of 0.6. Tree No.111 showed maximum length of pod and Tree No.27 showed minimum length of pod. Diameter of pod varied

Table 2. Range, mean and standard error of nine pod characters in 135 cocoa trees

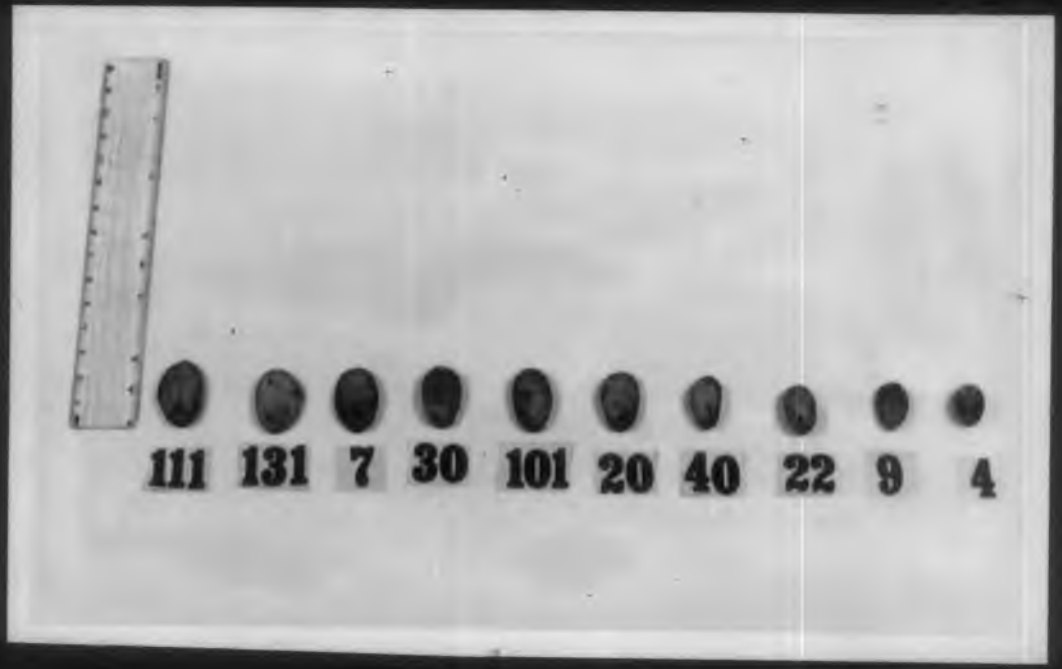
Sl. No.	Characters	Range		Mean	SE
1	Weight of pod (g)	162	804	483	39.6
2	Length of pod (cm)	10.3	18.3	14.3	0.6
3	Diameter of pod (cm)	5.2	10.1	7.65	0.2
4	Thickness of pod husk (cm)	0.3	1.86	1.08	0.14
5	Wet weight of beans per pod (g)	51.4	263.2	157.3	18.8
6	Number of beans per pod	31	51	41	4.34
7	Volume of pod (cc)	171	768	469.5	35.66
8	Pod value	18	57	37.5	3.57
9	Black pod incidence(%)	0	57.14	37.73	5.73

PLATE 2

a. A general trend in the variation of size and shape of pods in the population

b. A general trend in the variation of size and shape of beans in the population


127
110
22
108
20
65
9
14
15
26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9
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from a minimum 5.2 cm to a maximum 10.1 cm with a mean value of 7.65 and SE of 0.2. Tree No.49 showed maximum diameter of pod while Tree No.97 showed minimum diameter of pod. Thickness of pod husk at the middle portion of the pod ranged from 0.3 cm to 1.86 cm with a SE of 0.14. The mean value was worked out to be 1.08 cm. Tree No.119 showed maximum husk thickness whereas Tree No.26 had the minimum husk thickness.

The wet weight of beans per pod ranged from 51.4 g to 263.2 g with a mean value of 157.3 g. The SE was worked out to be 18.8. Tree No.117 exhibited highest value and Tree No.98 exhibited the lowest. The pod value ranged from 18 to 57 with a mean value of 37.5 and SE 3.57. Tree No.98 exhibited highest pod value and Tree No.127 exhibited lowest pod value. Volume of pod ranged from 171 cc to 768 cc with a SE of 35.66. The mean value was worked out to be 469.5 cc. Tree No.110 exhibited highest volume of pod and Tree No.98 exhibited lowest volume of pod. The highest number of beans per pod recorded was 51 in Tree No.124 and lowest number of beans per pod recorded was 31 in Tree No.14 with a mean value of 41.00 and SE 4.34. Incidence of black pod disease as manifested by the percentage of infected pods per tree ranged from zero to 57.14 in the case of 135 trees with a mean value of 37.73 and SE 5.73. Among all the trees observed 87 trees showed no incidence of the disease while tree No.85 was the maximum infected.

3. Bean characters

Seven characters of the beans were studied in all the 135 trees studied. The range, mean and standard error of the values of number of flat beans per pod, number of germinated beans per pod, weight of a bean, volume of a bean, cotyledon percentage, shell percentage and seed index are given in Table 3. Variation in bean size and shape is shown in Plate 2b. Bean characters also showed lesser extent of variation in few characters. Number of flat beans per pod varied from a zero to five with a mean value of 2.50 and SE 0.8. Flat beans were absent in three trees. Tree No.19 showed maximum number of flat beans per pod. The number of germinated beans per pod ranged from zero to 2 with a mean value of 1.00 and SE 0.6. Germinated beans were absent in 86 trees. Tree No.43 exhibited highest number of germinated beans per pod. The number of germinated beans per pod showed significant negative correlation with yield. Weight of a wet bean ranged from 1.7 g in Tree No.119 to 4.7 g in Tree No.119 to 4.7 g in Tree No.111 with a mean value of 2.55 g and SE 0.34. Volume of a bean ranged from 1.8 cc in Tree No.79 to 4.2 cc in Tree No.111 with a mean value of 2.54 and SE 0.12. Cotyledon percentage of the cured beans exhibited variation in all the 135 trees. It ranged from 75.71 to 88.89 with a mean value of 82.67 and SE of 1.35. Tree No.51 showed maximum cotyledon percentage while Tree No.115 showed

Table 3. Range, mean and standard error of seven bean characters in 135 cocoa trees

Sl. No.	Characters	Range		Mean	SE
1	Number of flat beans per pod	0	5	2.50	0.8
2	Number of germinated beans per pod	0	2	1.00	0.6
3	Weight of one bean (g)	1.7	4.7	2.55	0.34
4	Volume of one bean (cc)	1.8	4.2	2.54	0.12
5	Cotyledon content (%)	75.71	88.89	82.67	1.35
6	Shell content (%)	11.11	22.22	17.06	2.57
7	Seed index (g)	0.60	2.00	0.97	0.53

lowest percentage of the cotyledon. Shell percentage ranged from 11.11 to 22.22 with a mean value of 17.06 and SE 0.53. Tree No.91 exhibited highest value and Tree No.113 exhibited lowest value. The average weight of a dry bean (seed index) ranged from 0.60 g to 2.00 g. The mean value was 0.97 g with a SE of 0.53. Tree No.111 showed highest seed index while Tree No.56 showed the lowest. The seed index also exhibited significant positive correlation with yield.

Thus in terms of range, mean and standard error, a greater extent of variability was evident in all the tree, pod and bean characters. Among the 26 characters studied in the present investigations, weight of pod exhibited the greatest magnitude in variability, with a range between 162 and 804 g, a mean of 483 g and a SE of 39.6. Similar trends were also observed in the case of volume of pod, number of flowers on the trunk and wet weight of beans per pod. On the contrary, variability was not very much conspicuous in some of the characters like jorquette height, pod diameter, thickness of pod husk and number of germinated beans per pod.

Estimation of variability and heritability in bean and pod characters

The extent of variability present in a total of seven characters for which observations from a sample of five were

taken was measured at genotypic and phenotypic levels. Phenotypic coefficient of variation, genotypic coefficient of variation and heritability for different characters are presented in Table 4. Phenotypic coefficient of variation was found to be the highest for number of germinated beans (142.00) followed by thickness of husk (62.00) and weight of pod (23.00). The same trend was observed in genotypic coefficient of variation with values 62, 28 and 10 for number of beans per pod, thickness of husk and weight of pod respectively.

Among the seven characters weight of pod, thickness of pod husk and number of germinated beans per pod showed moderately high heritability (0.20). Volume of beans showed the lowest heritability (r=0.09) hence this character can be avoided during selection.

B. Correlation

Association of yield per plant with weight of pod, length of pod, diameter of pod, thickness of pod husk, wet weight of beans per pod, number of beans per pod, weight of one bean, number of flat beans per pod, number of germinated beans per pod, volume of pod, volume of bean, cotyledon percentage, shell percentage, pod value, number of cushions on trunk, number of cushions on branch and percentage of black pod incidence were examined and the results are presented in Table 7. Of these only correlation of yield per

Table 4. Phenotypic coefficient of variation (P.C.V.), genotypic coefficient of variation (G.C.V.) and heritability for seven selected pod and bean characters in 135 trees

Sl. No.	Characters	P.C.V.	G.C.V.	Heritability
1	Weight of pod	23.00	10.00	0.20
2	Diameter of pod	7.00	3.00	0.18
3	Thickness of pod husk	62.00	28.00	0.20
4	Wet weight of beans	3.00	1.00	0.14
5	Number of beans per pod	2.00	2.00	0.19
6	Number of germinated beans per pod	142.00	62.00	0.20
7	Volume of wet bean	3.00	1.00	0.09

Table 5. Phenotypic correlation (rp) among the seven pod and bean characters

Characters	Weight of pod	Diameter of pod	Thickness of pod husk	Wet weight of beans per pod	Number of beans per pod	Number of germinated beans per pod	Volume of beans
Weight of pod							
Diameter of pod	0.04						
Thickness of pod husk	0.01	0.08					
Wet weight of beans per pod	0.15	-0.15	0.01				
Number of beans per pod	0.19*	0.11	0.06	0.30**			
Number of germinated beans per pod	0.00214	0.02	-0.00055	0.03	0.04		
Volume of beans	-0.04	0.02	0.03	0.35**	0.17*	0.12	

Table 6. Genotypic correlation (rg) among the seven pod and bean characters

Characters	Weight of pod	Diameter of pod	Thickness of pod husk	Wet weight of beans per pod	Number of beans per pod	Number of germinated beans per pod	Volume of pod
Weight of pod							
Diameter of pod	0.04						
Thickness of pod husk	0.01	-0.04					
Wet weight of beans per pod	0.18*	0.26**	-0.2				
Number of beans per pod	0.20**	-0.12	0.05	0.30**			
Number of germinated beans per pod	0.0007	0.02	-0.00099	0.04	0.04		
Volume of beans	-0.15	0.0017	-0.03	0.19*	-0.10	0.16	

plant with diameter of pod (x_1), wet weight of beans per pod (x_2), number of beans per pod (x_3), number of germinated beans per pod (x_4), volume of pod (x_5), volume of bean (x_6), pod value (x_7) and number of cushions on trunk (x_8) were significant. On the other hand, the association of two of the traits namely, number of germinated beans per pod and pod value with yield was significantly negative. The multiple regression of mean yield (y) with x_1, x_2, x_3, x_4, x_5, x_6, x_7 and x_8 was computed and the results are presented in Table 8. Of the eight characters, pod value had the maximum contribution to yield.

Correlation of mean yield with jerquette height (x_1'), trunk girth (x_2'), number of pods per tree per year (x_3'), seed index (x_4'), number of flowers (x_5'), number of flushes (x_6') and number of cherelles per tree per year (x_7') was found out and presented in Table 10. Number of pods per tree per year was found strongly associated with yield. Seed index and trunk girth also were positively and significantly correlated with yield. Multiple regression of these characters (x_1' to x_7') on yield was examined (Table 11). Number of pods per tree per year appeared to be a major contributing factor for yield.

The interrelationship between seven pod and bean characters for which five readings could be taken on all the

Table 7. Correlation coefficients of wet bean yield with 17 characters in 155 cocoa trees

Sl. No.	Characters	Character selected	r
1	Weight of pod (g)	-	0.06596
2	Length of pod (cm)	-	-0.06935
3	Diameter of pod (cm)	x_1	0.19288*
4	Thickness of pod husk (cm)	-	0.03654
5	Wet weight of beans per pod (g)	x_2	0.424**
6	Number of beans per pod	x_3	0.21986*
7	Weight of one bean (g)	-	0.05491
8	Number of flat beans per pod	-	0.13238
9	Number of germinated beans per pod	x_4	-0.25853**
10	Volume of pod (cc)	x_5	0.41916**
11	Volume of one bean (cc)	x_6	0.34397**
12	Cotyledon content (%)	-	-0.10548
13	Shell content (%)	-	0.07394
14	Pod value	x_7	-0.5168**
15	Number of cushions on trunk	x_8	0.35059**
16	Number of cushions on branch	-	-0.05909
17	Black pod incidence percentage(%)		-0.172

* Significant at five per cent level

** Significant at one per cent level

Table 8. Multiple regression of yield on eight selected characters (x_1 to x_8)

Sl. No.	Character	Regression coefficient	SE
1	x_1	387.1915*	188.8336
2	x_2	191.0503*	18.1481
3	x_3	-18.4187	61.6910
4	x_4	-847.4694*	414.3168
5	x_5	6.3038	3.7428
6	x_6	-44.0975	75.3208
7	x_7	939.4159*	194.0072
8	x_8	133.3001*	38.1379

$y = 3.06x_1 + 1.15x_2 - 0.02x_3 + 0.14x_5 + 0.62x_7 + 4533.7782364$

trees in the population was estimated both at phenotypic and genotypic levels.

Phenotypic (r_p) correlations among the seven characters were presented in Table 5. Wet weight of beans per pod was positively correlated with number of beans per pod (r=0.3) and volume of beans (r=0.35) at one per cent level. Number of beans per pod was positively correlated with weight of pod (r=0.19) at five per cent level. Volume of beans was positively correlated with wet weight of beans per pod (r=0.35) at five per cent level.

Genotypic (r_g) correlation among the seven characters are presented in Table 6. Among the characters, weight of pod was found to be positively correlated with number of beans per pod (r=0.20) at one per cent level. Similarly wet weight of beans per pod was positively correlated with diameter of pod (r=0.26) and number of beans per pod (r=0.30) at one per cent level. Volume of beans was positively correlated with wet weight of beans per pod (r=0.19) at five per cent level. Weight of pod was found to be positively correlated with wet weight of beans per pod (r=0.18) at five per cent level.

Table 9. ANOVA for regression analysis of the selected characters

Source	df	SS	MS	F
Regression	8	1981791854.19	247723981.773	32.44*
Error	126	962143981.594	7636063.3458	

Table 10. Correlation coefficients of wet bean yield with seven characters in 135 trees

Sl. No.	Characters	Character selected	r
1	Jorquette height	x_1	-0.00367
2	Trunk girth	x_2	0.35975**
3	Number of pods per tree per year	x_3	0.89175**
4	Seed index	x_4	0.28945**
5	Number of flowers per unit length on the trunk	x_5	0.12807
6	Number of flushes per unit area	x_6	0.18623
7	Number of cherelles per unit length per year	x_7	0.01901

Table 11. Multiple regression of yield on seven characters (x_1 to x_7)

Sl. No.	Character	Regression coefficient	Standard error
1	x_1'	-13.4740	12.4913
2	x_2'	- 0.0152	21.0764
3	x_3'	164.2854	6.4548
4	x_4'	-52.3164	60.0350
5	x_5'	2.1569	2.3033
6	x_6'	-73.2478	28.9271
7	x_7'	-121.4128	17.7848

$$y = -0.04x_1' - 0.00159x_2' + 0.99x_3' - 0.03x_4' + 0.05x_5' - 0.10x_6' - 0.02506x_7' + 3674.8765304$$

Table 12. ANOVA for regression analysis of the selected characters

Source	df	SS	MS	F
Regression	7	2550930111.96	364418587.423	117.56*
Error	121	393687070.617	3099898.1983	

Discussion

DISCUSSION

The prime importance in plant breeding is to pick up desirable genotypes. Success of any crop improvement programme depends largely on the extent and availability of genetic variation in most of their characters. In order to boost the cocoa production in our country, genetic improvement of the crop through selection from the existing population offers considerable scope.

The development of biometrical genetics has revealed that yield and most other economic characters are being controlled by polygenes. The most important objective of a plant breeder is to increase yield. In the genetic improvement of crop, association between major characters is of great value. Once the relationship is established, it becomes easy for the breeder to select a trait which invariably affects a number of other associated characters.

The results obtained from the present investigations are discussed here in the light of available literature pertinent to cocoa or similar perennial crops.

In a population of 135 cocoa trees analysis of variance was made for seven pod and bean characters namely, weight of pod, diameter of pod, thickness of pod husk, wet weight of beans, number of beans per pod, number of germinated beans

per pod and volume of wet beans for which measurements from a sample of five were taken. The coefficient of variation at genotypic, phenotypic levels and heritability were estimated. The genotypic coefficient of variation (G.C.V.), phenotypic coefficient of variation (P.C.V.) and heritability for the seven characters are given in Table 4. In all the seven characters studied the phenotypic coefficient of variations (P.C.V.) were higher than the genotypic coefficient of variation (G.C.V.) indicating a positive influence of environment on these characters. P.C.V. was the lowest in number of beans per pod, medium for pod husk thickness while it was highest in number of germinated beans per pod. The G.C.V. also showed a similar trend, but the estimates were lower. Number of germinated beans had the highest G.C.V. (62) followed by pod husk thickness. Moderately high estimates of G.C.V. gives an indication that the magnitude of variability was reasonably marked in the population studied. Gupta (1972) and Rangaswamy and Shanmughavelu (1980) reported that the genotypic coefficient of variation generally helps to measure the extent of genetic variability and it also provides a measure to compare the same present in other characters, thus helping in selection. Moderately high estimates of G.C.V. gave an indication that the magnitude of variability was reasonably marked in the population studied.

Burton (1952) suggested that the estimation of genetic coefficient of variation along with heritability estimates help to determine the amount of heritable variation. Heritability estimates are the true indications of genetic potentiality of an individual which act as a tool in selection (Hanson et al., 1956). In the present study among the seven characters, weight of pod, thickness of pod husk and number of germinated beans per pod showed moderately high heritability estimate in the broad sense (0.20). This was followed by number of beans per pod (0.19), diameter of pod (0.18) and wet weight of beans per pod (0.14). Volume of beans showed the lowest heritability estimate (0.09).

The above mentioned findings indicate that selection based on phenotypic manifestation of the above characters would be effective. However, a very low heritability (0.09) for volume of wet beans suggests that this character cannot be relied upon for selection. Soria et al. (1974) reported high heritability (89 per cent) for yield in hybrids of Trinitario and Criollo varieties. They also found moderately high heritability for pod and bean characters like pod length (55 per cent), pod diameter (63 per cent) and pod weight (57 per cent). The relatively moderate and low heritability estimates in the present study can be attributed to considerable influence of the environment on the traits studied which in turn indicates that they are not highly

transmissible characters. Similar results were obtained by Kumaran and Prasannakumari (1981) who observed relatively high heritability estimate for weight of bean and weight of cotyledons and medium heritability for pod weight, pod length, pod diameter, pod husk thickness and weight of wet beans per pod in cocoa variety Forastero.

A considerable amount of variability as manifested by the range, mean and standard error (SE) was evident for almost all the twentysix attributes studied from all the 135 cocoa trees. Observations on variability with respect to nine tree characters including yield clearly indicated widely varying conditions in all the trees. Among these characters, number of flowers per unit length on the trunk exhibited maximum variability with a range of 93 to 904, a mean of 258.04 and a SE value of 20.53. Murray (1975) reported that a full grown tree on an average produced about 10,000 flowers in a year and only 10 to 50 of these finally developed into mature pods. Previous studies on the extent of variability of many of the tree characters are lacking, hence a comparison is rather difficult. However, being a cross pollinated crop considerable variability can be normally expected. Number of pods per tree per year in the present study also exhibited greater variability which is in accordance with the observations made by Pound (1932) and Soria (1975).

Among the nine pod characters studied for variability viz., weight of pod, length of pod, diameter of pod, thickness of pod husk, wet weight of beans per pod, pod value, volume of pod, number of beans per pod and black pod incidence, weight of pod showed maximum variability with a range of 162 g to 804 g, mean of 483 and with a SE of 39.6. This was followed by volume of pod and wet weight of beans per pod. Significantly high variability for pod length, diameter, pod husk thickness was reported by Kumaran and Prasannakumari (1981). Wet weight of beans per pod exhibited considerable variability with a range of 51.4 to 263.2 g, mean of 157.3 and with a SE of 18.8. These results are in agreement with those obtained by Pound (1932) and Soria (1975). In a study involving weight of pod and bean characters, Kumaran and Prasannakumari (1981) observed moderately high variability for pod weight and significantly high variability for pod length, pod diameter, pod husk thickness and weight of beans per pod.

As in the case of tree characters, seven of the bean characters studied namely, number of flat beans per pod, number of germinated beans per pod, weight of one bean, volume of one bean, cotyledon percentage, shell percentage and seed index also manifested considerable variability. Shell percentage showed high variability with a range from 11.11 to 22.22 and a mean of 17.06 with SE 2.57. This was

followed by cotyledon percentage and seed index. Identical trends in different populations of cocoa had been observed by Pound (1932), Enriques and Soria (1968), Soria (1975) and Kumaran and Prasannakumari (1981) in some of the characters listed above. The average weight of a dry bean (seed index) ranged from 0.60 g to 2.00 g with a mean of 0.97 and SE 0.53 in the present study. Pound (1932) reported that seed weight ranged from 0.5 g to 2.5 g in Forastero variety. He also observed variability of beans within a single pod. A tree having higher seed index contributes much to yield.

Among the 26 characters studied, it was evident that correlation was significant for a good number of characters with yield. Diameter of pod, wet weight of beans per pod, volume of pod, volume of one bean, number of cushions on trunk, girth, jorquette height and number of pods per tree per year individually had showed significant positive correlations with yield. On the other hand pod value and number of germinated beans per pod showed significant negative correlation with yield. A strong association, therefore exist between the above mentioned characters and yield. Jorquette height of the trees ranged from 0.53 m to 2.90 m. Dhaliwal (1968) observed that yield was positively correlated with height in coffee (Coffea arabica). Girth of the tree was positively correlated with yield and it ranged from 14.1 cm to 49.3 cm in the present study. Glendinning (1965) reported

that trunk diameter was positively correlated with yield in cocoa. Pod value ranged from 18 to 57. Pod value had significant negative correlation with yield. A tree having lesser pod value is always superior to others having higher pod value. This factor may be given due consideration while selecting superior trees. In the present investigations, number of beans per pod was positively correlated with yield. But in the case of weight of pod no positive correlation with yield could be observed. Thamburaj (1973) reported that weight of pod and number of beans per pod was positively correlated with yield in ridge gourd.

Soria (1975) suggested that four of the most important yield components in cocoa are number of fruits per tree, number of beans per pod, wet or dry bean weight per pod per tree and weight of individual beans. Thus correlation studies have revealed that characters such as pod value, seed index, number of pods per tree per year, wet weight of beans per pod and number of beans per pod could be considered as important yield contributing characters in cocoa. Moll and Stubber (1975) suggested that correlation among traits enhanced the rate of selection response in primary traits.

Multiple regression analysis has been used in many crops for formulating selection index. Anand and Torrie (1963) reported multiple regression analysis method for predicting the yield in soyabean. Thamburaj (1973) made

multiple regression analysis in ridge gourd and reported that the pod weight and number of seeds per pod had a significant positive effect on yield per plant.

Multiple regression analysis as suggested by Goulden (1952) has been used in many crops. In the present study, this method was followed to examine the effect of 15 selected characters on yield. Pod value was found to have a greater and positive contribution to yield followed by diameter of pod, length of pod and number of pods per tree per year. These characters can therefore be relied upon while making selection of trees for further utilisation. Number of beans per pod, however, showed negative effect on yield. Similarly, number of cherelles was found to have a negative effect towards yield. These findings should also be given cognisance of in any selection programme in the population studied. The multiple regression of mean yield (y) with diameter of pod (x_1), wet weight of beans per pod (x_2), number of beans per pod (x_3), number of germinated beans per pod (x_4), volume of pod (x_5), volume of bean (x_6), pod value (x_7) and number of cushions on trunk (x_8) have shown that of the eight characters studied, pod value had the maximum contribution to yield. The multiple regression of mean yield (y) with jorquette height (x_1'), trunk girth (x_2'), number of pods per tree per year (x_3'), seed index (x_4'),

number of flowers (x_5'), number of flushes (x_6') and number of cherelles per tree per year (x_7') showed that among these, number of pods per tree per year appeared to be a major contributing factor for yield.

Cheesman and Pound (1934) considered seed index as the main constant for the selection of individual trees. The basic methodology for selection of cocoa clones for yield was developed in Trinidad by them. Pound (1933) reported that in Trinidad pod value is 7.5 which is fixed as the criteria for selection of superior trees. Cheesman and Pound (1934) considered pod value or pod index as a constant for selection of superior trees. It can be seen that superior trees giving higher yields can be selected based on the following characters: Trees with pods having a greater pod diameter, higher wet weight of beans per pod, higher volume of pod, high volume of bean, greater trunk girth, lower pod value, less number of germinated beans per pod, higher seed index, greater number of pods per tree per year, higher number of cushions on trunk and greater number of beans per pod.

Phenotypic (rp) correlations among the different characters are presented in Table 5. Wet weight of beans per pod was positively correlated with number of beans per pod (r=0.30) and volume of beans (r=0.35) at one per cent level. Number of beans per pod was positively correlated with weight

of pod (r=0.19) at five per cent level. Volume of beans was positively correlated with wet weight of beans per pod (r=0.35) at five per cent level. A mere or less similar trend was evident from the estimates of genotypic correlations (Table 6) indicating that environmental influence on these attributes was rather uniform, but negligible. Pod weight was found to be positively correlated with number of beans per pod (r=0.20). Wet weight of beans per pod was positively correlated with diameter of pod (r=0.26) and number of beans per pod (r=0.30) at one per cent level. Volume of beans was positively correlated with wet weight of beans per pod (r=0.19) at five per cent level. Weight of pod was positively correlated with wet weight of beans per pod (r=0.18) at five per cent level in the present study. It could be suggested that traits such as number of beans per pod, and wet weight of beans per pod can be considered as the most important yield contributing pod and bean characters.

Correlation coefficients at genotypic and phenotypic levels were worked out for the seven pod and bean characters (Table 5 and 6). In general, the two sets of estimates are almost identical. There was significant correlation for the characters, namely, wet weight of beans and number of beans per pod. Wet weight of beans per pod showed significant association at genotypic level, whereas number of beans per pod showed significant correlation at phenotypic level. From

these it could be concluded that the above mentioned characters should be given priority in selection. However, the existence of the negative correlation should not be ignored. An understanding of the interrelationship among yield contributing characters is useful to bring about genetic improvement of any crop. Kumaran and Prasannakumari (1981) reported strong association between pod weight and pod length, pod diameter, weight of beans per pod, weight of bean and weight of cotyledons. They also observed highly significant and positive correlation between pod diameter with pod husk thickness, weight of beans per pod and number of developed beans and suggested that these characters can be relied upon in the selection programme although their heritability estimates were low.

The studies conducted on genetic variability and correlation studies in cocoa showed that characters like diameter of pod, wet weight of beans per pod, number of beans per pod, number of germinated beans per pod, volume of pod, volume of bean, pod value, number of cushions on trunk, trunk girth, number of pods per tree per year and seed index have a direct and marked influence on the yield of cocoa. Trees exhibiting superiority in the above mentioned traits can thus be considered to have high yield potential. These characters can be utilized for locating potential mother trees for obtaining high yielding progenies.

Summary

SUMMARY

Investigations on the genetic variability and correlation studies in cocoa were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period from July 1980 to August 1981 in a well established cocoa garden at Alpara in Trichur district. The experiments were conducted to elucidate information on the extent of variability and the degree of association existing between important plant, pod and bean characteristics of a total number of 135 trees of the Forastero variety cocoa. The results obtained are briefly summarised below:

In general, considerable variation was noted among all the 26 characters studied in the sample of cocoa trees studied. Substantial amount of variability as manifested by the range, mean and standard error was evident in almost all the 10 tree characters. Among these, number of flowers per unit length on the trunk exhibited maximum variability with a range of 93 to 904 and a mean of 258.04.

Number of pods per tree per year during the study also exhibited greater variability. It ranged between 2 and 134 with an overall mean 4.318 and SE 1.05.

Among nine pod characters studied, weight of pod showed maximum variability with a range of 162 g to 804 g and

a mean of 483 g. This was followed by volume of pod which ranged from 171 cc to 768 cc. The mean value was worked out to be 469.5 cc. Wet weight of beans per pod ranged from 51.4 g to 263.2 g with a mean value of 157.3 g.

Seven characters of the beans were studied in all the 135 trees. Out of these, shell percentage and seed index manifested considerable variability. The seed index ranged from 0.60 g to 2.00 g with a mean value of 0.97 g.

Phenotypic coefficient of variation was found to be the highest for number of germinated beans (142.00) followed by thickness of husk (62.00) and weight of pod (23.00). The same trend was observed in genotypic coefficient of variation with values, 62, 28 and 10 for characters number of beans per pod, thickness of husk and weight of pod respectively. Among the seven characters weight of pod, thickness of pod husk and number of germinated beans showed moderately high heritability (0.20). Volume of beans showed the lowest heritability (0.09) hence this character need not be considered for selection of promising genotypes.

The yield par plant was positively correlated with diameter of pod, wet weight of beans per pod, volume of pod, volume of bean, number of beans per pod and number of cushions on trunk. On the other hand the association of two of the traits namely, number of germinated beans per pod and pod

value with yield was significantly negative. Of the eight characters pod value had maximum contribution to yield.

Number of pods per tree per year was found strongly associated with yield. Seed index and trunk girth also were positively and significantly correlated with yield.

Phenotypic (r_p) correlation among seven characters indicated that wet weight of beans per pod was positively correlated with number of beans per pod and volume of beans. Number of beans per pod was positively correlated with weight of pod. Volume of beans was positively correlated with wet weight per pod.

Genotypic (r_g) correlation among the seven characters showed that weight of pod was found to be positively correlated with number of beans per pod. Similarly wet weight of beans per pod was positively correlated with diameter of pod and number of beans per pod. Volume of beans was positively correlated with wet weight of beans per pod. Weight of pod was found to be positively correlated with wet weight of beans per pod.

The studies conducted on genetic variability and correlation studies on cocoa, showed that characters like diameter of pod, wet weight of beans per pod, number of beans per pod, number of germinated beans per pod, volume of pod,

volume of bean, pod value, number of cushions on trunk, trunk girth, number of pods per tree per year and seed index have direct and marked influence on the yield of cocoa. Trees exhibiting superiority in the above mentioned traits can thus be considered to have high yield potential. Selection of promising trees for establishing as clones should therefore, be based on such characters.

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Appendices

Appendix I

Meteorological data during the cropping period (1980)

Month	Number of rainy days 1980	Rainfall in mm 1980	Average number of rainy days for last 5 years	Average rainfall for the last 5 years	Temperature (°C)				U.S.A. Pan evaporation		
					Highest maximum	Lowest maximum	Highest minimum	Lowest Minimum	Highest (mm)	Lowest (mm)	Mean (mm)
January	Nil	Nil	Nil	Nil	34.3	31.0	20.0	16.5	7.0	4.5	6.1
February	Nil	Nil	1.2	9.9	36.8	32.5	21.5	17.8	7.3	5.3	6.2
March	Nil	Nil	1.6	16.5	37.5	34.6	24.5	22.0	6.4	5.0	5.5
April	7	113.5	4.0	50.6	36.4	33.1	26.5	22.8	6.3	4.0	4.9
May	11	196.8	11.6	208.7	36.0	33.0	26.0	23.5	4.6	2.6	4.0
June	27	948.3	23.8	624.4	32.5	25.8	24.2	22.5	3.6	2.0	2.7
July	31	1231.1	28.0	741.8	31.0	25.1	23.1	21.8	4.0	2.2	3.1
August	28	554.6	21.6	491.0	32.0	26.0	23.6	21.5	4.0	2.2	2.9
September	12	148.1	15.0	203.5	32.8	29.2	24.2	23.0	4.0	2.3	3.1
October	17	324.3	12.8	211.1	33.2	28.6	24.4	22.0	4.8	2.0	3.2
November	9	205.5	12.4	267.3	33.8	29.9	23.6	21.5	4.9	3.0	3.8
December	1	2.5	0.6	17.0	33.6	30.0	23.6	21.2	6.0	2.0	4.1
Total	143	324.7	132.6	2841.8	-	-	-	-	-	-	-

Source: CPCRI, Kannara

Appendix II

Meteorological data during the cropping period (1981)

Month	Number of rainy days	Rainfall in 1981	Average number of rainy days for last 5 years	Mean rainfall for the last 5 years	Temperature (°C)				U.S.A. Pan Evaporation		
					Highest maximum	Lowest maximum	Highest minimum	Lowest minimum	Highest (mm)	Lowest (mm)	Mean (mm)
January	Nil	Nil	Nil	Nil	33.3	31.0	22.4	20.0	6.4	3.0	4.8
February	Nil	Nil	1.2	9.9	38.0	33.0	23.0	19.8	6.3	4.0	5.2
March	Nil	Nil	1.0	9.8	39.0	35.5	24.8	22.5	8.1	4.1	5.7
April	2	57.1	4.2	60.4	38.5	34.5	26.2	23.5	6.1	4.4	5.3
May	8	181.8	11.0	193.1	38.0	30.5	26.1	23.0	5.5	2.1	4.2
June	28	1113.0	25.4	812.0	31.2	26.3	23.2	21.3	3.0	0.5	1.7
July	18	536.5	26.2	846.1	32.5	25.5	23.5	21.0	4.0	0.9	2.4
August	25	580.9	22.8	521.0	31.0	25.8	23.0	21.0	4.3	0.9	2.2
September	19	540.1	13.6	234.4	32.5	26.0	26.0	22.5	7.0	0.2	2.3
October	10	136.6	12.6	222.8	33.5	26.0	26.0	23.0	4.0	0.2	2.5
November	3	99.8	10.6	239.7	34.0	29.0	27.0	20.0	6.0	0.6	2.8
December	Nil	Nil	0.8	17.5	35.0	30.0	25.0	18.5	7.0	2.3	4.6
Total	113	3245.8	129.4	3168.7	-	-	-	-	-	-	-

Source: CPCRI, Kannara

APPENDIX III Range, Mean and Standard error of pod and bean characters in 135 trees. [Five observations]

Tree No.	Weight of pod (g)				Length of pod (cm)				Diameter of pod (cm)				Volume of pod (cc)				Pod husk thickness (cm)				Wet weight of beans per pod (g)				Number of beans per pod				Number of flat beans per pod				Number of germinated beans per pod			
	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE
1	140	250	202	20.12	10	14	12.4	0.737	5.4	6.5	5.84	0.23	165	300	218	25.33	0.7	0.9	0.82	0.05	62	86	75	5.15	35	42	38.4	1.52	0	8	3	1.58	0	0	0	0
2	310	500	444	39.47	12.5	17.5	15.26	0.98	7.4	8.1	7.64	0.2	320	580	464	45.08	0.8	1.0	0.9	0.05	84	125	100	8.12	30	41	36.2	2.1	0	2	0.6	0.45	0	1	0	0
3	380	600	470	43.01	14.2	19.5	16.34	0.99	5.1	8.0	7.0	0.56	380	660	482	57.03	0.7	1.1	0.9	0.25	90	162	114	13.9	35	40	36.2	1.52	0	2	0.8	0.42	0	1	0.4	0.3
4	190	290	232	25.35	9.7	13.1	11.4	0.63	5.4	8	6.72	0.5	210	290	246	18.91	0.6	1.0	0.8	0.08	62	100	81	6.84	21	42	35.4	4.18	0	2	0.8	0.42	0	2	0.6	0.3
5	300	370	338	14.32	13.2	14.1	14.56	0.54	6.1	8.2	7.16	0.37	295	425	370	26.04	0.7	1.0	0.8	0.21	85	110	99.4	5.52	24	40	33.4	3.38	0	0	0	0	0	0	0.3	0.3
6	310	520	426	44.24	13.0	17.1	15.04	0.82	6.3	9	8.0	0.51	320	690	479	17.07	0.6	1.1	0.8	0.1	110	139	126.8	5.89	30	48	41	3.35	0	5	2.2	1.08	0	0	0	0
7	210	300	268	20.43	12.5	14	13.32	0.29	6.1	7.1	6.64	0.20	200	310	268	21.04	1.0	1.7	1.12	0.15	84	132	96.6	10.03	29	43	39	2.85	0	6	2.2	1.52	0	0	0	0
8	160	220	192	14.94	9	12.3	10.6	0.75	5.0	6.1	5.68	0.28	145	290	199	15.24	0.6	1.0	0.74	0.08	62	84	74.4	4.55	26	40	31.6	2.89	0	4	1.0	0.87	0	0	0	0
9	220	300	264	16.43	12	13.5	12.72	0.37	6.4	7.3	6.88	0.21	200	355	288	30.44	0.7	0.9	0.834	0.03	83	100	90.4	3.17	28	44	39	3.16	0	4	1.6	0.91	0	2	0.6	0.5
10	220	340	296	23.08	11.5	15	13.3	0.68	6.5	7.5	5.62	1.55	200	340	284	27.75	0.8	1.0	0.88	0.04	83	140	111.2	14	39	43	41.4	0.91	0	5	1.2	1.08	0	2	0.8	0.5
11	210	320	282	21.62	11	13.5	12.54	0.51	6.0	7.1	5.26	1.49	220	320	280	20.31	1.0	1.2	1.06	0.04	72	140	107	12.96	36	46	42.4	2.02	0	3	0.8	0.65	0	2	0.6	0.4
12	300	420	360	24.49	12.5	16.1	14.42	0.66	6.9	7.8	5.84	1.64	290	420	372	26.55	0.7	0.8	0.76	0.03	82	140	104.4	11.26	34	51	45	3.24	0	5	0.8	0.65	0	0	0	0
13	110	500	358	93.18	10.5	14.9	13.11	0.82	5.1	8.2	6.66	0.7	100	540	341	80.9	0.4	1.0	0.66	0.12	50	115	94.4	12.74	20	38	33	3.69	0	3	1.2	1.08	0	0	0	0
14	110	220	180	20.92	9.6	12.6	10.74	0.63	5.3	6.6	6.1	0.32	120	220	186	19.87	0.2	0.4	0.28	0.04	49	83	69.8	7.03	19	41	28.8	4.58	0	4	0.8	0.65	0	2	0.6	0.5
15	150	250	200	19.24	10.4	17.5	13.22	1.32	5.8	6.7	6.06	0.19	160	335	215	35.04	0.3	0.6	0.46	0.08	66	85	78.2	3.85	26	42	32.8	2.97	0	4	1.2	0.89	0	2	0.6	0.5
16	260	320	292	11.4	12.1	15.7	14.28	0.69	5.9	6.8	6.34	0.22	285	345	302	14.09	0.3	1.0	0.64	0.15	78	130	98.4	9.76	26	43	34.6	3.97	0	5	1.4	0.84	0	3	0.8	0.7
17	180	280	210	20	10	13.5	11.62	0.82	5.5	7	6.1	0.28	175	310	228	25.41	0.2	0.5	0.34	0.08	62	85	77.6	4.62	20	42	33.6	4.44	0	5	1.8	1.24	0	1	0.4	0.3
18	300	420	360	21.5	11	18	14.44	1.25	5.3	7.5	6.64	0.46	285	440	364	28.31	0.3	0.6	0.5	0.06	84	110	98.8	5.86	30	32	37.2	2.72	0	5	2.0	1.06	0	2	0.6	0.5
19	140	220	186	17.89	9	14	11.18	1.03	5.1	6.8	6.12	0.33	150	230	196	15.65	0.3	0.8	0.6	0.11	64	86	72.8	5.62	19	42	33.2	5.09	0	19	4.8	4.05	0	2	0.6	0.5
20	280	380	310	20	13.5	14.5	13.86	0.20	7.4	7.8	7.54	0.08	270	370	312	19.28	0.7	1.1	0.86	0.08	84	180	104	13.43	28	41	33.6	2.59	0	4	2.2	0.89	0	0	0	0
21	260	420	376	33.47	12.5	15	13.88	0.51	6.4	8.1	7.42	0.35	285	420	383	27.93	0.7	1.1	0.9	0.10	90	120	110.8	7.7	30	46	36.6	2.9	0	3	1.2	0.63	0	2	0.4	0.5
22	480	700	560	45.28	15.1	19.8	17.48	1.04	7.6	8.6	7.92	0.34	485	780	596	59.88	0.8	1.3	0.9	0.1	131	222	167.4	16.7	41	52	46.6	1.9	0	4	1.2	0.8	0	3	1.0	0.7
23	250	400	308	28.59	11.8	15.1	13.46	0.61	6.1	8.2	7.3	0.43	270	375	316	21.17	0.2	0.8	0.4	0.12	83	138	104.2	10.8	35	43	39.6	1.9	0	4	2.0	1.0	0	3	1.0	0.7
24	180	320	242	28.37	9.9	15	12.72	1.02	5.3	6.9	6.04	0.3	185	350	260	35.04	0.2	0.5	0.4	0.24	79	100	86.4	4.2	29	43	37.4	2.8	0	12	3.0	2.5	0	3	0.6	0.7
25	170	310	216	27.29	9.8	14.2	11.82	0.93	5.6	6.9	6.0	0.26	200	380	232	15.17	0.2	0.6	0.4	0.08	54	136	83.8	16.9	22	43	33	4.1	0	8	2	1.7	0	4	0.8	0.9
26	170	200	184	5.7	9.6	11.8	10.52	0.54	5.1	6.4	5.56	0.09	175	210	195	8.3	0.2	0.4	0.3	0.04	55	80	74.4	5.4	30	42	37.2	2.3	0	6	2	1.7	0	2	0.6	0.5
27	160	220	190	11.18	8.9	12.6	10.3	0.69	5.1	6.1	5.58	0.24	180	230	202	16.07	0.3	0.6	0.4	0.06	63	85	72.6	3.7	20	42	28.6	4.1	0	20	4.4	4.4	0	3	0.6	0.7
28	300	420	356	25.85	13	17.5	14.66	0.89	6.1	7.8	6.98	0.3	310	410	364	21.09	0.8	1.0	0.9	0.05	88	116	101.4	6.4	30	42	37.2	2.3	0	4	1.2	0.9	0	3	0.8	0.7

APPENDIX III Range, Mean and Standard error of pod and bean characters in 135 trees [Five observations] contd.

Tree No	Weight of pod (g)				Length of pod (cm)				Diameter of pod (cm)				Volume of pod (cc)				Pod husk thickness (cm)				Wet weight of beans per pod (g)				Number of beans per pod				Number of flat beans per pod				Number of germinated beans per pod.			
	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE	Range		Mean	SE
29	130	410	236	56.9	8.1	14.9	12.42	1.46	4.3	8.2	5.98	0.78	140	420	252	60.6	0.6	1.1	0.9	0.12	69	145	100	15.8	26	40	33	3.2	0	6	1.2	0.5	0	0	0	0
30	210	340	288	24.4	12	14.5	13.24	0.61	6.0	7.5	6.7	0.33	210	355	308	21.84	0.4	0.8	0.6	0.36	82	140	116	13.6	31	44	39.6	2.7	0	2	0.4	0.5	0	0	0	0
31	300	500	396	44.8	12.1	18	15.64	1.11	4.3	6.4	7.5	0.34	310	490	412	49.42	0.8	1.0	0.9	0.04	89	139	114	10.1	37	41	39	0.8	0	2	0.4	0.9	0	0	0	0
32	160	280	200	24.4	9.3	14.3	11.34	1.19	5.5	8.1	5.26	0.38	170	270	203	19.96	0.4	0.7	0.6	0.07	68	88	77	3.9	27	36	32.4	2.1	0	4	1.0	0.8	0	0	0	0
33	350	420	382	15.8	12.8	15.0	14.06	0.48	6.0	7.6	7.08	0.6	380	425	402	11.26	0.8	1.0	0.9	0.04	100	118	107.4	3.5	35	49	40.8	2.9	0	4	1.4	0.2	0	0	0	0
34	320	410	374	16.8	12.5	16.0	14.34	0.63	5.1	6.3	7.08	0.32	330	420	377	16.92	0.75	0.9	0.8	0.03	110	120	115	2.5	35	47	39.6	2.8	0	1	0.8	0.8	0	3	1.0	0.7
35	180	220	200	7.91	10.2	12.6	11.48	0.46	5.8	8.1	5.64	0.43	180	260	215	14.36	0.4	0.6	0.5	0.05	56	86	73.6	1.567	29	43	35	2.9	0	4	1.4	0.9	0	1	0.4	0.3
36	280	400	336	27.52	12.8	15.0	13.6	0.62	5.8	7.6	7.1	0.42	320	495	365	39.84	0.4	0.9	0.6	0.12	85	110	100.2	4.6	36	46	41.8	1.9	0	5	1.4	1.1	0	3	0.6	0.7
37	310	410	368	21.03	12.1	18.0	14.32	1.19	5.8	7.6	7.0	0.35	320	460	394	26.36	0.9	1.1	0.9	0.04	85	125	105.8	6.7	33	41	37.4	1.6	0	5	1.8	2.1	0	1	0.2	0.2
38	210	360	296	37.2	11.8	15.1	13.7	0.8	5.6	7.8	6.8	0.4	230	360	318	26.3	0.7	1.0	0.8	0.05	75	118	100.8	10.9	27	48	41.2	4.2	0	4	1.0	0.8	0	0	0	0
39	280	490	340	42.6	12.5	16.1	14.1	0.7	6.8	8.1	7.2	0.3	290	510	350	45.7	0.3	1.1	0.7	0.14	106	138	124.4	7.7	38	50	43.6	2.1	0	0	0	0	0	0	0	0
40	170	210	194	9.1	9.0	11.5	10.3	0.5	4.5	6.7	5.4	0.4	185	220	203	6.5	0.3	0.6	0.4	0.08	68	100	81	5.3	26	48	35.4	4.6	0	1	0	0	0	0	0	0
41	210	370	290	37.6	12.3	14.5	11.3	1.9	5.6	7.9	6.7	0.5	230	380	313	9.9	0.7	1.1	0.9	0.08	70	127	101.8	37.6	37	44	39.2	1.7	0	2	0.6	0.4	0	1	0.2	0.2
42	180	320	262	33.2	10	14.5	12.3	0.3	4.3	7.6	5.9	0.7	195	380	281	36.7	0.2	0.7	0.4	0.1	73	139	91.8	13.5	26	43	34.8	3.1	0	2	0.8	0.6	0	1	0.2	0.2
43	220	410	324	40.4	12.6	15.1	13.8	0.4	6.1	8.2	7.1	0.5	240	440	340	44.6	0.6	1.1	0.9	0.09	80	110	95.8	6.4	30	43	36.4	2.7	0	4	1.4	0.9	0	6	2.0	1.4
44	220	310	280	17.7	12.7	14.5	13.8	0.4	6.1	7.6	7.0	0.3	230	330	292	18.8	0.4	0.6	0.5	0.04	83	103	90.8	4.3	25	41	34.4	2.9	0	2	0.8	0.4	0	3	0.8	0.7
45	180	260	206	15.7	9.6	12.5	11.1	0.6	5.1	6.8	5.9	0.3	190	280	214	18.9	0.4	0.8	0.6	0.09	58	98	97.2	7.3	29	35	32.8	1.3	0	6	1.4	1.3	0	0	0	0
46	180	460	222	66.7	10.2	10.5	10.5	0.1	6.0	6.5	6.2	0.1	140	425	213	6.1	0.6	1.1	0.8	0.12	64	76	69.2	2.9	32	45	38.0	2.4	0	2	0.8	0.4	0	0	0	0
47	280	510	414	56	14.5	16.8	16.4	0.5	5.8	8.3	6.9	0.6	295	570	439	66.1	0.7	1.1	0.9	0.07	78	157	119	15.5	26	48	38.8	5.0	0	5	1.8	1.4	0	0	0.4	0.3
48	280	400	336	23.9	13.5	14.4	13.9	0.2	6.1	7.8	7.0	0.3	300	410	383	24.6	0.4	0.8	0.7	0.08	88	120	101.2	6.2	36	49	40.6	2.6	0	3	1.4	0.7	0	3	0.6	0.7
49	310	410	364	23.1	13.0	15.1	13.9	0.2	6.8	7.5	10.1	0.1	300	420	366	26.4	0.7	0.9	0.8	0.04	90	139	111.8	9.5	38	43	39	1.1	0	2	0.8	0.6	0	1	0.2	0.2
50	200	310	244	24.1	10.1	13.1	12.2	0.6	4.8	7.4	6.4	0.5	190	320	258	26.1	0.3	0.5	0.4	0.07	73	87	81.4	3.3	26	42	36.2	3.3	0	4	0.8	0.9	0	0	0	0
51	260	410	342	32.1	12.3	14.8	13.6	0.5	6.0	8.3	6.9	0.5	280	430	360	28.4	0.6	0.9	0.8	0.06	88	120	108	9.8	30	42	36.6	2.3	0	1	0.2	0.2	0	2	0.4	0.5

APPENDIX III Range, Mean and Standard error of pod and bean characters in 135 trees [Five observations] Contd.

Tree	Weight of pod (g.)				Length of pod (cm.)				Diameter of pod (cm.)				Volume of pod (c.c)				Pod husk thickness (cm.)				Wet weight of beans per pod (g)				Number of beans per pod				Number of flat beans per pod				Number of germinated beans per pod			
NO	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE
52	110	210	178	19·8	10·1	12·8	11·1	0·5	5·0	6·3	5·6	0·3	120	210	177	16·9	0·2	0·3	0·2	0·03	50	89	72·8	7·2	20	40	33·8	4·1	0	3	1·2	0·7	0	1	0·2	0·2
53	430	510	446	18·2	17·0	18·1	17·7	0·2	7·1	8·1	7·7	0·2	460	580	508	31·1	0·6	0·9	0·8	0·01	78	128	105·6	11·4	27	46	38·4	4·4	0	1	0·4	0·3	0	1	0·2	0·2
54	200	390	260	38·9	11·0	15·8	13·3	0·9	4·9	8·0	6·3	0·6	195	420	234	72·2	0·5	1·0	0·7	0·13	80	126	96·6	8·9	26	45	32·2	3·8	0	3	1·0	0·6	0	1	0·2	0·2
55	200	360	272	32·6	11·0	14·0	12·8	0·6	6·1	7·6	6·8	0·3	190	380	299	42·8	0·8	0·9	0·8	0·03	80	119	96·4	8·9	28	41	38·6	3·1	0	0	0	0	0	3	0·8	0·7
56	140	500	278	67·31	12·1	16·3	12·6	1·1	5·1	8·1	6·6	0·6	160	490	290	62·8	0·2	0·8	0·5	0·12	63	160	91·4	10·6	28	48	38·8	3·7	0	5	1·6	1·0	0	3	0·8	0·7
57	320	410	380	17·68	13·5	15·8	14·4	0·5	6·1	8·1	7·9	0·3	330	460	408	24·8	0·7	0·9	0·8	0·05	103	140	118	7·3	37	45	40·2	1·5	0	3	0·8	0·9	0	0	0	0
58	220	320	284	19·6	12·1	15·1	13·8	0·6	5·4	7·1	6·3	0·3	210	320	284	21·9	0·3	0·6	0·4	0·05	82	140	107·4	12·9	27	44	37·2	3·9	0	4	1·0	0·9	0	1	0·2	0·2
59	380	500	438	25·1	14·1	18	15·7	0·7	6·1	7·9	7·1	0·3	380	560	450	38·4	0·6	1·1	0·9	0·09	86	132	114·8	9·6	32	44	39	2·6	0	10	0·8	0·7	0	1	0·2	0·2
60	380	420	386	14·4	12·8	15·5	14·3	0·6	7·6	8	7·8	0·1	330	425	389	18·4	0·8	1·1	0·76	0·02	90	132	109·6	8·4	38	44	42	1·5	0	1	0·6	0·3	0	0	0	0
61	190	250	236	19·2	10·5	15·0	12·3	0·8	5·5	6·6	6·1	0·2	180	280	240	19·6	0·6	0·9	0·76	0·07	84	110	93·6	4·9	38	45	41·8	1·3	0	10	2·8	2·1	0	0	0	0
62	400	510	460	25·7	10·8	18·5	15·4	1·5	5·9	8·1	7·0	0·4	440	580	498	29·7	0·6	0·9	0·74	0·07	102	158	129·2	9·9	35	50	43·4	2·8	0	5	1·2	1·1	0	0	0	0
63	280	410	322	25·6	13·0	16·5	14·2	0·7	5·8	7·2	6·7	0·3	270	425	329	29·2	0·5	0·8	0·68	0·05	99	140	112	8·2	35	51	42·2	2·9	0	3	1·2	0·7	0	0	0	0
64	160	300	230	33·2	8·0	13·4	11·0	1·2	5·1	7·1	6·2	0·5	145	340	275	38·0	0·7	0·8	0·76	0·03	78	110	90·2	7·1	26	48	36·6	4·5	0	5	1·6	1·1	0	0	0	0
65	140	380	244	45·1	9·8	15·6	12·4	1·1	5·2	8·5	6·8	0·6	150	500	275	69·6	0·6	0·8	0·72	0·04	62	110	87·6	9·1	20	45	33·6	5·1	0	4	1·0	0·9	0	0	0	0
66	340	400	358	12·4	14·0	16·1	14·9	0·1	6·6	7·8	7·2	0·2	320	380	353	10·8	0·8	1·1	0·9	0·06	71	90	77·8	3·6	34	46	33·6	2·8	1	5	3·0	0·8	0	0	0	0
67	280	340	301	10·6	12·3	14·7	13·7	0·5	6·0	6·8	6·6	0·2	260	365	302	19·6	0·9	1·05	0·98	0·03	76	94	84	2·8	38	45	40·4	1·5	0	7	2·7	1·5	0	0	0	0
68	160	290	232	27·5	10·0	13·7	11·7	0·8	7·1	8·2	7·8	0·2	180	285	238	22·7	0·8	0·9	0·84	0·03	55	83	71·2	6·4	34	41	40·3	1·5	0	4	1·6	0·9	0	0	0	0
69	380	600	502	50·3	14	20	16·7	1·2	5·5	8·2	7·8	0·2	395	640	521	54·8	0·5	0·9	0·7	0·08	96	170	119·4	14·9	34	46	37·4	2·9	0	2	0·4	0·5	0	2	1·0	0·7
70	200	440	332	52·7	12·5	19	15·6	1·3	5·5	8·1	6·6	0·5	190	430	329	50·3	0·8	1·1	0·98	0·05	77	128	102	12·0	28	43	38·8	3·0	0	5	2	1·2	0	0	0	0
71	260	470	372	38·9	11·0	18·5	16·0	1·5	7·0	8·1	7·4	0·2	265	460	361	35·7	0·9	1·1	1·0	0·04	86	126	105·2	7·4	42	49	35·8	1·3	0	2	1	0·5	0	0	0	0
72	110	220	180	21·8	9·6	12·5	11·0	0·61	5·0	6·3	5·5	0·2	120	240	189	23·5	0·2	0·6	0·36	0·08	49	85	69·4	6·6	20	42	46·2	4·3	0	6	1·4	1·3	0	3	1·0	0·7
73	210	320	260	24·5	12·0	14·5	13·5	0·5	6·0	7·5	6·6	0·3	200	310	269	26·2	0·6	0·8	0·7	0·03	84	133	101	10·3	29	47	33·2	3·4	0	10	2·6	2·2	0	0	0	0
74	160	230	196	13·1	10·5	12·0	11·4	0·3	6·1	7·0	6·4	0·2	175	240	199	14·6	0·7	0·8	0·7	0·03	56	89	69·4	7·6	32	44	39·8	2·2	0	4	1·8	0·7	0	0	0	0
75	210	410	346	40·1	12·6	20	15·1	1·4	6·1	7·5	6·9	0·3	200	420	349	43·2	0·6	0·9	0·78	0·07	88	120	110·6	6·6	35	48	38·8	2·4	0	5	1·4	1·1	0	3	0·6	0·7
76	180	200	176	9·1	9·8	12·5	10·8	0·5	5·4	6·1	5·5	0·5	160	210	192	14·3	0·2	0·6	0·38	0·07	62	90	76·8	5·1	35	43	42·8	1·6	0	2	0·8	0·6	0	0	0	0
77	110	350	264	45·2	10·8	15	12·7	0·8	5·6	7·5	6·7	0·4	140	370	274	42·2	0·2	0·8	0·5	0·13	51	120	89·4	13·1	31	45	36	4·7	0	3	0·6	0·7	0	1	0·2	0·2
78	290	320	304	6·7	12	16	14·9	0·9	6·1	7·2	6·8	0·2	275	340	308	14·4	0·8	0·9	0·8	0·04	93	140	125·2	9·8	39	46	40	1·9	0	4	1·0	0·9	0	0	0	0
79	180	300	220	23·5	10	13	10·8	0·6	5·5	7	6·0	0·3	190	290	222	19·8	0·5	0·8	0·66	0·01	71	90	79	4·4	34	41	36·4	1·4	0	6	3·0	1·4	0	0	0	0
80	180	260	212	15·6	9	14	12·1	1·1	6·0	6·3	6·2	0·1	180	280	228	19·9	0·7	0·8	0·73	0·04	32	90	71·6	12·1	27	40	34	2·9	0	8	2·0	1·7	0	3	1·2	0·8

APPENDIX III Range, Mean and Standard Error of pod and bean characters in 135 trees [Five observations] Contd.

Tree	Weight of pod (g)				Length of pod (cm.)				Diameter of pod (cm.)				Volume of pod (c.c)				Pod husk thickness (cm.)				wet weight of beans per pod (g)				Number of beans per pod.				Number of flat beans per pod				Number of germinated beans per pod			
No.	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE
81	220	340	266	26.4	12	13.5	12.5	0.3	6.1	7.2	6.5	0.3	230	320	267	17.8	0.7	0.8	0.74	0.03	85	110	93.4	4.9	35	42	39	1.3	0	5	1.4	1.0	0	0	0	0
82	260	410	340	31.0	11.8	15.6	13.8	0.7	6.4	7.4	7.1	0.2	265	410	348	33.8	0.6	0.8	0.72	0.04	80	133	104	10.6	38	50	40.8	2.9	0	4	2.2	0.9	0	0	0	0
83	140	360	284	42.2	12.5	14	13.6	0.3	6.6	7.6	7.2	0.2	155	355	286	38.9	0.8	1.1	0.94	0.06	72	110	91.4	7.7	35	48	43	2.6	0	3	1.0	0.7	0	0	0	0
84	110	190	162	15.6	9.5	10.4	9.9	0.2	4.3	6.2	5.4	0.4	160	210	177	10.3	0.3	0.7	0.5	0.07	48	80	67.2	7.0	19	36	30.2	3.7	0	3	0.6	0.7	0	1	0.2	0.2
85	110	210	166	21.9	9.9	12.6	10.9	0.6	5.1	6.3	5.7	0.3	120	240	186	26.4	0.2	0.6	0.44	0.09	50	83	70.8	7.1	20	37	32.6	3.9	0	3	1.0	0.7	0	0	0	0
86	190	300	238	24.6	11.8	14.8	13.2	0.7	4.6	7.1	6.1	0.6	175	325	252	32.1	0.4	0.9	0.62	0.09	55	115	90.4	12.0	26	43	36.8	3.6	0	2	0.4	0.4	0	0	0	0
87	200	400	286	48.1	12.3	15.0	13.5	0.5	5.5	8.0	6.6	0.5	210	410	302	46.9	0.4	1.2	0.7	0.17	82	111	94.2	7.7	28	45	35.2	4.3	0	3	1.0	0.6	0	0	0	0
88	260	360	296	30.8	13.0	16.5	14.6	0.7	7.0	8.2	7.8	0.2	375	570	428	40.3	0.9	1.2	1.1	0.07	82	120	108.8	7.7	36	48	44.4	2.5	0	1	0.4	0.3	0	0	0	0
89	160	220	200	12.8	11.8	15	13.6	0.6	6.5	7.5	6.9	0.2	270	345	290	18.3	0.7	0.9	0.8	0.04	85	130	101.6	9.3	38	44	41	1.3	0	8	2.4	1.8	0	0	0	0
90	270	510	372	46.2	9.2	15	12.1	1.1	5.8	7.8	6.7	0.4	210	415	263	47.1	0.8	1.0	0.9	0.05	68	110	90	8.2	28	40	34.4	2.2	0	2	0.4	0.5	0	2	0.4	0.5
91	280	480	332	46.3	9.0	12	10.4	0.7	6.0	6.8	6.4	0.2	180	240	212	10.8	0.7	0.8	0.74	0.03	58	90	75.8	7.2	27	46	37.2	3.5	0	2	0.4	0.5	0	1	0.2	0.2
92	160	220	196	11.5	12.8	16.5	14.8	0.8	6.8	8.1	7.3	0.3	290	520	390	41.5	1.0	1.4	1.1	0.08	91	135	109.6	9.4	30	44	37.2	2.6	0	3	0.8	0.7	0	0	0	0
93	270	400	346	30.5	12.0	15.8	13.3	0.8	6.1	8.0	6.9	0.4	245	460	348	38.9	0.9	1.0	0.9	0.02	80	125	99	8.9	34	40	36.8	1.2	0	3	0.8	0.7	0	0	0	0
94	210	280	240	16.2	9.0	11.0	9.9	0.4	6.0	7.2	6.6	0.2	185	230	212	8.4	0.6	1.1	0.8	0.1	54	80	67	5.1	35	41	37.8	1.1	0	3	1.2	0.7	0	0	0	0
95	270	400	346	30.5	12.5	15.6	14.4	0.6	7.0	8.0	7.4	0.2	275	415	355	26.5	0.7	1.0	0.7	0.2	88	159	118.4	13.6	36	46	41.6	1.9	0	4	1.4	0.9	0	0	0	0
96	210	280	240	16.2	10.8	13.0	11.9	0.4	6.0	7.1	6.4	0.2	230	300	274	14.1	0.3	0.8	0.6	0.12	79	99	88.6	3.6	34	50	40	3.0	0	2	1.2	0.4	0	0	0	0
97	160	200	182	7.4	8.9	11.0	10.2	1.1	4.3	5.8	5.2	0.3	180	210	196	6.5	0.2	0.4	0.2	0.04	58	80	69.6	4.9	20	36	28.8	3.3	0	1	0.6	0.3	0	2	0.8	0.6
98	160	190	170	13.0	9.0	14.2	9.4	2.6	4.8	6.5	5.6	0.3	140	200	171	11.5	0.3	1.0	0.6	0.15	32	69	51.4	9.7	18	37	27.4	3.4	0	4	1.6	0.8	0	0	0	0
99	200	240	218	12.5	11	12	11.4	0.2	6.0	7.1	6.6	0.3	185	270	217	17.3	0.5	0.8	0.62	0.05	71	84	77.8	2.5	31	39	36.4	1.6	0	5	1.4	1.1	0	0	0	0
100	200	400	294	40.1	12	15.5	13.2	0.9	5.1	8.0	6.9	0.6	240	395	300	36.3	0.5	1.1	0.86	0.13	85	110	96.8	6.5	26	44	37.8	3.5	0	2	0.8	0.6	0	0	0	0
101	380	500	452	28.2	13.4	16.5	14.7	1.0	7.8	8.4	8.2	0.7	410	570	480	39.2	1.0	1.1	1.08	0.04	100	158	126.2	11.2	36	50	44.2	3.4	0	1	0.2	0.2	0	0	0	0
102	240	390	320	29.8	12.1	14.5	12.9	0.5	6.1	8.0	7.3	0.4	230	385	335	30.3	0.7	0.8	0.78	0.02	90	110	101	5.7	28	46	36.6	3.7	0	4	1.4	0.8	0	0	0	0
103	280	600	438	65.1	14.5	17.0	15.7	0.5	7.2	8.5	7.8	0.3	270	555	430	57.9	0.9	1.3	1.1	0.1	80	120	106.2	8.4	42	46	43.6	0.8	0	4	2.2	0.9	0	0	0	0
104	320	520	398	33.9	14.3	18	15.9	0.7	7.2	8.1	7.5	0.2	385	540	405	42.2	0.8	1.1	0.92	0.07	80	141	124.2	12.6	25	48	40.6	4.6	0	3	0.8	0.7	0	0	0	0
105	480	680	518	38.6	15.1	14.4	15.9	0.3	7.8	9.8	8.4	0.4	475	620	529	29.3	0.9	1.2	1.04	0.08	95	157	124	12.1	34	49	42.4	2.9	0	4	1.0	0.9	0	0	0	0
106	290	400	332	25.7	13.0	15.5	14.1	0.5	6.5	7.9	7.4	0.3	290	420	334	32.2	0.8	1.1	0.94	0.06	90	127	114.2	7.5	36	47	42.2	2.1	0	3	0.8	0.7	0	0	0	0

APPENDIX III

Range, Mean and Standard error of pod and bean characters in 135 trees [Five observations] Cont'd

Tree No.	Weight of pod (g)				Length of pod (Cm)				Diameter of pod (cm.)				Volume of pod (cc)				Pod husk thickness (cm.)				Wet weight of beans per pod (g)				Number of beans per pod				Number of flat beans per pod				Number of germinated beans/pod			
	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		mean	SE	Range		Mean	SE	Range		mean	SE	Range		Mean	SE
107	380	560	474	39.6	13.2	18.9	15.1	0.9	7.5	8.3	7.9	0.5	380	590	495	46.2	0.7	1.2	0.98	0.1	103	164	138.4	13.8	36	47	42	2.4	0	4	0.8	0.9	0	0	0	0
108	300	490	392	34.8	13.2	17.6	16.1	0.9	7.1	8.0	7.5	0.2	320	480	401	29.5	0.8	1.1	0.94	0.06	85	160	119.4	15.9	27	45	38	3.6	0	4	9.4	0.9	0	0		
109	210	340	276	26.1	12.0	14	13.1	0.5	6.0	7.7	6.9	0.3	220	325	274	22.5	0.7	1.3	0.98	011	79	140	111.6	13.9	29	44	37.4	3.7	0	5	3.0	0.9	0	0		
110	600	930	804	99.0	15.5	21.5	17.7	1.2	7.1	9.0	8.1	0.3	620	920	768	93.4	1.1	1.8	1.3	0.16	98	320	170	43.8	40	68	49.8	5.3	0	4	1.8	0.9	0	0	0	0
111	410	600	494	26.7	16.6	20.5	18.3	1.0	7.0	8.0	7.6	0.3	430	620	512	47.4	0.6	0.8	0.74	0.06	163	256	204.8	19.8	35	48	41.4	2.5	0	8	3.8	1.6	0	0	0	0
112	250	350	294	21.9	12.6	15.7	13.8	0.6	6.6	7.6	7.1	0.2	305	380	344	14.1	065	1.1	0.91	0.09	86	124	105.2	8.2	30	47	36.4	3.2	0	5	1.8	0.9	0	0	0	0
113	350	410	373	11.3	14.0	15.3	14.8	0.3	7.0	7.8	7.4	0.2	330	495	390	31.3	0.8	1.0	0.92	0.04	104	124	1118.5	3.7	30	36	33.5	1.1	0	3	1.0	0.6	0	0	0	0
114	450	610	520	26.9	16.0	20.1	17.9	0.7	7.5	8.0	7.9	0.2	460	625	520	31.3	0.9	1.8	1.4	0.18	73	120	97	9.1	29	49	41	3.9	0	4	2.0	0.8	0	0	0	0
115	450	610	584	31.7	17.5	19.5	18.6	0.4	8.1	9.0	8.5	0.1	440	625	547	35.3	1.1	1.4	1.24	0.08	85	157	123.6	14	36	43	39.2	1.4	0	3	1.0	0.7	0	0	0	0
116	310	390	382	15.2	13.0	14.5	13.7	0.3	7.5	8.0	7.7	0.1	320	400	365	14.4	0.9	1.2	1.03	0.06	93	102	97.4	1.6	36	43	40.2	1.5	0	4	2.2	0.9	0	0	0	0
117	200	390	286	42.4	11.5	14.0	12.7	0.5	5.8	7.4	6.6	0.4	185	380	284	45.4	0.6	0.8	0.68	0.04	54	108	263.2	199.7	29	42	32.8	4.3	0	6	1.8	1.3	0	0	0	0
118	280	360	312	15.6	13.4	16.5	14.9	0.7	6.9	7.3	7.1	0.1	260	380	320	22.4	0.3	1.2	0.58	0.18	66	121	96.8	10.6	28	47	37.4	3.5	0	4	1.4	0.9	0	0	0	0
119	350	650	522	58.5	13.5	16.5	15.2	0.6	8.1	10	8.8	0.4	365	640	525	52.0	1.4	2.1	1.86	0.14	49	96	73.2	8.6	24	34	29.6	2.4	0	23	6.0	4.8	0	0	0	0
120	440	670	566	49.9	16.2	20	18.6	0.8	7.5	8.5	8.0	0.3	420	680	564	50.8	1.1	1.6	1.42	0.09	108	164	134.8	10.1	46	58	50.8	3.2	0	5	1.2	1.1	0	0	0	0
121	300	480	356	32.1	14.4	16.9	15.2	0.5	6.6	8.2	7.2	0.3	310	420	357	27.1	0.8	1.4	1.1	0.13	60	150	96.0	17.8	31	7.7	47	8.9	0	6	3.0	1.5	0	0	0	0
122	260	420	354	29.9	13	15.6	14.4	0.6	6	8	7.4	0.4	280	440	359	29.9	0.8	1.0	0.9	0.05	80	115	96.6	7.7	37	46	41.4	1.8	0	14	4.8	2.7	0	0	0	0
123	300	420	374	23.9	11	14.8	13.5	0.8	5.8	7.8	6.8	0.4	305	410	361	24.8	0.8	1.1	0.96	0.04	89	123	108.6	6.7	35	43	39.4	1.4	0	4	1.2	0.9	0	0	0	0
124	250	450	340	42.7	14.2	17	15.3	0.6	6.5	8	7.1	0.3	260	465	338	42.1	0.8	1.1	0.98	0.07	81	143	110.6	14.5	45	58	51.5	3.2	0	4	1.0	0.8	0	0	0	0
125	300	640	518	65.9	14	17.5	15.8	0.8	5.9	10.2	7.4	0.9	325	640	551	64.5	0.9	1.3	1.08	0.09	130	160	148.4	5.8	38	42	40.6	0.8	0	5	1.8	1.2	0	0	0	0
126	240	360	300	26.2	11	13	12.2	0.4	5.5	7.5	6.5	0.2	210	375	302	33.6	0.7	0.9	0.78	0.08	60	121	96.4	13.2	36	44	40.2	1.7	0	26	8.8	5.5	0	0	0	0
127	320	920	536	114.8	15.5	24	18.4	1.7	7.0	9.1	7.6	0.4	380	910	575	100.3	1.1	1.8	1.42	0.16	85	340	165.4	50.8	33	64	45.6	5.9	0	2	1.0	0.5	0	0	0	0
128	240	450	306	42.9	12	14.7	12.9	0.5	6.1	8.2	7.0	0.4	230	420	300	36.4	0.6	0.9	0.78	0.28	58	140	99.4	19.0	26	43	37.6	3.5	0	5	2.2	0.9	0	0	0	0
129	260	350	294	18.2	12.4	16.5	14.0	0.8	5.1	7.0	6.3	0.4	275	380	321	20.8	0.3	0.8	0.54	0.11	75	92	84.4	3.3	28	40	33.8	2.4	0	4	1.4	0.8	0	0	0	0
130	520	590	476	49.6	14	18.5	16.2	0.9	7.2	8.2	7.9	0.2	330	565	474	44.4	1.0	1.2	1.08	0.04	100	150	119.8	10.4	32	45	39.8	3.6	0	6	1.4	0.8	0	0	0	0
131	240	530	416	55.8	11.2	18.5	16.7	1.6	7.1	8.5	7.8	0.3	220	520	418	60.4	0.8	1.1	1.96	0.06	80	179	143.2	18.8	34	48	44	2.9	0	4	0.8	0.9	0	0	0	0
132	400	520	466	26.0	13.3	16.3	15.3	0.7	7.9	8.5	8.2	0.1	380	520	467	27.5	0.9	1.4	1.2	0.09	104	164	129	13.2	36	49	41.8	2.6	0	4	0.8	0.9	0	0	0	0
133	290	340	310	10	11.5	14	12.9	0.6	6.4	7.5	6.9	0.2	280	360	309	17.4	0.7	0.9	0.82	0.04	98	130	110	6.4	38	48	42.6	1.9	0	8	2.6	1.6	0	0	0	0
134	250	380	314	27.1	12.5	16.5	14.2	0.8	6.5	7.5	7.0	0.2	260	390	314	27.5	0.9	1.2	1.06	0.07	80	122	104.2	8.8	34	40	38.2	1.2	0	1	0.4	0.5	0	0	0	0
135	260	360	306	21.7	11.8	13.5	12.8	0.3	6.1	7.1	6.7	0.2	270	340	307	14.5	0.9	1.7	1.16	0.16	80	140	105.8	12.3	39	46	41.8	1.4	0	4	2.2	0.8	0	0	0	0

APPENDIX IV Data on various tree, pod and bean characters and estimated yield in 135 trees. [contd.]

Tree No	Jorquette height (m)	Trunk girth (cm)	Number of flushes per unit area	Number of cushions on trunk	Number of cushions on branch	Number of flowers per unit length	Pollen fertility (%)	Number of chavelles per unit length	Number of pods per tree per year.	Pod Value	Weight of one bean (g.)	Volume of one bean (cc)	Seed Index (g)	Cotyledon Content (%)	Shell Content (%)	Black pod incidence (%)	Yield per tree per year (kg)
1	1·06	22·1	9	9	7	223	72	9	15	37	1·9	1·8	0·85	82·35	17·65	20	1·125
2	0·90	38·4	12	23	17	331	78	11	17	29	2·6	2·7	0·95	84·21	15·79	0	1·700
3	1·44	46·8	14	14	4	268	80	14	16	24	3·0	3·1	1·05	85·71	14·29	0	1·824
4	1·67	20·4	5	22	13	265	69	19	18	35	2·3	2·4	0·65	84·61	15·38	0	1·458
5	1·10	21·9	7	17	13	365	79	19	18	29	2·7	2·4	0·80	81·25	18·75	5·56	1·789
6	0·98	38·6	12	14	13	394	83	16	15	22	2·9	2·6	0·95	78·95	21·05	0	1·902
7	1·13	34·5	6	23	18	371	75	15	9	28	2·4	2·2	2·00	83·33	16·67	0	0·869
8	1·12	20·6	6	15	12	231	81	12	18	37	2·4	2·5	0·75	80·00	20·00	0	1·339
9	1·79	36·2	5	18	12	250	80	15	10	31	2·4	2·5	1·00	85	15	20	0·904
10	1·05	34·8	13	21	14	246	80	12	6	24	3·2	3·2	1·00	80	20	0	0·667
11	0·85	35·4	8	19	10	347	79	20	24	26	2·5	2·4	0·85	82·35	17·65	0	2·568
12	1·48	47·5	9	23	10	433	80	13	18	26	2·4	2·1	1·05	80·95	19·05	0	1·879
13	1·29	49·3	15	19	22	349	82	13	13	29	2·4	3·4	0·95	84·21	15·79	0	1·227
14	1·10	22·7	5	20	14	193	82	15	20	40	2·2	3·1	0·70	85·71	14·29	15·0	1·369
15	0·66	32·4	4	18	21	244	83	15	17	35	2·2	2·3	0·75	86·67	13·33	11·76	1·329
16	1·54	41·2	5	20	5	302	80	10	13	29	2·4	2·3	0·95	84·21	17·79	0	1·279
17	1·29	31·1	3	20	15	165	80	16	25	35	2·4	2·5	1·00	85·0	15·0	0	1·940
18	1·67	28·1	13	16	8	387	82	9	23	29	2·4	2·6	0·95	78·95	21·05	0	2·272
19	1·55	19·8	6	16	11	168	88	13	12	40	2·0	2·1	0·90	77·78	22·22	0	0·873
20	0·24	28·3	11	8	14	313	81	17	10	26	2·7	2·6	1·05	80·95	19·05	30·0	1·040
21	1·95	32·8	17	20	13	399	78	12	22	24	2·7	2·7	0·75	86·67	13·33	0	2·437
22	2·40	36·1	20	13	5	177	82	15	24	18	3·6	3·7	1·10	81·82	18·18	0	4·017
23	1·14	34·3	11	16	10	346	80	20	6	26	2·3	2·8	0·85	82·35	17·65	0	0·625
24	0·85	27·9	7	8	11	336	78	15	11	33	2·3	2·6	0·70	85·71	14·29	0	0·950

APPENDIX IV Data on various tree, pod and bean characters and estimated yield in 135 trees. [Contd.]

Tree No	Torquette height (m)	Trunk girth	Number of flushes per unit area	Number of cushions on trunk	Number of cushions on branch	Number of flowers per unit length	Pollen fertility (%)	Number of cherelles per unit length	Number of pods per tree per year	Pod index	Weight of one bean (g)	Volume of one bean (cc)	Seed Index (g)	Cotyledon Content (%)	Shell Content (%)	Black pod incidence (%)	Yield per tree per year (kg)
25	1·08	26·8	0	12	0	140	80	7	9	33	2·7	2·9	1·00	80·00	20·00	0	0·754
26	1·15	22·1	4	5	6	119	83	6	5	37	2·1	2·1	0·95	78·95	21·05	0	0·372
27	1·38	19·8	4	12	14	224	80	20	10	40	2·2	2·3	0·70	85·71	14·28	15·38	0·726
28	1·29	34·6	8	12	11	326	75	19	26	26	2·8	2·9	1·05	80·95	19·05	0	2·636
29	0·83	28·5	5	12	8	238	80	20	20	26	2·7	2·7	1·05	85·71	14·28	0	2·000
30	0·66	26·6	8	10	14	468	83	23	30	21	2·9	3·1	0·90	83·33	16·67	0	3·348
31	1·44	26·5	13	13	15	489	86	6	12	24	3·1	3·1	1·00	80	20	0	1·372
32	1·43	24·5	3	10	8	204	81	9	7	35	2·2	2·3	0·90	83·33	16·67	0	0·539
33	1·53	35·5	13	8	7	168	82	9	13	26	2·8	2·7	1·05	80·95	19·05	0	1·396
34	1·53	30·1	13	16	14	369	80	16	39	24	2·6	2·7	1·15	78·26	21·74	7·69	4·485
35	1·95	26·0	0	24	0	204	72	6	32	18	2·4	2·6	1·05	80·95	19·05	0	6·899
36	1·30	32·6	10	15	11	256	83	13	20	29	2·5	2·9	1·00	80	20	0	2·004
37	1·82	26·5	12	12	9	211	72	14	14	20	2·6	2·6	1·15	82·6	17·39	28·57	1·481
38	1·26	27·1	8	9	8	204	86	10	42	26	2·6	2·7	0·85	82·35	17·65	0	4·233
39	1·83	29·4	14	12	11	320	82	14	29	22	2·7	2·7	1·05	80·95	19·05	0	3·607
40	1·35	22·1	5	10	13	140	80	9	33	35	2·2	2·3	0·75	86·67	13·33	0	2·673
41	1·87	27·8	0	13	0	75	78	7	10	29	2·5	2·6	0·85	82·35	17·65	10	1·018
42	1·42	26·8	5	15	10	155	81	9	5	31	2·3	2·4	0·85	88·24	11·76	0	0·459
43	0·77	25·8	13	13	11	167	79	11	8	29	2·5	2·5	0·75	86·67	13·33	0	0·766
44	2·10	23·3	0	10	0	94	78	7	2	31	2·4	2·6	0·65	84·62	15·38	0	0·181
45	1·36	20·5	4	13	15	202	79	12	9	35	2·1	2·0	0·70	78·57	21·43	22·22	0·694
46	1·64	33·1	5	12	9	195	82	6	7	42	2·0	1·9	0·85	82·35	17·65	0	0·484
47	1·26	32·4	16	17	10	298	75	20	31	24	2·7	2·7	1·00	80	20	0	3·689
48	1·29	29·3	15	6	7	275	82	7	8	26	2·5	2·3	0·85	88·24	11·76	0	0·809

APPENDIX IV Data on various tree, pod and bean characters and estimated yield in 135 trees. [contd.]

Tree No	Jorquette height (m)	Trunk girth (cm)	Number of flushes per unit area	Number of cushions on trunk	Number of cushions on branch	Number of flowers per unit length	Pollen fertility (%)	Number of cherelles per unit length	Number of pods per tree per year	Pod Value	Weight of one bean (g)	Volume of one bean (cc)	Seed index (g)	Cotyledon Content (%)	Shell Content (%)	Black pod incidence (%)	yield per tree per year (kg)
49	1·81	16·4	15	7	11	345	77	7	10	24	2·8	2·9	1·00	85	15	30	1·180
50	1·49	19·5	6	10	11	257	79	12	32	35	2·0	2·1	1·05	78·71	21·29	0	2·604
51	1·52	32·1	17	12	16	332	80	14	30	26	2·7	2·7	0·90	88·89	11·11	0	3·240
52	1·56	33·6	4	10	16	530	81	16	16	40	1·8	1·9	1·00	85	15	0	1·164
53	1·22	27·5	7	13	14	213	74	14	14	26	2·6	2·7	0·80	87·5	12·5	14·29	1·478
54	1·15	30·2	16	22	21	259	77	14	11	29	2·3	2·4	0·85	76·47	21·53	18·18	1·062
55	1·41	16·5	7	10	13	502	74	13	17	29	2·4	2·4	0·75	80	20	0	1·638
56	1·13	33·4	4	13	17	198	80	12	14	30	2·4	2·4	0·60	83·33	16·67	0	1·729
57	1·87	20·1	0	14	0	212	84	11	16	24	2·6	2·9	0·95	76·19	21·0	0	1·888
58	1·72	29·5	7	19	11	478	78	14	13	26	2·8	3·0	0·85	88·24	11·76	0	1·401
59	0·93	32·4	19	30	20	219	79	14	11	24	3·0	3·1	1·10	81·82	18·18	0	1·262
60	1·42	28·6	15	18	14	262	79	14	19	24	2·7	2·5	1·00	85	15	0	2·082
61	1·62	18·2	6	12	9	201	80	10	8	31	2·4	2·3	0·65	76·92	23·08	50	0·748
62	0·81	25·2	15	9	20	378	84	18	21	22	2·9	3·1	1·00	85	15	0	2·713
63	0·93	19·5	9	16	17	255	75	17	24	24	2·6	2·8	1·00	80	20	0	2·688
64	0·90	26·4	7	10	15	199	85	18	14	31	2·5	2·0	0·85	88·24	11·76	0	1·262
65	0·82	27·1	4	14	14	227	79	21	27	33	2·6	2·2	0·65	76·92	23·08	0	2·365
66	0·69	32·4	13	27	13	243	81	10	43	35	2·0	2·1	1·00	85	15	0	3·345
67	0·53	30·5	12	17	12	201	74	18	44	33	2·0	2·1	1·15	82·61	19·05	2·27	3·696
68	1·24	40·1	6	15	7	402	80	18	20	40	1·8	2·0	1·10	81·82	18·18	0	1·424
69	1·57	34·2	15	18	15	310	71	18	13	24	2·8	2·8	0·90	83·33	16·67	30·77	1·552
70	1·20	25·4	12	17	10	281	82	10	11	26	2·5	2·5	1·00	85	15	0	1·122
71	1·81	24·1	13	13	14	222	69	10	12	26	2·7	2·6	1·15	78·26	21·74	0	1·262
72	1·70	18·2	3	15	10	161	71	10	9	40	1·9	2·0	0·85	82·35	17·65	8·33	0·624
73	1·03	19·6	0	15	0	93	73	10	22	26	2·4	2·4	0·70	85·71	16·29	0	2·2222
74	1·53	21·3	4	28	17	187	76	9	14	40	1·9	2·0	0·85	88·24	11·76	0	0·971
75	1·23	24·6	5	10	9	214	84	10	19	24	2·6	2·7	0·60	83·33	16·68	5·26	2·101
76	1·75	14·1	4	19	10	205	79	8	6	37	4·0	2·1	1·15	82·61	17·39	0	0·460
77	1·36	18·6	12	19	14	212	75	16	30	31	2·2	2·3	0·85	82·35	17·65	16·67	2·682

APPENDIX IV Data on various tree, pod and bean characters and estimated yield in 135 trees.

Tree NO	Jorquette height (m)	Trunk girth (cm)	Number of flushes per unit area	Number of Cushions on trunk	Number of Cushions on branch	Number of flowers per unit length	Pollen fertility (%)	Number of Chevelles per unit length	Number of pods per tree per year	Pod Value	weight of one bean (g)	Volume of one bean (cc)	Seed index (g)	Cotyledon Content (%)	shell Content (%)	Black pod incidence (%)	Yield per tree per year (k.g)
18	1·36	24·3	5	7	10	269	75	9	9	22	3·1	3·2	0·85	88·24	11·76	22·22	1·126
19	2·90	25·5	0	15	0	115	84	6	10	35	1·9	1·8	1·15	78·26	21·74	10	0·790
30	0·68	26·1	4	25	28	255	73	13	28	40	1·9	2·1	1·10	86·36	13·64	0	2·004
31	0·65	32·4	10	17	18	165	73	10	25	22	2·4	2·4	0·85	82·35	17·65	12	2·335
32	0·98	30·6	0	17	0	306	78	11	13	26	2·4	2·4	1·00	80	20	7·69	1·352
33	1·01	27·8	9	26	20	193	76	9	19	31	2·2	2·2	1·05	85·71	14·29	0	1·736
34	2·14	25·1	0	26	0	196	73	7	12	42	1·9	2·1	0·85	82·35	16·65	8·33	0·806
35	1·15	16·1	4	18	15	146	72	7	7	40	1·9	2·1	0·85	88·24	11·76	57·14	0·495
36	0·74	24·8	5	18	19	161	85	16	10	31	2·4	2·2	0·90	83·33	16·67	0	0·904
37	1·45	25·3	5	12	10	372	78	13	20	31	2·5	2·8	1·10	81·82	18·18	0	1·884
38	0·84	34·8	17	23	22	247	85	14	19	24	2·6	2·6	0·65	76·92	23·08	0	2·067
39	1·24	30·2	5	10	11	244	76	15	35	26	2·6	2·6	0·90	88·89	11·11	5·71	3·556
70	1·33	25·3	17	14	19	483	86	16	18	31	2·6	2·4	1·05	85·71	14·29	0	1·620
71	1·43	32·4	4	13	10	253	78	12	10	37	2·1	2·2	0·90	77·78	22·22	10	0·758
72	1·81	20·7	14	21	15	384	85	23	22	24	2·6	2·2	0·90	83·33	16·67	0	2·411
73	1·14	34·2	16	9	17	148	69	11	15	29	2·7	2·3	0·95	89·47	10·53	6·67	1·485
74	0·78	25·6	5	10	14	214	70	7	17	42	1·8	2·1	0·85	82·35	17·65	5·88	1·139
75	2·22	32·5	7	17	4	157	71	9	9	24	3·0	2·9	1·00	80	20	41·44	1·065
76	0·87	15·2	4	3	12	87	80	4	4	31	2·1	2·3	0·85	82·35	17·65	0	0·354
77	1·52	28·6	3	22	15	197	73	15	27	40	2·2	2·2	0·80	81·25	18·75	18·52	1·879
78	1·13	32·1	4	17	6	198	80	12	32	57	2·1	2·8	0·70	85·71	14·29	0	1·644
79	1·21	26·8	5	23	15	353	73	11	12	35	1·9	2·0	0·80	81·25	18·75	0	9·336
100	0·79	34·5	5	12	17	413	74	19	31	29	2·4	2·4	0·85	88·24	11·76	0	3·000
101	1·58	36·8	11	22	18	904	75	23	77	22	2·9	2·7	1·15	82·61	17·39	6·49	3·407
102	1·40	40·2	10	30	16	348	85	10	53	26	2·1	2·0	0·75	80	20	7·55	5·353
103	1·48	40·2	16	20	12	234	86	15	68	26	2·3	2·4	0·70	78·57	21·43	0	7·221
104	1·35	36·7	6	17	7	346	80	9	63	22	2·7	2·6	0·90	83·33	16·67	0	7·824
105	1·22	28·9	13	23	13	293	88	17	91	22	3·0	3·1	1·05	80·95	19·05	2·2	11·284
106	0·82	47·9	5	16	20	209	76	9	109	24	2·5	2·4	0·90	83·33	16·67	0	12·447
107	1·27	48·6	15	15	16	193	80	14	58	20	3·2	3·0	1·05	80·95	19·05	3·45	8·027

APPENDIX IV Data on various tree, pod and bean characters and estimated yield in 135 trees. [contd]

Tree No	Total height (m)	Trunk girth (cm)	Number of flushes per unit area	Number of cushions on trunk	Number of cushions on branch	Number of flowers per unit length	Pollen fertility (%)	Number of Chevelles per unit length.	Number of pods per tree per year.	Pod Value	Weight of the bean (g)	Volume of one bean (cc)	Seed Index (g)	Cotyledon Content (%)	Shell Content (%)	Black pod incidence (%)	Yield per tree per year [K.g]
108	0·70	32·5	14	32	15	198	80	8	118	22	3·0	3·1	1·05	80·95	19·05	0	14·089
109	1·52	32·8	13	27	11	263	83	13	56	24	3·2	3·0	0·95	81·21	15·79	1·79	6·249
110	1·98	42·6	0	13	0	368	82	13	132	15	3·7	3·8	1·15	82·61	17·39	3·53	22·440
111	1·26	48·9	14	28	16	267	83	16	98	18	4·7	4·2	2·00	85·71	14·29	0	20·050
112	2·00	30·1	0	20	0	116	75	8	33	26	2·6	2·1	1·00	85	15	0	3·471
113	1·08	48·0	11	24	15	397	78	21	66	24	3·2	2·2	0·90	88·89	11·11	9·09	7·623
114	1·62	46·5	12	25	16	383	73	18	103	29	2·6	2·7	1·15	82·61	19·05	0	9·991
115	1·00	32·8	16	17	11	229	84	14	74	22	3·0	2·9	1·05	75·71	14·29	0	9·146
116	·9	29·8	0	21	0	171	85	7	71	29	2·4	2·3	1·00	80	20	0	6·915
117	·0	38·1	0	20	0	253	83	9	134	16	2·5	2·5	0·90	83·33	16·67	18·6	35·268
118	·84	36·2	0	8	0	244	88	17	34	29	2·7	2·8	0·95	84·21	15·79	1·39	3·291
119	1·50	28·6	14	19	9	371	75	10	72	37	1·7	2·0	1·15	82·61	17·39	0	5·270
120	1·35	46·2	17	25	14	317	80	17	53	22	3·1	3·0	1·10	81·82	18·18	0	7·144
121	1·03	35·8	16	17	15	252	86	15	87	29	2·3	2·2	1·05	80·95	19·05	2·29	8·352
122	1·56	48·8	15	24	9	492	85	19	55	29	2·5	2·4	1·15	82·61	17·39	0	5·313
123	1·60	47·9	14	28	16	614	80	23	36	26	2·8	2·4	1·10	86·36	16·34	0	3·909
124	1·64	34·0	16	22	12	229	86	16	26	24	2·0	1·9	1·05	85·71	14·29	0	2·875
125	1·37	29·4	17	21	15	202	80	11	93	20	3·7	3·7	1·20	80	20	4·3	13·243
126	2·30	28·7	0	22	0	185	76	12	67	29	2·3	2·3	0·95	84·21	15·79	4·48	6·485
127	1·36	36·5	16	29	16	468	85	14	75	18	3·3	2·4	1·05	80·95	19·05	0	12·405
128	0·98	28·6	12	32	15	198	84	10	20	29	3·0	2·8	1·00	85	15	0	1·988
129	1·26	30·4	11	20	13	277	85	14	45	33	2·3	2·3	1·05	80·95	19·05	6·67	3·798
130	1·09	42·5	18	28	24	269	80	13	82	24	2·6	2·5	1·00	80	20	3·66	9·823
131	0·54	29·8	17	31	20	370	80	14	92	20	3·2	3·2	1·25	83·33	16·67	0	13·174
132	0·68	32·8	18	21	19	493	76	20	78	22	3·3	3·0	1·15	82·61	17·39	2·56	10·062
133	0·53	38·9	8	28	23	302	86	14	42	26	2·8	2·9	0·95	84·21	15·79	0	4·620
134	0·89	39·4	13	29	11	249	81	11	57	26	2·7	2·7	1·05	80·95	19·05	0	5·939
135	·50	42·6	9	32	18	230	84	13	48	26	2·6	2·5	0·95	84·21	15·79	6·25	5·078

GENETIC VARIABILITY AND CORRELATION STUDIES IN COCOA *(Theobroma cacao L.)*

By

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ABSTRACT OF A THESIS

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ABSTRACT

Investigations on the genetic variability and correlation studies in cocoa were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period from July 1980 to August 1981 in a well established cocoa garden at Alpara in Trichur district, to elucidate information on the extent of variability and the degree of association existing among the 26 important plant, pod and bean characters, in a group of 135 cocoa trees, variety Forastero.

Considerable variability was noted among all the characters of the sexually reproduced population of cocoa trees. Number of flowers per unit length on the trunk, number of pods per tree per year, weight of pod, volume of pod and wet weight of beans per pod showed maximum variability. Shell percentage and seed index manifested considerable variability among the bean characters.

Phenotypic coefficient of variation (P.C.V.), genotypic coefficient of variation (G.C.V.) and heritability were estimated for 7 pod and bean characters. Both (P.C.V.) and (G.C.V.) were highest for attributes such as thickness of pod husk, number of beans per pod and weight of pod. Moderately high heritability was observed for weight of pod,

thickness of pod husk and number of germinated beans. Volume of beans showed the lowest heritability.

Yield from trees was found to be positively correlated with 6 of the characters studied, while number of germinated beans per pod and pod value were negatively correlated with yield. Out of the eight characters, pod value had the maximum contribution to yield. Number of pods per tree per year was found strongly associated with yield. Seed index and trunk girth also were positively and significantly correlated with yield.

Phenotypic (r_p) correlations among seven characters indicated that number of beans per pod was positively correlated with weight of pod. Positive correlations were also established between volume of beans and wet weight of beans per pod.

Among the seven characters observed for genotypic (r_g) correlations, wet weight of beans showed positive correlation with diameter of the pod and pod weight.

Positive phenotypic as well as genotypic correlations were established in the case of wet weight of beans per pod with number of beans per pod and volume of beans. Number of beans per pod in turn, showed positive correlation with weight of pod at both levels.

From the present studies it was evident that characters like diameter of pod, wet weight of beans per pod, number of beans per pod, number of germinated beans per pod, volume of pod, volume of bean, pod value, number of cushions on trunk, trunk girth, number of pods per tree per year and seed index have direct influence on the yield of cocoa. These traits can be considered while selecting cocoa trees for using in breeding programmes.