VARIABILITY STUDIES IN COWPEA

BY

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Agricultural Botany

COLLEGE OF HORTICULTURE

VELLANIKKARA - TRICHUR

1981

DECLARATION

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

Vellanikkara,
7th, March, 1981.

M.B. JALAJAKUMARI

CERTIFICATE

Certified that this thesis is a record of research work done independently by Miss.Jalajakumari, M.D. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
7th, March, 1981.

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C E R T I F I C A T E

We, the undersigned, members of the advisory committee of Miss. Jalajakumari, M.B., a candidate for the degree of Master of Science in Agriculture with major in Agricultural Botany, agree that the thesis entitled "VARIABILITY STUDIES IN COWPEA" may be submitted by Miss. Jalajakumari, M.B. in partial fulfilment of the requirements for the degree.

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ACKNOWLEDGEMENTS

I have immense pleasure to record my deep sense of gratitude and indebtedness to Dr. K.M. Narayanan Namboodiri, Professor of Agricultural Botany, College of Horticulture, Vellanikkara for suggesting the problem and for his valuable guidance and encouragement for the successful completion of the research programme.

Sincere thanks are also due to Dr. P.C.Sivaraman Nair, Associate Dean, College of Horticulture, Vellanikkara for the facilities and timely help given to me during the course of my studies here.

I would like to express my deep sense of gratitude to Dr. K. Kumaran, Associate Professor, College of Horticulture, Vellanikkara for his valuable suggestions for the progress of the work.

I am greatful to Dr. N. Mohanakumaran, Professor of Horticulture, College of Horticulture, Vellanikkara for all the help rendered by way of encouragement and suggestions throughout the course of the study.

To Shri. P.V. Prabhakaran, Associate Professor of Statistics, I owe my deep sense of gratitude for all the assistance by way of guidance and advice on the statistical aspect of the study.

I am also to place on record my sincere thanks to Shri. V.K.G. Unnithan, Assistant Professor of Statistics, College of Horticulture, Vellanikkara and Dr.M. Rathinam, Associate Professor of Forestry, and Shri.R. Rangaswamy, Associate Professor of Statistics, Tamil Nadu Agricultural University, Coimbatore for rendering all the necessary advice at all stages of the statistical analysis and for providing all facilities for the statistical analysis of the data with the use of computer.

I also wish to express my sincere appreciation to my colleagues and to the members of the staff of the Division of Agricultural Botany, College of Horticulture for their co-operation and help, which have always been so spontaneous and overwhelming.

To Dr. T.V. Viswanathan, Associate Professor and Mr. Inasi, K.A., Junior Agricultural Officer, I express my boundless and sincere thanks for their timely advice and assistance.

I would also wish to record my gratitude to Dr. K. Karunakaran, Associate Professor (B) and to all the members of staff of the Rice Research Station, Pattambi, for their sincere co-operation and attention at all stages of the present investigation.

Vellanikkara,
7th, March, 1981.

(M.B. JALAJAKUMARI)

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INTRODUCTION

Pulses are important as a major source of protein in the vegetarian diet of the people and also as fodder to cattle. They also restore fertility of the soil through fixation of nitrogen by root nodules. Realising the manifold importance of pulses, great attention is now being focussed to increase their production in the country through various means.

In general, pulses are considered to be uncertain crops. But cowpea, a prominent member of the genus *Vigna*, owing to appreciable amount of hardiness and adaptability, stands out from this group as an exception. It does well over a wide range of soils including acid clays and is capable of withstanding heavy rains or even prolonged drought. Among the three widely cultivated species of this taxon, viz., common cowpea, asparagus bean and catjang bean, *Vigna unguiculata* L. (common cowpea) is characterised by subreniform to sub-globose seeds and semipendent, medium sized pods, best suited both for vegetable as well as for grain purposes.

Kerala, with its widely varying soils and heavy rainfall, has not been favourable for most of the pulses. Nonetheless, cowpea due to its adaptability and ease of cultivation, has turned up as a choice catch crop in this part. In India pulses are cultivated over an area of 22.8 million hectares and yield about 12.17 metric tonnes of grain. As such the great possibilities of this crop in Kerala need no emphasis. However, the average yield of pulses is coming only 340 kg per hectare in Kerala which is rather poor and is the lowest among the Indian States. With the increasing cost of almost all the agricultural inputs, this group of crop plants calls for highly intensified research to attract more farmers to the cultivation of these crops.

Active extension or popularisation programme of any crop presupposes adequate information on the varieties to be recommended and on the agronomic practices to be adopted under different agro-climatic conditions. In cowpea, these informations are lacking because of the fact that very little breeding or agronomic research has been carried out, particularly in our State.

Primary aim of a plant breeder is to improve yield and quality by evolving superior varieties. Selection of superior varieties will be effective only when genetic variability exists in the material chosen for improvement. The observed variability for a character is the product of interaction of hereditary effects of the concerned genes and the influence of micro and macro environments.

In any crop improvement programme, search for variability available in the germplasm is the preliminary step. Selection of genotypes showing high heritability for the desirable characters that contribute to yield is a prerequisite in the development of new varieties with increased yield potentiality. However, yield by itself is a very complex character conditioned by numerous genetical factors interacting with environment. It, therefore, becomes difficult to evaluate or select for this character directly. Such situation dictates the breeder to employ more indirect methods as determination of the association existing between yield and other less variable plant characters which would serve as simple guides for spotting out high yielders. The existence of association is usually determined by studying the correlations existing between the different characters and yield. Further, it will be more helpful in the selection to have an understanding on the association between yield and its components and the relative influence of each component on yield.

Cowpea has been chosen for the present study, because of its high adaptability and importance as pulse crop grown in our State. Informations on the source of variability for various factors contributing to yield are inadequate in cowpea and hence it is necessary to evaluate the available germplasm in this regard. With this view in mind, the present investigations were undertaken with the following objectives.

a) To study the genetic variability in the expression of economic characters in selected cultivars of cowpea.

b) To estimate the genotypic and phenotypic correlation coefficients for selected characters between themselves and between yield.

c) To seperate the correlation coefficient into direct and indirect effect through the Path Coefficient Analysis in order to get some idea of the casual system of the factors contributing to yield.

d) To estimate the heritability and genetic advance for the different characters.

e) To evolve a selection index for isolating superior genotypes from among those tested.

Review Of Literature

REVIEW OF LITERATURE

Cowpea is an important crop extensively grown in the tropical countries. However, studies to estimate the extent of genetic variability in its germplasm are found to be relatively few. Most of the works with reference to pulses in general and cowpea in particular has been done only during last decade. A review pertaining to the aspects of present study in cowpea is given below. Similar works on the other important leguminous crops are also included in the review wherever the literature in cowpea is seen to be insufficient. The important findings relevant to the present study are reviewed under the following chapters.

I. Variability.
II. Heritability and genetic advance.
III. Correlation studies and
IV. Path Coefficient Analysis.

I. Variability

Many workers have studied the extent of variability in various pulse crops by working out genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). But the extent of genetic variability is more important than the total variation since greater the genetic diversity, wider will be the scope for selection.

Cowpea (*Vigna unguiculata*, L.):

Karthikeyan (1963) appears to be the first to report in some detail the results of genetic studies. He has reported that genotypic variability was found to be the largest with the number of fruiting nodes and this was followed in order by number of pods per plant, number of branches and seed yield.

Studies of Singh and Mehndiratta (1969) have shown that number of pods per plant had the highest genotypic coefficient of variation.

Doku's (1970) studies of variability in cowpea have shown that genotypic coefficients were generally higher than phenotypic coefficients.

Trehan *et al.* (1970) after their studies of genetic variability in cowpea have reported that genetic variance estimates were high for branches per plant, pods per plant and peduncle length.

Veeraswamy *et al.* (1973 a) have reported that seeds per pods showed high GCV and clusters per plant showed low GCV.

Bordia et al. (1973) found that high genetic coefficients of variation were observed for pod number and grain yield per plant was strongly associated with pod number and length and with number of seeds per pod.

Lakshmi and Goud (1977) reported that the genotypic coefficients of variation was higher for plant height, grain yield, number of pods per plant and 100-grain weight.

Black gram (Vigna mungo, L.):

Singh et al.(1972) reported that seed yield and pods per plant showed high genotypic coefficient of variation.

Veeraswamy et al. (1973 b) also agreed that pods per plant exhibited maximum GCV followed by plant height. They further observed low GCV values for pod length and seeds per pod.

Green gram (Vigna radiata (L.) Wilczek):

Rathnaswamy et al. (1978) worked out estimates of variability in 24 early maturing varieties of green gram and concluded that characters like 100 seed-weight, pods per plant and seed yield showed high genotypic coefficient of variation.

Other pulses:

Joshi (1971 a) observed high GCV for pods per plant and seed yield in bengal gram.

In lablab, Joshi (1971 b) reported high GCV for seed yield and low GCV for branches per plant.

In Soybean, Lal and Mehta (1973) reported that plant height showed high GCV. The study of Malhotra (1973) revealed maximum GCV for pods per plant and minimum GCV for seeds per pod and pod length.

Chandra et al. (1975) studied in 23 divergent strains of *Cajanus cajan* and reported that a wide range of phenotypic variability occured for days to flowering and maturity, height, number of primary branches and secondary branches and yield, but not for pod length and seed number per pod. The genotypic coefficient of variation was high for all characters except seed number per pod.

Singh and Shrivastava (1977) observed that the number of secondary branches had the highest GCV in red gram.

II. Heritability and genetic advance

The extent to which the variability of a quantitative character is transferable to the progeny is referred to as heritability for that particular character. The characters which exhibit a wide range of expression may be controlled by many genes whose action may either be additive and/or geometric. While selecting for such a character, consideration of the mere phenotypic variability without estimating the heritable part of it will not be of much success. Heritability estimation along with genetic gain is usually more useful in predicting the resultant effect through selection of the best individuals (Johnson _et al_. 1955 a).

The broad sense heritability and genetic advance estimates have been reported by many authors.

Cowpea (_Vigna unguiculata_, L.):

Studies of Singh and Mehndiratta (1969) have shown that high values of heritability estimates were exhibited by 100 - seed weight, days to flowering, pod length and days to maturity. Expected genetic advance was found to be appreciable for number of branches, 100 grain weight, pod number, pod length and yield.

Trehan *et al*. (1970) reported that heritability estimates were medium for nine characters studied except for days to flower, which was low and genetic advance was high for peduncle length, pods per plant and yield.

Sohoo *et al*. (1971) showed wide genetic variability and gave high estimates of heritability and genetic advance in vine length, pod number per plant and plant weight.

Bordia *et al*. (1973) reported that heritability was highest for 100-seed weight, followed by number of days to flowering and pod length. High genetic advance was observed for pod number and length and number of seeds per pod.

High heritability and genetic advance were noticed for 100-grain weight, yield of grain and yield of haulms by Sreekumar *et al*. (1979). The lowest heritability was recorded by number of grains per pod, while total duration showed the lowest values of genetic advance.

Black gram (*Vigna mungo* L.):

Singh *et al*. (1972), Veeraswamy *et al*. (1973 b) and Goud *et al.*(1977) have reported in black gram heritability and genetic advance.

Green gram (*Vigna radiata* (L.) Wilczek):

Singh and Malhotra (1970 a), Joshi and Kabaria (1973) have also reported the same in green gram.

Other pulses:

Rathnaswamy *et al.*(1973) have reported that plant height, branches per plant, plant height and days to flowering have high heritability and genetic gain in red gram. Singh and Shrivastava (1977) also reported in red gram about heritability and genetic advance.

Malhotra (1973) reported in soybean that characters which had high genotypic coefficient of variation had also high genetic advance.

Veeraswamy *et al.* (1973 c) in soybean reported that a high heritability value was noted for number of pods per plant. A high genetic advance was noticed in respect of seed yield per plant, number of pods per plant, and plant height.

In bengal gram, Rastogi and Singh (1977) found that the heritability for yield was high and moderate for other characters.

Chowdhury *et al.* (1978) estimated the heritability and genetic advance in lentil and concluded that the greatest estimates of heritability and genetic advance were obtained for pod number per plant.

In a study, Sarafi (1978) estimated the heritability (narrow sense) and genetic advance in common bean and found that pods per plant, seeds per pod and 100-seed weight had the maximum genetic advance values.

In cluster bean, heritability was found to be high for pods per cluster, pod length, days to maturity and 100-seed weight, while it was found to be low to medium for all other characters (Chaudhary, 1979).

III. Correlation studies

In a programme of breeding for improving the yield potential of a crop, information on the inter-relationship of yield with other traits is of immense help. This will facilitate selection of suitable high yielding plants through other related components. Measurements of phenotypic, genotypic and environmental correlations between yield and other characters have been reported by many workers in pulses and a review of this aspects is presented below:

A) Association between yield and its components:-

Cowpea (*Vigna unguiculata* L.)

In cowpea, seed yield exhibited positive and significant correlations with the branches and pods per plant, 100-seed weight and seeds per pod /Singh and Mehndiratta (1969), Trehan *et al.* (1970), Doku (1970), Premsekar and Raman (1972)7.

Bordia *et al.* (1973) reported that grain yield per plant was strongly associated with pod number and length, and with number of seeds per pod.

Patel (1973) recorded significant correlations with yield for plant height, pod length, 100-seed weight, and number of branches and pods per plant and seeds per pod. Of these, pod number and 100-seed weight appeared to be the most important.

Kheradnam and Niknejad (1973) also reported positive association between seed yield and all the traits studied except branches per plant.

Studies of Kumar *et al.* (1976) have shown that pod yield was positively associated with branches per plant pods per plant, pod length, thickness of pod, days to flowering and days taken to maturity. Analysing the regression values, these workers have also shown that clusters per plant, pods per plant and 100-seed weight were the important characters in determining pod yield.

Black gram (Vigna mungo L.):

Components like pods per plant, seed size and pod length showed positive correlation with seed yield in black gram (Verma and Dubey (1970) and Singh et al. (1972).

Green gram (Vigna radiata (L.) Wilczek):

Singh and Malhotra (1970 b) reported that seed yield was strongly associated with pods per plant, clusters per plant and seeds per pod.

According to Tomar et al. (1973) yield was positively correlated with pods per plant, seeds per pod, 100-seed weight and pod length.

Other pulses:

Singh and Shrivastava (1977) assessed the association of yield with other traits in 20 F_2 populations of red gram and concluded that the seed yield was positively associated with plant height, plant spread, pod-bearing length, pods per plant and 100 seed weight in red gram.

According to Baluch and Soomro (1968) high positive correlations were found between plant height and internode length, between number of days to flowering and number of nodes upto the 1st flower, between height at flower initiation and seed yield and between seed size and seed yield.

Harbans Singh *et al.* (1976) reported in gram (*Cicer arietinum* L.) that seed yield was positively correlated with the number of branches and pods per plant. In general, 100-seed weight was negatively correlated with number of seeds per pod according to them.

In soybean the yield was positively and significantly correlated with days to maturity, days to flower, plant height, branches per plant and pods per plant and it showed a negative association with 100-seed weight [Gautam and Singh (1977)].

B) Intercorrelation among yield components:-

Cowpea (*Vigna unguiculata*, L.)

Positive inter correlations among 100-seed weight, pod length and seeds per pod and between pods per plant and branches per plant were reported by Singh and Mehndiratta (1969) in cowpea. They also reported seed weight, and pod length were negatively correlated with pods per plant and branches per plant.

Black gram (*Vigna mungo* L.)

The work done by Singh *et al.* (1972) in blackgram revealed that seed yield was positively correlated with number of pods, number of fruiting nodes, number of primary branches, pod length and seed size. Singh *et al.* (1975) in black gram reported that 100-seed weight was negatively correlated with plant height.

Soundarapandian *et al.* (1975) suggested that high positive association existed between clusters per plant and pods per plant.

Green gram (*Vigna radiata* (L.) Wilczek)

According to Singh and Malhotra (1970 b) 100-seed weight was negatively correlated with almost all characters except yield.

The study conducted by Joshi and Kabaria (1973) revealed that the pods and seeds per plant and seeds per pod showed strong and positive association among themselves.

Pod length and positive association with 100-seed weight, but negative association with pods per plant (Ratnaswamy *et al.* 1978).

Other pulses:

Veeraswamy *et al.* (1973) reported that branches per plant exhibited positive and significant correlation with clusters per plant, pods per plant and plant height in red gram.

In soybean, 100-seed weight was negatively associated with all other characters. The association of seeds per pod with other traits did not assume significance. The remaining characters were positively correlated with one another [Gautam and Singh (1977)].

In cluster bean, Nath (1979) studied the association of yield components and concluded that all the component characters were positively correlated with each other.

In chick pea, Katiyar (1979) observed negative correlation between seeds per pod and 250-grain weight and positive correlations between pods per plant and secondary branches per plant.

IV. Path Coefficient Analysis

Yield is the end product of many complex components which singly or jointly influence the seed yield [Grafius, (1959) and White house et al.(1958)]. Hence it is necessary for a plant breeder to have information on their direct and indirect influences on yield. Wright (1921) developed a technique known as Path Coefficient Analysis which is an effective tool for analysing the direct and indirect causes of information and it also permits critical examination of specific factors that produce a given correlation.

Path Coefficient Analysis has been employed in different pulse crops by many workers and their reports are summarised below:

Cowpea (Vigna unguiculata, L.):

In cowpea, Singh and Mehndiratta (1970) employed path coefficient and concluded that pods per plant, seeds per pod and 100 seed weight were the important yield components in cowpea, since they showed significant direct effect on yield.

Tikka et al. (1978) recorded that the contribution to yield of number of pods per plant and 100-seed weight were made mainly through their direct effect and most other characters exerted a substantial indirect effect through these two characters. An important indirect effect was also exerted by several characters through the number of seeds per pod. Simultaneous selection for increases in 100-seed weight, pods per plant and seeds per pod has also been recommended.

Black gram (Vigna mungo L.):

In black gram, pods per plant had a maximum direct effect on seed yield followed by pod length and seed weight as reported by Singh et al. (1972). Similar findings were reported by Bhattacharya (1976). He further stated that days to flowering also had a positive direct effect on seed yield.

According to Soundarapandian et al. (1976) plant height and clusters per plant showed high positive direct effects on seed yield, while branches per plant, pods per plant and seeds per pod showed little or negative direct influence on seed yield.

Green gram (Vigna radiata (L.) Wilczek):

Path coefficient analysis indicated that the pods per plant, seeds per pod and seed size influenced on the seed yield. The seed size had negative indirect effect on yield through seeds per pod and pods per plant and vice-versa (Singh and Malhotra (1970 b) and Singh and Singh (1973).

Giriraj and Vijayakumar (1974) stated that the plant height and pod length exerted maximum direct effects on yield. Pods per plant showed little direct effect, while seeds per pod produced negative direct effect on seed yield followed by 100-seed weight.

Malhotra and Singh (1976) reported that protein content was negatively correlated with most of the agronomic characters but positively correlated with 100-seed weight.

Singh et al. (1977) reported that the primary branches and clusters per plant entitled indirect contribution to seed yield, while the pods per cluster and pods per plant contributed directly towards seed yield.

Recently, Rathnaswamy et al.(1978) revealed that seed yield was directly influenced by components like 100-seed weight, seeds per pod and pods per plant and the significant and positive direct effect of 100-seed weight on seed yield was nullified by the negative indirect effects through pods per plant and seeds per pod in green gram.

Boomikumar (1980) indicated that in green gram plant height, pods per cluster and cluster per plant were the major factors in determining the seed yield. The indirect effects of component characters through plant height were maximum and positive.

Other pulses:

In redgram, Veeraswamy et al. (1973) suggested that branches per plant exhibited maximum direct effect on seed yield, while pods and clusters per plant and plant height showed little direct effects on yield though they expressed an appreciable indirect effect through branches per plant.

Wakankar and Yadav (1975) reported in red gram that pod number had the highest positive direct effect on seed yield followed by number of secondary branches and 100-seed weight.

Studies in Phaseolus aconitifolius of Tikka (1976) revealed that pod number had the greatest direct effect on yield, followed by test weight and number of seeds per pods. Days to flowering and maturity which were strongly and positively associated with grain yield had negative direct effect.

In field beans (Phaseolus vulgaris) studies of Duarte and Adams (1972) showed that pods per plant exerted a preponderent effect upon yield.

In Dolichos biflorus (L.) results from path coefficient analysis suggested that the character pods per plant could be used to select for higher yield (Aggarwal and Kang, 1976).

In soybean, Pandey and Torrie (1973) reported that number of pods per unit area and number of seeds per pod were important factors in determining seed yield.

Patil and Pokle (1974) reported that in soybean, weight of pods was the most important character affecting yield, followed by number of pods per plant, number of branches per plant and 100-seed weight.

Srivastava et al. (1976) employed path analysis of yield components in soybean and concluded that days to flowering and seed number per pod exhibited positive and highly significant genotypic correlations with seed yield and were the major yield components having both direct and indirect correlations.

In soybean, Gautam and Singh (1977) reported that pod number, 100-seed weight, seeds per pod directly and plant height, branches, days to flower and maturity indirectly via pods per plant exerted the greatest influence on seed yield.

In cluster bean, clusters per plant and pods per plant were the major component characters of seed yield (Nath (1979).

The path coefficient analysis done by Katiyar (1979) in F_1 and F_2 population of chickpea revealed that seeds per pod and primary branches per plant exerted the greatest positive direct effects on seed yield.

<u>Discriminent function:</u>

Studies of Karthikeyan (1963) showed that, among the four selection indices constructed in four suitable combinations using discriminant function analysis the one based on yield, number of fruiting nodes on the mainstem and the number of pods per plant, was found to be most advantageous.

Materials and Methods

MATERIALS AND METHODS

The investigations reported herein were carried out in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the years 1978-80.

A. Materials:-

From among the cowpea germplasm collections maintained in the Department of Agricultural Botany, College of Horticulture, Vellanikkara, 17 varieties representing 17 distinct clusters based on the genetic distances between them were made use of for the present study.

The list of the varieties with some of their important characteristics is presented below:

TABLE I

List of varieties with some of their important characters

Cluster Number	Variety number	Name of the variety	Character/characters for which selection is done
1.	50	No. 62	Low 100-seed weight.
2.	2	GP.PLS. 63	Maximum flower number.
3.	56	Pusa Phalguni	Minimum number of branches, flowers, pod yield, seed yield etc.
4.	30	Manchori Mottled-dark	High number of seeds per pod.

5.	4	GP.PLS. 139	Low 100-seed weight and maximum flowering duration.
6.	21	Red seeded selection	Maximum flowering spread.
7.	1	GP. M.S. 931½	Bushy habit, medium flowering duration.
8.	38	Kolingipayar	Maximum number of pods and maximum pod yield per plant.
9.	15	GP.T. 536	Bushy habit, minimum flowering spread.
10.	19	IC. 20729	Maximum 100-seed weight.
11.	47	C_{152} x New Era-1	Maximum seed yield.
12.	24	Pattambi Local-1	High weight of pod.
13.	28	C_{152} x New Era-1	Bushy habit.
14.	34	Pannithodan early	Increased breadth and thickness of the seed.
15.	32	P_{118}	Spreading habit, minimum flowering duration.
16.	51	Kolingipayar white	Low weight of pod, length and low breadth of seed.
17.	55	Mancheri-black	Larger seed

B. Methods:-

1. Experimental:- A field experiment was laid out during Khariff season of 1979-80 in the farm attached to the College of Horticulture, Vellanikkara, with the 17 varieties mentioned above in a Randomised Block Design

with four replications. Each variety was represented by 12 plants per replication. Sowing was done on ridges at a spacing 1 M x 1 M. Farm yard manure @ 1000 kg per hectare was applied and incorporated while ploughing before the formation of ridges. Ammonium sulphate, super phosphate and muriate of potash to supply NPK at the rate of 10 : 30 : 10 kg per hectare respectively were also applied after the final ploughing and before the ridge formation. The experimental plots were carefully maintained with timely spraying, earthing up, propping etc. At the time of earthing up i.e. 20 days after sowing, a top dressing with ammonium sulphate to supply N at the rate of 10 kg per hectare was also given. Two border rows of the variety, C_{152} were grown allaround in each of the four replications to avoid any border effect and also to ensure protection to the experimental crop.

Observations on the following 15 characters were recorded, the same being confined to ten individual plants in each treatment.

1. Height of plant (in m).
2. Number of primary branches.
3. Days to commence flowering (in days).
4. Days to complete flowering (in days).

5. Number of flowers per plant.
6. Number of pods per plant.
7. Length of pod (in cm).
8. Weight of pod (in g).
9. Number of seeds per pod.
10. 100-seed weight (in g).
11. Length of seed (in cm).
12. Breadth of seed (in cm).
13. Thickness of seed (in cm).
14. Pod yield per plant (in g).
15. Seed yield per plant (in g).

The following procedures were adopted in taking observations on the various characters studied:-

Height of plant:- The plant height in ~~m~~ was recorded after full maturity of the plants.

Number of primary branches per plant:- Total number of primary branches per plant was recorded after full maturity of the plants.

Days to commence flowering:- Date of opening of the first flower in each plant was recorded and from that the number of days from sowing to commencement of flowering was computed.

Days to complete flowering:- Date of opening of the last flower in each plant was recorded and from that the number of days from sowing to completion of flowering was computed. The number of days between the date of opening of the first flower and that of the last flower in a plant was taken as the flowering spread of that plant.

Number of flowers per plant:- The total number of flowers produced, by each plant was worked out by counting the total number of flowers opened per day from the first day of flowering upto 45 days there on in each variety.

Number of pods per plant:- Pods harvested periodically from each plant were seperately kept and counted to obtain the total number of pods per plant.

Length of pod:- From each plant, 10 random pods selected after the harvest and drying, were measured with ordinary scale and length recorded in cm.

Weight of pod:- The same 10 pods used for length measurement were made use of for recording pod weight also. The pod weight in g was recorded using an electric balance.

Number of seeds per pod:- The number of seeds was counted in 10 pods selected at random of a plant and the mean arrived at.

<u>100-seed weight</u>:- One hundred seeds from each plant after drying and seed extraction from the pods were weighed using an electric precision balance and weight in g recorded.

<u>Length, breadth and thickness of seed</u>:- Length, breadth and thickness of 10 seeds per plant were measured using a vernier calipers and recorded in cm.

<u>Pod yield per plant</u>:- Weight of the total pods from each plant in g was recorded after drying before threshing and extraction of seeds and the mean worked out.

<u>Seed yield per plant</u>:- Total pods harvested from each plant were dried and threshed and seeds extracted and weight of these seeds recorded in g and mean calculated.

<u>Statistical Analysis</u>:-

Data on different characters studied were subjected to statistical analysis. Part of the analytical work was done in a Micro 2200 Computor of the Department of Agricultural Statistics, College of Horticulture, Vellanikkara and part in another Micro 1100 Computor of Tamil Nadu Agricultural University, Coimbatore-3.

The analysis of variance technique suggested by Fisher (1954) was employed for the estimation of various genetic parameters. The extent of association among characters, was measured by correlation coefficients. Path coefficient analysis was used for estimating the direct and indirect effects. A selection index was worked out using discriminant function technique.

Phenotypic, genotypic and environmental variances:

Estimates of variance components were obtained by using the following formula as suggested by Burton (1951).

Phenotypic variance (Vp)		=	(Vg) + (Ve)
Where	(Vg)	=	Genotypic variance.
	(Ve)	=	Environmental variance.
Genotypic variance (Vg)		=	$\frac{Vt - Ve}{N}$
Where	Vt	=	Mean sum of square due to treatments.
	Ve	=	Mean sum of square due to error.
Environmental variance(Ve)		=	Ve.

Phenotypic and genotypic coefficients of variation:

The phenotypic and genotypic coefficients of variation were calculated by the formulae suggested by Burton and Devane (1953).

Phenotypic coefficient of variation

PCV = ~~$\frac{\sqrt{(Vp)} \times 100}{\bar{X}}$~~ $\frac{\sqrt{(Vp)}}{\bar{X}} \times 100$

$\bar{X}$ = Mean of the character under study.

Genotypic coefficient of variation

~~$\frac{\sqrt{(Vg)} \times 100}{\bar{X}}$~~ $\frac{\sqrt{(Vg)}}{\bar{X}} \times 100$

<u>Heritability:</u>

Heritability in the broad sense was estimated by the following formula as suggested by Burton and Devane (1953).

$$\text{Heritability (H)} = \frac{(Vg) \times 100}{(Vp)}$$

<u>Expected genetic advance:</u>

The expected genetic advance (GA) of the available germplasm was measured by using the formula suggested by Lush (1949) and Johnson <u>et al.</u> (1955 a) at 5 per cent selection intensity using the constant K as 2.06 given by Allard (1960).

$$GA = \frac{(Vg) \times K}{\sqrt{(Vp)}}$$

K = Selection differential

<u>Genetic gain:</u>- The method for the assessment of genetic

advance as per cent of mean suggested by Johnson et al. (1955 a) was used.

$$\text{Genetic gain (GG)} : \frac{GA \times 100}{\bar{X}}$$

Where GA : Expected genetic advance.

Phenotypic and genotypic correlation coefficients:

Phenotypic and genotypic covariances were worked out in the same way as the variances were calculated. Mean sum of products of the covariance are analogous to the mean sum of square of the analyses of variance. The different covariance estimates were calculated by the method suggested by Fisher (1954).

Phenotypic co-variance between characters 1 and 2.

$$(COVp_{12}) = COVg_{12} + COVe_{12}$$

Where $COVg_{12}$ = Genotypic covariance between characters 1 and 2.

$COVe_{12}$ = Environmental covariance between characters 1 and 2.

Genotypic covariance between characters 1 and 2.

$$COVg_{12} = \frac{Mt_{12} - Me_{12}}{N}$$

Where Mt_{12} = Mean treatment sum of product of characters 1 and 2.

Me_{12}	: Mean error sum of product of characters 1 and 2.
N	: Number of replication.

The phenotypic and genotypic correlation coefficients among the various characters were worked out in all possible combinations according to the formulae suggested by Johnson et al. (1955 b) and Al - Jibouri et al. (1958).

Phenotypic correlation coefficient between characters.

1 and 2 (rp_{12})	: $\frac{COVp_{12}}{\sqrt{Vp_1 \times Vp_2}}$
Where $COVp_{12}$	: Phenotypic covariance between characters 1 and 2.
Vp_1	: Phenotypic variance of character 1.
Vp_2	: Phenotypic variance of character 2.

Genotypic correlation coefficient between two characters 1 and 2.

($r_{g_{12}}$)	: $\frac{COVg_{12}}{\sqrt{(Vg_1)(Vg_2)}}$
Where $COVg_{12}$	: Genotypic covariance between characters 1 and 2.
Vg_1	: Genotypic variance of character 1.
Vg_2	: Genotypic variance of character 2.

Path coefficient analysis:-

Path coefficients are standardised regression coefficients. In path coefficient analysis the correlations among cause and effect are partitioned into direct and indirect effects of causal factors on an effect factor. The principles and techniques suggested by Wright (1921) and Li (1955) for cause and effect system were adopted for the analysis. The characters having significant correlations with yield at 1 per cent level were selected and accordingly number of pods per plant, weight of pod, number of seeds per pod, breadth of seed, thickness of seed, yield of pods per plant were considered for the path coefficient analysis.

Discriminant function:

The best prediction formula based on the concept of discriminant function and that could serve as a yardstick in the selection of plants for yield, was evolved by using the estimates of the genotypic components of yield of seeds per plant (X_1) and six characters, namely, the number of pods per plant, weight of pod, number of seeds per pod, breadth of seed, thickness of seed and yield of pods per plant which are expected to have direct bearing on yield.

The genotype of the plant for yield can be represented by the function.

$$Y' = a_1 X_1' + a_2 X_2' + \ldots\ldots\ldots\ldots a_n X_n'$$

where X_1', X_2' .... X_n' are the genotypic values of the components X_1, X_2 ....X_n, and a_1, a_2, ...a_n are the weights attached to them depending on the relative importance of the characters contributing to yield of seed. And phenotype can be represented by the relation,

$$Y = b_1 X_1 + b_2 X_2 + \ldots\ldots\ldots + b_n X_n$$

In the discriminant function the problem is to derive values of b_1, b_2, ... b_n.

Phenotype = genotype + environment. Naturally, therefore, phenotype is highly correlated with genotype and consequently Y and Y' are also correlated. So in the function the weights b_1, b_2, b_3 ..... b_n should be estimated in such a way that the correlation between Y and Y' will be the maximum.

The selection of the phenotype using Y as a discriminant function will ensure a maximum concentration of the desired genes in the plants or lines selected.

In the present study the discriminant function chosen was $Y = b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7$. 'b' values were calculated by solving the following normal equations with a view to maximise the correlation of Y and Y'.

$$
\begin{aligned}
b_1 t_{11} + b_2 t_{12} + \cdots\cdots\cdots + b_7 t_{17} &= A_1 \\
b_1 t_{12} + b_2 t_{22} + \cdots\cdots\cdots + b_7 t_{27} &= A_2 \\
b_1 t_{13} + b_2 t_{23} + \cdots\cdots\cdots + b_7 t_{37} &= A_3 \\
b_1 t_{14} + b_2 t_{24} + \cdots\cdots\cdots + b_7 t_{47} &= A_4 \quad \text{------}(1) \\
b_1 t_{17} + b_2 t_{27} + \cdots\cdots\cdots + b_7 t_{77} &= A_7
\end{aligned}
$$

Where

$$
\begin{aligned}
A_1 &= a_1 g_{11} + a_2 g_{12} + \cdots\cdots + a_7 g_{17} \\
A_7 &= a_1 g_{17} + a_2 g_{27} + \cdots\cdots + a_7 g_{77} \quad \text{------}(2)
\end{aligned}
$$

The phenotypic and genotypic variances and covariances for the different characters were computed from the respective tables of analysis of variance and covariance. The sum of squares and the sum of products at error and varietal levels were taken as error and phenotypic variances and covariances (eij and tij) respectively. And for obtaining the genotypic variances and covariances (gij) the sum of squares and the sum of products at error level were deducted from their respective values at varietal level (Goulden, 1959).

A's were calculated from the data by substitution of the calculated gij and the assigned values of 'a'. The values for a_1 to a_7 were arbitrarily taken as 1. These values were inserted in equation (1) and solved for the values of $b_1, b_2 \ldots\ldots\ldots b_n$.

The discriminant function was then set up by the equation.

$I = b_1 X_1 + b_2 X_2 + \text{-----} + b_7 X_7$; where, $b_1, b_2 \text{---} b_7$ are the economic weights and X_1, X_2, X_7 the contributing characters.

Using this function, the selection criterion or the index value for each treatment may be determined. This can be done as follows:-

$$\begin{bmatrix} I_1 \\ \vdots \\ \vdots \\ I_7 \end{bmatrix} = \begin{bmatrix} \bar{X}_{11} & \bar{X}_{12} & \cdots & \bar{X}_{17} \\ \vdots & & & \\ \vdots & & & \\ X_{71} & X_{72} & \cdots & X_{77} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_7 \end{bmatrix}$$

Finally, on the basis of these selection criteria, the treatments are arranged in the order of merit and then a specified percentage of the best parents are be selected for further breeding programme.

Analysis of genetic divergence through metroglyph method:

From the selected characters, two characters were taken, one of them was taken along the X-axis and the other on the Y-axis. The means of Y values were plotted against the means of X values for each genotypes. A particular genotype was thus represented by a glyph on the graph.

The other characters were represented by rays on the glyph, the rays for the same character having the same position on each glyph.

The range of variation in each character was represented by different length of ray i.e. a genotype having low values for the character will have a smaller ray and so on. Thus the length of the ray is either short, medium or long depending upon the magnitude of values.

Results

RESULTS

The data collected from the present experiments have been statistically analysed and the results are presented under the following heads:

Estimation of variability, heritability and genetic advance:

Observations on the behaviour of the seventeen varieties with reference to sixteen characters viz., plant height, number of primary branches, days to commence and complete flowering, flowering spread, number of flowers per plant, number of pods per plant, length of pod, weight of pod, number of seeds per pod, 100-seed weight, length of seed, breadth of seed, thickness of seed and yields of pod and seed per plant have been made from 10 plants in each of the respective varieties and the means worked out. The data are presented in Tables II to XVII.

The analysis of variance carried out for 16 characters is presented in the Appendix-II. The phenotypic, genotypic and environmental variances for the different characters are presented in Table XVIII. Table XIX presents the phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for different characters. Range, mean and standard error of mean of the different characters are presented in Table XX.

Height of plant:

The mean values of plant height in respect of 17 varieties are presented in Table II.

(TABLE II)

The results presented in the above table reveal that the mean ~~of~~ height of plant among the cowpea varieties under study ranged from 0.49 m in cluster No.3 (Pusa phalguni) to 1.90 m in cluster No.8 (Kolingipayar) with a general mean of 1.34 m. From the analysis of variance it can be seen that the differences among the varieties for this character were highly significant (Appendix II).

The estimated phenotypic variance (Vp) for this character was 0.249, and the same could be apportioned between genotypic variance (Vg) and environmental variance (ve) as 0.144 and 0.105 respectively, (Table XVIII) indicating influence of environmental effect on this character. The phenotypic and genotypic coefficients of variation (PCV = 37 and GCV = 28) presented in Table XIX also confirmed the above fact. Heritability, (58%) and genetic gain as percentage of mean (45%) were also found to be high (Table XIX) (Vide Fig.1).

TABLE II

Ranking of the varieties for height of plant (in m)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Kolingipayar	8	1.90
2.	GP. PLS. 63	2	1.83
3.	Mancheri-black	17	1.82
4.	Mancheri mottled-dark	4	1.68
5.	No. 62	1	1.66
6.	GP. T. 536	9	1.62
7.	Kolingipayar white	16	1.50
8.	IC. 20729	10	1.46
9.	C_{152} x New Era-I	11	1.46
10.	Pannithodan early	14	1.39
11.	GP. PLS. 139	5	1.29
12.	C_{152} x New Era-I	13	1.16
13.	Red seeded selection	6	1.00
14.	Pattambi local	12	0.90
15.	GP. MS. 9314	7	0.88
16.	P_{118}	15	0.78
17.	Pusphalguni	3	0.49

General mean : 1.34
C.D. : 0.46

Number of primary branches:

Data pertaining to the mean number of primary branches per plant are presented in Table III.

(TABLE III)

From the table given above it can be seen that among the varieties under trial, the maximum number (.951) of primary branches was noted in the case of cluster No.3 (Pusa phalguni) and the minimum (3.69) in the case of cluster No.15 (P_{118}) with a general mean of 5.40. The statistical analysis showed that the differences between varieties under study for this character were found to be significant (Appendix II).

The genetic component of variance for this character was found to be high with a high heritability of 82 per cent and genetic gain of 40 per cent, (Vp = 1.66, Vg : 1.36; Ve: 0.30; PCV = 24 and GCV = 22) as is given in Tables XVIII and XIX (Vide Fig. 1).

Days to commence flowering:

Observations on the mean number of days taken by each plant for the commencement of flowering are presented in Table IV.

TABLE III

Ranking of the varieties for number of primary branches

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Pusa phalguni	3	9.51
2.	10. 20729	10	6.06
3.	Pattambi local-I	12	5.79
4.	GP. T. 536	9	5.67
5.	GP. PLS. 139	5	5.63
6.	GP. PLS. 63	2	5.44
7.	Mancheri black	17	5.42
8.	C_{152} x New Era-1	11	5.31
9.	GP. MS. 9314	7	5.21
10.	Mancheri mottled-dark	4	5.15
11.	Kolingipayar	8	5.06
12.	Red seeded selection	6	4.94
13.	No. 62	1	4.88
14.	C_{152} x New Era-I	13	4.77
15.	Pannithadan early	14	4.70
16.	Kolingipayar white	16	4.51
17.	P_{118}	15	3.69

General mean : 5.40
C.D. : 0.78

(TABLE IV)

From the table it is seen that the general mean for this character was 48.82 with a range from 42.10 to 60.38 days among the varieties. Cluster No.5 (GP. PLS. 139) recorded the maximum value for this character, while Cluster No.3 (Pusaphalguni) was the first to commence flowering taking only an average of 42.10 days from sowing. From the anova results it can be seen that differences among the varieties for this character were significant (Appendix II).

The phenotypic, genotypic and environmental variances for this character among the varieties were estimated to be 25.33, 20.47 and 4.86 respectively (Table XVIII). Phenotypic and genotypic coefficients of variation (PCV and GCV) were 10 and 9 respectively (Table XIX), (Vide Fig.4), showing that the predominant influence on variability for this character was of the genetic component. Heritability for this character was found to be very high (81%) and the genetic gain was 17 per cent (Table XIX) (Vide Fig. 1).

Days to complete flowering:

The data are furnished in Table V.

(TABLE V)

TABLE IV

Ranking of the varieties for flowering commencement (in days)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	GP. PLS. 139	5	60.38
2.	GP. T. 536	9	57.18
3.	I.C. 20729	10	56.60
4.	C_{152} x New Era-I	11	55.42
5.	Mancheri mottled-dark	4	54.08
6.	Pannithadan early	14	53.27
7.	Pattambi Local-I	12	53.04
8.	GP.PLS.63	2	52.86
9.	Mancheri-black	17	52.30
10.	No. 62	1	52.17
11.	Kolingipayar white	16	51.55
12.	C_{152} x New Era-I	13	51.25
13.	Kolingipayar	8	50.88
14.	Red seeded selection	6	48.35
15.	GP. MS. 9314	7	47.59
16.	P_{118}	15	43.25
17.	Pusaphalguni	3	42.10

General mean : 48.82
C.D. : 3.13

TABLE V

Ranking of the varieties for flowering completion (in days)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	IC. 20729	10	88.04
2.	GP. PLS. 139	5	87.81
3.	Pattambi local-I	12	86.13
4.	Mancheri-black	17	85.62
5.	Mancheri mottled-dark	4	82.81
6.	GP.T. 536	9	81.23
7.	Red seeded selection	6	79.35
8.	Pannithodan early	14	79.18
9.	C_{152} x New Era-I	11	78.74
10.	GP. PLS.63	2	77.99
11.	Kolingipayar white	16	77.99
12.	No. 62	1	77.54
13.	C_{152} x New Era-I	13	75.66
14.	Kolingipayar	8	74.85
15.	GP. MB. 9314	7	74.47
16.	P_{118}	15	70.95
17.	Pusaphalguni	3	69.05

General mean : 80.44

C.D. : 5.15

From the results presented in the above table, it can be seen that the varieties studied had a range from 69.05 to 88.04 with a mean of 80.44 days for the expression of this character.

The total phenotypic variance of 40.44 could be apportioned into genotypic and environmental variances as 27.30 and 13.14 respectively (Table XVIII). The PCV, GCV, H, GA and GG were observed to 8, 6, 68 per cent, 8.84 and 11 per cent respectively (Table XIX) (Vide Fig.1).

<u>Flowering spread:</u>

The mean values for this character are presented in the Table VI.

(TABLE VI)

From the above results, it can be observed that, among the varieties under trial the maximum flowering spread was noted in case of Cluster No.17 (Mancheri-black) and the minimum in the case of Cluster No.11 (C_{152} x New Era-1). Differences among the varieties under study for this character were found to be highly significant (Appendix II) with a range of variability

TABLE VI

Ranking of the varieties for flowering spread (in days)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Mancheri-black	17	33.32
2.	IC. 20729	10	31.44
3.	Red seeded selection	6	31.00
4.	Pattambi local-I	12	30.59
5.	Mancheri mottled-dark	4	28.73
6.	P_{118}	15	27.70
7.	GP. PLS. 139	5	27.43
8.	Pusaphalguni	3	26.95
9.	GP. M.S. 9314	7	26.88
10.	Kolingipayar white	16	26.40
11.	Pannithodan early	14	25.92
12.	No. 62	1	25.38
13.	GP. PLS. 63	2	25.13
14.	C_{152} x New Era-I	13	24.41
15.	GP. PLS. 536	9	24.05
16.	Kolingipayar	8	23.98
17.	C_{152} x New Era-I	11	23.32

General mean : 27.21
C.D. : 4.4

from 23.22 and 33.32 days and a general mean of 27.21 days.

The genetic component of variance for this character was found to be high with 39 per cent of heritability and a genetic gain of 12 per cent, (V_p = 15.78, V_g = 6.18, V_e = 9.60, PCV = 15, GCV = 9) as shown in Tables XVIII and XIX (Vide Fig. 1).

Number of flowers per plant:

The results relating to the number of flowers per plant are summarised in Table VII.

(TABLE VII)

From the results it can be seen that the range of variability for this character was from 121.05 (Cluster No.15 - P_{118}) to 271.88 (Cluster No.16 - Kolingipayar white) with a general mean of 195.15. The varietal differences for this character were found to be highly significant (Appendix II).

The total phenotypic variance for this character was observed to be 3168.29 which could be apportioned into genotypic and environmental as 1077.20 and 2091.01 respectively (Table XVIII). The heritability and genetic

TABLE VII

Ranking of the varieties for number of flowers per plant

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Kolingipayar white	16	271.88
2.	C_{152} x New Era-I	13	246.92
3.	GP. PLS. 139	5	242.01
4.	Pattambi local-I	12	241.84
5.	C_{152} x New Era-I	11	233.67
6.	No. 62	1	208.70
7.	Kolingipayar	8	194.48
8.	Mancheri mottled-dark	4	187.89
9.	GP. PLS. 63	2	185.54
10.	Red seeded selection	6	181.25
11.	Mancheri-black	17	180.08
12.	GP. T. 536	9	171.99
13.	Pusaphalguni	3	168.68
14.	IC. 20729	10	166.99
15.	Pannithodan early	14	161.42
16.	GP. MS. 9314	7	153.13
17.	P_{118}	15	121.05

General mean : 195.15

C.D. : 65.01

gain for this character were estimated as 34 and 20 per cent respectively (Table XIX) (Vide Fig.1).

Number of pods per plant:

The mean number of pods per plant among the cowpea varieties under study is presented in Table VIII.

(TABLE VIII)

From the table it can be revealed that the varieties ranged from 36.57 to 134.18 with a general mean of 87.36 for this character. Among the varieties, variety 16 recorded the maximum number of pods, whereas, variety 6 had the minimum number of pods per plant. The varietal difference for the character were found to be highly significant (Appendix II).

The genetic component of the total variance for this character was very high, (Vp = 1057.60, Vg = 769.03, Ve = 288.57, PCV = 37.23; and GCV = 32) (Tables XVIII & XIX) (Vide Fig.1). The heritability and genetic gain for this character were estimated as 73 and 56 per cent respectively (vide Fig.1).

TABLE VIII

Ranking of the varieties for number of pods per plant

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Kolingipayar white	16	134.18
2.	Pattambi local-I	12	129.97
3.	C_{152} x New Era-I	13	120.97
4.	C_{152} x New Era-I	11	120.95
5.	Kolingipayar	8	105.55
6.	GP. PLS. 63	2	96.95
7.	No. 62	1	94.93
8.	GP. T. 536	9	94.35
9.	Mancheri-black	17	91.33
10.	Pusaphalguni	3	78.5
11.	Mancheri mottled-dark	4	73.34
12.	GP. MS. 9314	7	72.62
13.	Pannithodan early	14	67.95
14.	P_{118}	15	67.48
15.	GP. PLS. 139	5	59.31
16.	IC. 20729	10	41.56
17.	Red seeded selection	6	36.57

General mean : 87.36
C.D. : 24.15

Length of pod:

Data pertaining to mean length of pod are presented in Table IX.

(TABLE IX)

As is seen above the varieties studied showed good amount of variation for this character with Cluster No. 10 - IC. 20729 showing the maximum pod length (28.92 cm) and the Cluster No.16 - Kolingipayar white the minimum (10.49 cm). The overall mean pod length of the varieties was 17.82 cm and the varietal differences from the statistical analysis were found to be highly significant (Appendix II).

Out of the phenotypic variance of 21.02 for this character 20.27 was contributed by the genetic component (Table XVIII). Heritability for this character was also found to be high (PCV = 26; GCV = 25 and H = 96 %) and genetic gain was estimated as 51 per cent (Table XIX) (Vide Fig.1).

Weight of pod:

The mean values are presented in Table X.

(TABLE X)

TABLE IX

Ranking of the varieties for length of pod (in cm)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	IC. 20729	10	28.92
2.	Mancheri-black	17	22.47
3.	Mancheri mottled-dark	4	22.34
4.	GP. MS. 9314	7	21.56
5.	Pattambi local-I	12	20.32
6.	Pannithodan early	14	20.31
7.	GP. PLS. 63	2	17.69
8.	GP. T. 536	9	17.67
9.	Red sealed selection	6	17.29
10.	Kolingipayar	8	16.97
11.	C_{152} x New Era-I	13	16.63
12.	P_{118}	15	16.62
13.	C_{152} x New Era-I	11	16.03
14.	No. 62	1	14.41
15.	GP. PLS. 139	5	12.65
16.	Pusaphalguni	3	12.55
17.	Kolingipayar white	16	10.49

General mean : 17.82

C.D. : 1.23

TABLE X

Ranking of the varieties for weight of pod (in g)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	GP M.S. 9314	7	3.80
2.	IC. 20729	10	3.24
3.	Pattambi local-I	12	2.86
4.	GP.T. 536	9	2.64
5.	GP. PLS. 63	2	2.53
6.	Mancheri mottled-dark	4	2.48
7.	C_{152} x New Era-I	11	2.33
8.	Mancheri-black	17	2.22
9.	No. 62	1	2.20
10.	Pannithodan early	14	2.17
11.	P_{118}	15	2.11
12.	Kolingipayar	8	2.05
13.	C_{152} x New Era-I	13	1.89
14.	Red seeded selection	6	1.58
15.	GP. PLS. 139	5	1.15
16.	Pusaphalguni	3	0.90
17.	Kolingipayar white	16	0.83

General mean : 2.18
C.D. : 7.07

From the table it can be observed that the Cluster No.7 (GP.M.S. 9314) ranked first and Cluster No.16 (Kolingipayar white) - last. The range of varietal mean values was found to be from 0.83 g to 3.80 g with a general mean of 2.18 g. The differences between the varieties were highly significant (Appendix II).

The genetic component of variance for this character (Tables XVIII & XIX) (Vide Fig.1) was found to be high with high estimates of heritability and genetic gain (Vp = 0.83; Vg = 0.58; Ve = 0.25; PCV = 42; GCV = 35; H = 70% and GG = 61%).

<u>Number of seeds per pod:</u>

Data are presented in Table XI.

(TABLE XI)

The range of variability for this character was found to be from 10.41 (Cluster No.3 - Pusa phalguni) to 17.67 (Cluster No.12 - Pattambi local-1) and the general mean value of the 17 varieties was found to be 14.36. The varietal differences from the anova were found to be significant (Appendix II).

From the Tables XVIII and XIX (Vide Fig.1) the

TABLE XI

Ranking of the varieties for number of seeds per pod

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Pattambi local-I	12	17.67
2.	GP. PLS. 63	2	17.44
3.	GP.T. 536	9	17.19
4.	C_{152} x New Era-I	11	16.04
5.	C_{152} x New Era-I	13	15.96
6.	GP. MS. 9314	7	15.29
7.	Mancheri-black	17	15.04
8.	Mancheri mottled-dark	4	14.99
9.	Kolingipayar	8	14.63
10.	Pannithodan early	14	14.48
11.	No. 62	1	13.35
12.	IC. 20729	10	13.02
13.	GP. PLS. 139	5	12.57
14.	Kolingipayar white	16	12.21
15.	Red seeded selection	6	12.12
16.	P_{118}	15	11.70
17.	Pusaphalguni	3	10.41

General mean : 14.36

C.D. : 1.36

apportionment of the total variance for this character between the genetic and environmental components was found to be with a predominance of the genetic component (Vp = 5.31; Vg = 4.39; Ve = 0.92). Heritability was found to be 82 per cent and the estimated genetic gain as percentage of mean was 27 (PCV = 16; GCV = 15).

100-seed weight:

Observations regarding 100-seed weight are presented in Table XII.

(TABLE XII)

From the data presented, it is seen that the mean 100-seed weight among the varieties ranged from 5.29 g (Cluster No.16 - Kolingipayar white) to 18.60 g (Cluster No.7 - GP.M.S. 9314) with a general mean of 11.40 g. The statistical analysis showed that differences between the varieties were significant (Appendix II).

Genetic component of variance for this character was found to be very high (Vp = 12.19; Vg = 11.10) (Table XVIII) and the heritability was found to be of

Ranking of the varieties for weight of 100 seeds (in g)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	GP. MG. 9314	7	18.60
2.	IC. 20729	10	18.45
3.	P_{118}	15	13.73
4.	GP.T. 536	9	12.42
5.	C_{152} x New Era-I	11	12.40
6.	Pattambi local-I	12	12.24
7.	Mancheri mottled-dark	4	12.02
8.	Pannithodan early	14	11.65
9.	GP. PLS. 139	5	11.32
10.	Mancheri-black	17	10.63
11.	GP. PLS. 63	2	10.56
12.	Kolingipayar	8	9.85
13.	C_{152} x New Era-I	13	9.17
14.	No. 62	1	8.89
15.	Red seeded selection	6	8.37
16.	Pusaphalguni	3	8.29
17.	Kolingipayar white	16	5.29

General mean : 11.40
C.D. : 1.48

the order of 91 per cent. Genetic gain for this character was estimated to be 57 per cent. The genotypic and phenotypic coefficients of variation was 29 and 31 per cent respectively (Table XIX) (Vide Fig.1).

Length of seed:

Mean lengths of seed among the varieties studied are presented in the Table XIII.

(TABLE XIII)

From the table presented above, the mean values ranged from 0.51 cm (Cluster No. 16 - Kolingipayar white) to 1.21 cm (Cluster No.10 - IC.20729) with a general mean of 0.79 cm. The varietal differences from the anova for this character were found to be significant (Appendix II).

Major part of the varience for this character was found to be genetic (Vp = 0.026 and Vg = 0.025) as is seen from the Table XVIII. The phenotypic and genotypic coefficients of variation were 22 and 20 per cent respectively. The heritability was 97 per cent and the estimated genetic gain - 42 per cent (Table XIX) (Vide Fig.1).

TABLE XIII

Ranking of the varieties for length of seed (in cm)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	IC. 20729	10	1.21
2.	Manchari mottled-dark	4	0.99
3.	Manchari-black	17	0.96
4.	GP. M.S. 9314	7	0.89
5.	Red seeded selection	6	0.83
6.	Pannithodan early	14	0.82
7.	Pattambi local-I	12	0.78
8.	P_{118}	15	0.78
9.	GP. T. 536	9	0.77
10.	GP. PLS. 63	2	0.73
11.	C_{152} x New Era-I	11	0.73
12.	C_{152} x New Era-I	13	0.73
13.	Kolingipayar	8	0.72
14.	No. 62	1	0.66
15.	GP. PLS. 139	5	0.65
16.	Pusaphalguni	3	0.65
17.	Kolingipayar white	16	0.51

General mean: 0.79

C.D. : 0.0433

Breadth of seed:

The data are presented in Table XIV.

(TABLE XIV)

Maximum breadth of seed (0.69 cm) was recorded by Cluster No. 7 (GP.M.S. 9314), and the minimum (0.37 cm) by Cluster No.16 (Kolingipayar white). The general mean for this character among the varieties studied was 0.55 cm. From the anova, the differences among the varieties for this character were seen to be significant (Appendix II).

The genetic component to total variance for this character was found to be quite high and the heritability was also found to be high (Vp = 0.008; Vg = 0.007; H = 97%). The phenotypic and genotypic coefficients of variation for this character and the expected genetic gain as percentage of mean were 18, 15 and 29 per cent respectively (Tables XVIII and XIX) (Vide Fig.1).

Thickness of seed:

The mean values are presented in the Table XV.

(TABLE XV)

TABLE XIV

Ranking of the varieties for breadth of seed (in cm)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	GP. M.S. 9314	7	0.69
2.	IC. 20729	10	0.69
3.	GP. T. 536	9	0.63
4.	P_{118}	15	0.63
5.	C_{152} x New Era-I	11	0.63
6.	C_{152} x New Era-I	13	0.61
7.	Pattambi local-I	12	0.60
8.	GP. PLS. 63	2	0.57
9.	Pannithodan early	14	0.57
10.	Mancheri mottled-dark	4	0.54
11.	Mancheri-black	17	0.53
12.	Red seeded selection	6	0.51
13.	Kolingipayar	8	0.51
14.	No. 62	1	0.47
15.	GP. PLS. 139	5	0.45
16.	Pusaphalguni	3	0.42
17.	Kolingipayar white	16	0.37

General mean : 0.55
C.D. : 0.02

TABLE XV

Ranking of the varieties for thickness of seed (in cm)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	GP. M.S. 9314	7	0.52
2.	IC. 20729	10	0.47
3.	C_{152} x New Era-I	11	0.47
4.	CPT 536	9	0.46
5.	C_{152} x New Era-I	13	0.43
6.	Pannithodam early	14	0.43
7.	P_{118}	15	0.43
8.	GP. PLS. 63	2	0.42
9.	Pattambi local-I	12	0.41
10.	Mancheri-black	17	0.41
11.	Mancheri mottled-dark	4	0.40
12.	Kolingipayar	8	0.40
13.	Pusaphalguni	3	0.36
14.	No. 62	1	0.35
15.	GP. PLS. 139	5	0.35
16.	Red seeded selection	6	0.33
17.	Kolingipayar white	16	0.33

General mean : 0.41

C.D. : 0.0192

Among the varieties studied the values ranged from 0.33 cm (Cluster No. 16 - Kolingipayar white) to 0.52 cm (Cluster No.7 - GP.M.S. 9314) with a general mean of 0.41 cm. Among the different characters studied so far the least variation between varieties could be noticed for this character.

The phenotypic and genotypic variances for this character (Table XVIII) were 0.003 and 0.003 respectively and the heritability was estimated to be 93 per cent. The genetic gain as percentage of mean for this character was 29 and the phenotypic and genotypic coefficient of variation were 12 and 12 per cent respectively (Table XIX) (Vide Fig.1). This shows that thickness of seed is not influenced by environmental effects.

<u>Yield of pods per plant:</u>

Mean yields of pods per plant for the 17 varieties studied are presented in the Table XVI.

(TABLE XVI)

From the above table it can be seen that the mean values ranged from 40.11 g (Cluster No. 6 - Red seeded selection) to 288.73 g (Cluster No.12 - Pattambi local-1).

TABLE XVI

Ranking of varieties for yield of pods per plant (in g)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Pattambi local-I	12	283.73
2.	GP. T. 536	9	227.44
3.	GP. M.S. 9314	7	210.04
4.	C_{152} x New Era-I	11	208.60
5.	GP. PLS. 63	2	198.11
6.	C_{152} x New Era-I	13	197.71
7.	Kolingipayar	8	165.85
8.	Mancheri-black	17	158.13
9.	Mancheri-mottled-dark	4	142.29
10.	P_{118}	15	119.68
11.	Pannithodan early	14	119.33
12.	Io. 20729	10	118.11
13.	No. 62	1	115.25
14.	Kolingipayar white	16	101.41
15.	GP. PLS. 139	5	89.20
16.	Pusaphalguni	3	66.18
17.	Red seeded selection	6	40.11

General mean : 150.96

C.D. : 39.39

The statistical analysis showed that varietal differences for this character were found to be highly significant (Appendix II).

Genetic components appeared to contribute very highly to the total variance for this character. The phenotypic and genotypic variances were 4730.44 and 3962.65 respectively (Table XVIII). Heritability, genetic gain as percentage of mean, phenotypic and genotypic coefficient of variation were 84, 79, 46 and 42 per cent respectively (Table XIX) (Vide Fig.1).

Yield of seeds per plant:

The data are presented in the Table XVII.

(TABLE XVII)

The variability for this ultimate economic character was found to be very high among the varieties studied. The highest yield of 159.28 g (Cluster No.12 - Pattambi local-1) being almost 9 times the lowest yield of 18.34 g (Cluster No.6 - Red seeded selection) with a general mean for yield of seeds per plant of 80.65 g was observed. The varietal differences from the anova were highly significant (Appendix II).

TABLE XVII

Ranking of the varieties for yield of seeds per plant(in g)

Sl. No.	Name of the variety	Cluster No.	Mean value
1.	Pattambi local-I	12	159.28
2.	C_{152} x New Era-I	11	120.93
3.	GP. T. 536	9	118.99
4.	C_{152} x New Era-I	13	112.52
5.	GP. PLS. 63	2	111.09
6.	GP. M.S. 9314	7	101.15
7.	Kolingipayar	8	97.45
8.	Mancheri mottled-dark	4	74.42
9.	Mancheri-black	17	71.9
10.	P_{118}	15	60.41
11.	Kolingipayar white	16	60.27
12.	Pannithodan early	14	58.94
13.	No. 62	1	57.38
14.	IC. 20729	10	53.60
15.	GP. PLS. 139	5	52.77
16.	Pusaphalguni	3	41.55
17.	Red seeded selection	6	18.34

General mean : 80.65
C.D. : 25.26

This character was found to show high estimates of heritability and genetic gain, which were 79 and 80 per cent respectively (Table XIX). The phenotypic and genotypic coefficients of variation was 49 and 43 per cent respectively for this characters (Table XIX) (Vide Fig.1).

While each of the tables from II to XVII gives only information about one single character in respect of all the varieties, information on all the characters in respect of 17 selected varieties representing the two extremes of yield potential is furnished in the Table XX.

(TABLE XX)

The results presented in the above table indicated that the materials selected for the present study were highly variable.

<u>Correlation between yield and selected yield components:</u>

The genotypic and phenotypic correlation coefficients were estimated based on genotypic, phenotypic and environmental variances for the selected characters. The correlation coefficients between yield and selected component characters and intercorrelations among the

TABLE XVIII

Phenotypic, genotypic and environmental variance for the different characters

Sl. No.	Character	Phenotypic variance V_p	Genotypic variance V_g	Environmental variance V_e
1.	Height of plant (inmm)	0.249	0.144	0.105
2.	Number of primary branches	1.660	1.360	0.301
3.	Days to commencement of flowering (in days)	25.330	20.470	4.860
4.	Days to completion of flowering (in days)	40.440	27.300	13.140
5.	Flowering spread (in days)	15.780	6.180	9.600
6.	Number of flower per plant	3168.290	1077.200	2091.09
7.	Number of pods per plant	1057.600	769.030	288.570
8.	Length of pod (in cm)	21.020	20.270	0.750
9.	Weight of pod (in g)	0.830	0.580	0.250
10.	Number of seeds per pod	5.31	4.39	0.92
11.	100-seed weight (in g)	12.190	11.100	1.090
12.	Length of seed (in cm)	0.026	0.025	0.0009
13.	Breadth of seed (in cm)	0.008	0.007	0.0002
14.	Thickness of seed (in cm)	0.003	0.003	0.0002
15.	Yield of pod/plant (in g)	4730.440	3962.650	767.790
16.	Yield of seed/plant (in g)	1536.450	1220.750	315.700

TABLE XIX

Phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for the different characters

Sl. No.	Characters	PCV	GCV	Herita-bility H	Expected genetic advance	Genetic gain GG
1.	Height of plant (in m)	37	28	58	0.60	45
2.	Number of primary branches	24	22	82	2.16	40
3.	Days to commencement of flowering (in days)	10	9	81	8.38	17
4.	Days to completion of flowering (in days)	8	6	68	8.84	11
5.	Flowering spread (in days)	15	9	39	3.21	12
6.	Number of flowers per plant	29	17	34	39.43	20
7.	Number of pods per plant	37.23	32	73	48.72	56
8.	Length of pod (in cm)	26	25	96	9.13	51
9.	Weight of pod (in g)	42	35	70	1.32	61
10.	Number of seeds per pod	16	15	82	3.93	27
11.	100-seed weight (in g)	31	29	91	6.55	57
12.	Length of seed (in cm)	22	20	97	0.33	42
13.	Breadth of seed (in cm)	18	15	97	0.16	29
14.	Thickness of seed (in cm)	12	12	93	0.12	29
15.	Yield of pods/plant (in g)	46	42	84	118.68	79
16.	Yield of seed/plant (in g)	49	43	79	64.15	80

Fig.1. HERITABILITY AND EXPECTED GENETIC ADVANCE AS PERCENTAGE OF MEAN.

1. Height of plant (in m).
2. Number of primary branches.
3. Days to commencement of flowering (in days).
4. Days to completion of flowering (in days).
5. Flowering spread (in days).
6. Number of flowers per plant.
7. Number of pods per plant.
8. Length of pod (in cm).
9. Weight of pod (in g).
10. Number of seeds per pod.
11. 100-seed weight (in g).
12. Length of seed (in cm).
13. Breadth of seed (in cm).
14. Thickness of seed (in cm).
15. Yield of pods/plant (in g).
16. Yield of seeds/plant (in g).

Fig. 1 - HERITABILITY AND EXPECTED GENETIC ADVANCE AS PERCENTAGE OF MEAN

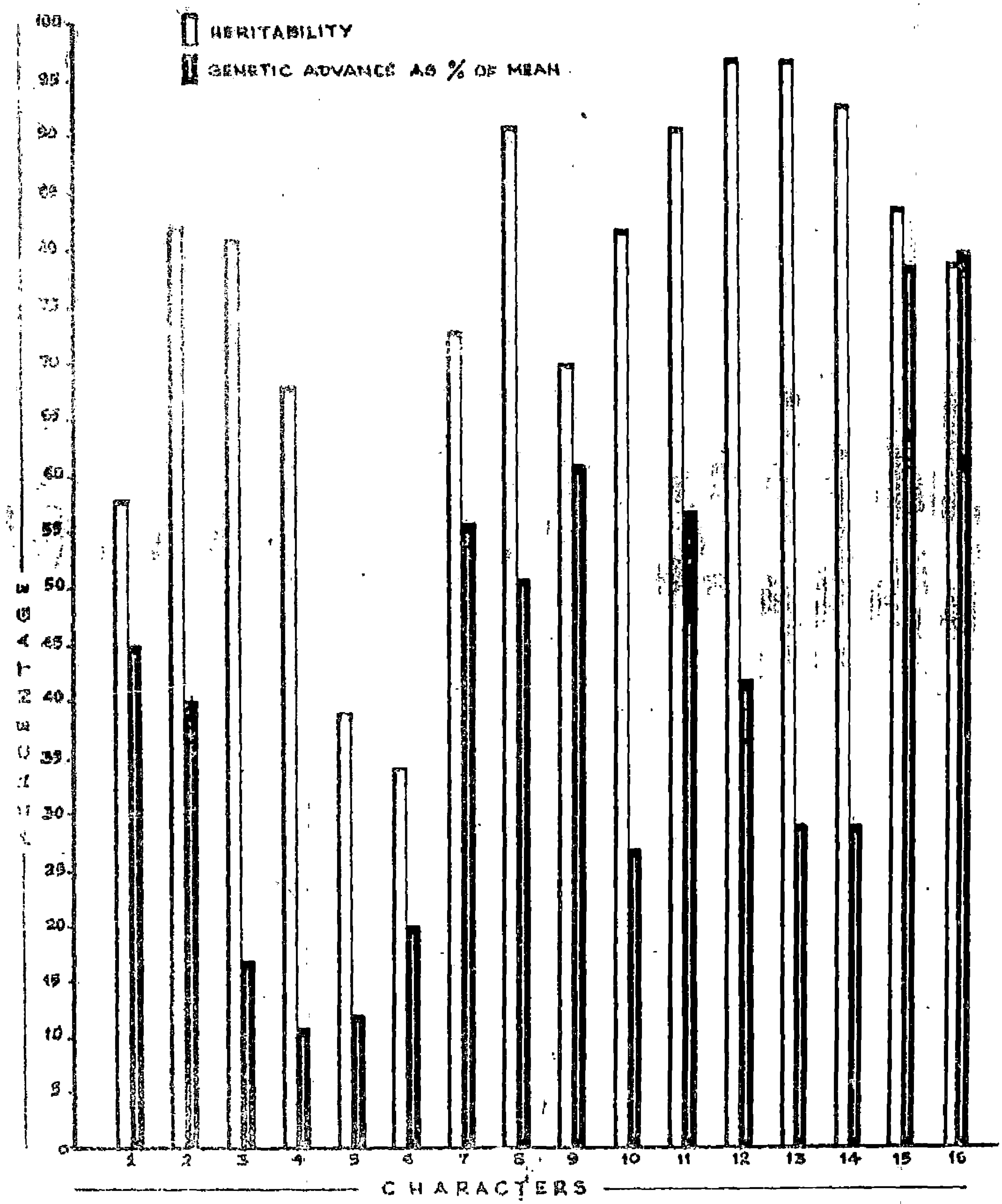


TABLE XX

Range, mean and standard error of mean of the different characters

Sl. No.	Characters	Range		Mean	Standard error of mean
		From	To		
1.	Height of plant (in m)	0.49	1.9	1.34	0.17
2.	Number of primary branches	3.69	9.51	5.4	0.28
3.	Days to commencement of flowering	42.1	60.38	48.82	1.10
4.	Days to completion of flowering	69.05	88.04	80.44	1.81
5.	Flowering spread (in days)	23.32	33.32	27.21	1.55
6.	Number of flowers per plant	121.05	271.88	195.15	22.86
7.	Number of pods per plant	36.57	134.18	87.36	8.49
8.	Length of pod (in cm)	10.49	28.92	17.82	0.44
9.	Weight of pod (in g)	0.83	3.8	2.18	0.24
10.	Number of seeds per pod	10.41	17.67	14.36	0.48
11.	100-seed weight (in g)	5.29	18.60	11.40	0.52
12.	Length of seed (in cm)	0.51	1.21	0.79	0.015
13.	Breadth of seed (in cm)	0.37	0.69	0.55	0.007
14.	Thickness of seed (in cm)	0.33	0.515	0.41	0.007
15.	Yield of pods per plant (in g)	40.11	288.73	150.96	13.87
16.	Yield of seeds per plant (in g)	18.34	159.29	80.65	8.88

yield components are furnished in Table XXI.

(TABLE XXI)

The genotypic and phenotypic correlation coefficients followed the same trend of association. Generally, the genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients. Hereafter, the word correlation will denote the genotypic correlation.

Number of pods per plant (0.70218), number of seeds per pod (0.92455) and yield of pods per plant (0.98603) showed significantly maximum (significant at 1% level) correlation with yield of seeds per plant (Table XXI) (Vide Fig.2). Among these, yield of pods per plant showed the highest correlation with yield of seed per plant (0.98603) followed by number of seeds per pod (0.92455). All the selected component characters showed significant positive correlation with yield of seed per plant.

Number of pods per plant showed negative correlation with weight of pod (- 0.04571) and breadth of seed (- 0.14186). Weight of pod showed positively significant correlation with all the characters. Thickness of seed

TABLE XXI

Genotypic (r_g) and phenotypic (r_p) coefficient correlations among seed yield and its selected components

	Number of pods per plant	Weight of pod	Number of seeds per pod	Breadth of seed	Thickness of seed	Yield of pod per plant	Yield of seeds per plant
Number of pods per plant	1	- 0.04571 (- 0.04634)	0.50279* (0.37726)	- 0.14186 (- 0.01213)	0.00611 (0.01732)	0.60376* (0.61410**)	0.70218** (0.67039)**
Weight of pod		1	0.67210** (0.63773)**	0.67788** (0.49917)*	0.91059** (0.70229)**	0.70745** (0.57278)*	0.57028* (0.47305)
Number of seeds per pod			1	0.69198** (0.42882)	0.62059** (0.54787)*	0.95056** (0.82315)**	0.92455** (0.77571)**
Breadth of seed				1	0.95655** (0.62033)**	0.66925** (0.48395)*	0.55099* (0.42733)
Thickness of seed					1	0.66391** (0.60039)*	0.57167* (0.50640)*
Yield of pods per plant						1	0.98603** (0.96754)**

Figures in brackets indicate phenotypic correlation coefficients.

* Significant at 5% level

** Significant at 1% level

Fig. 2. CORRELATION COEFFICIENTS BETWEEN YIELD AND ITS SELECTED COMPONENTS

X_1Y = Correlation coefficients between number of pods per plant and yield of seeds per plant.

X_2Y = Correlation coefficients between weight of pod and yield of seeds per plant.

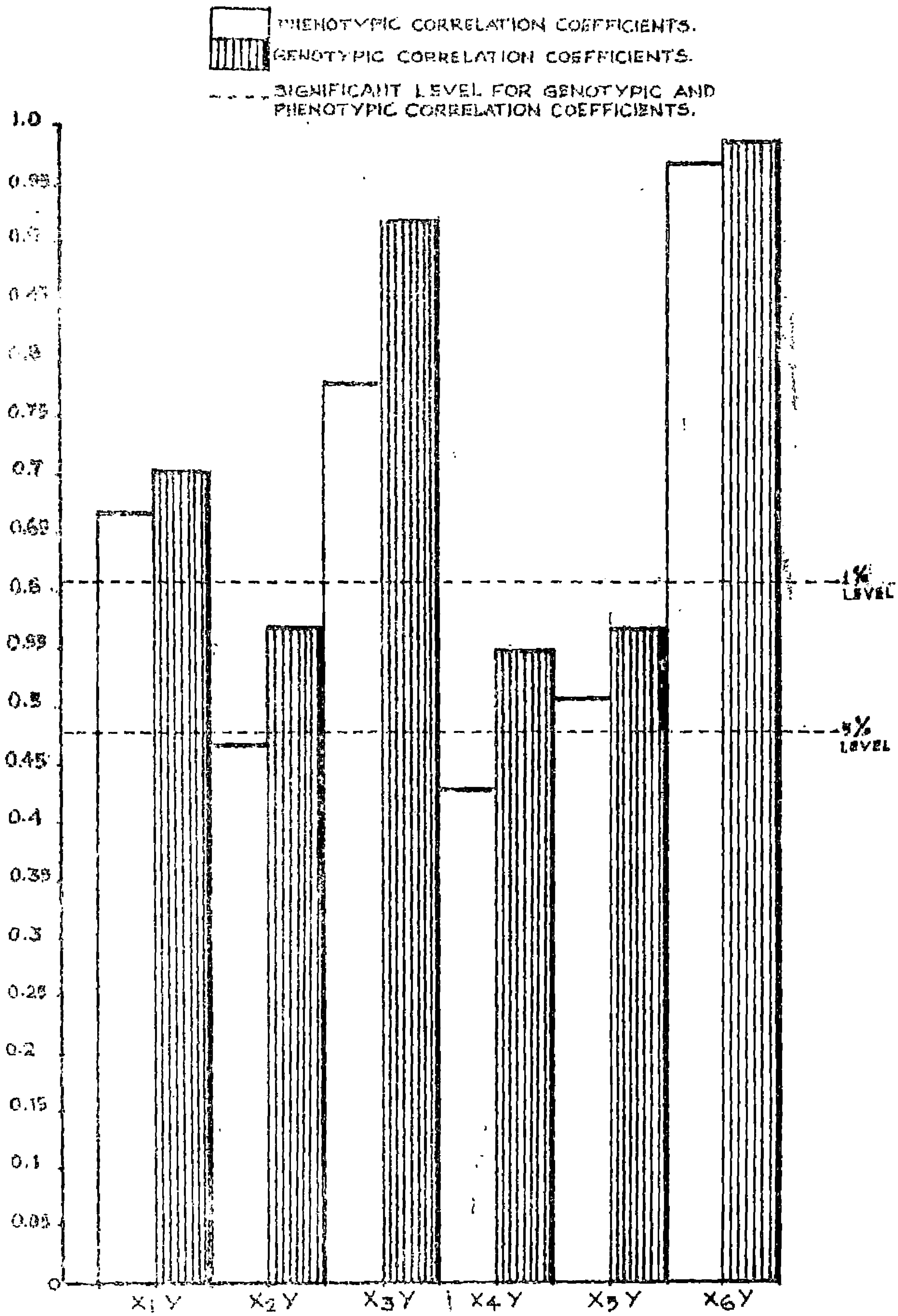
X_3Y = Correlation coefficients between number of seeds per pod and yield of seeds per plant.

X_4Y = Correlation coefficients between breadth of seed and yield of seeds per plant.

X_5Y = Correlation coefficients between thickness of seed and yield of seeds per plant.

X_6Y = Correlation coefficients between yield of pods per plant and yield of seeds per plant.

FIG. 2. CORRELATON COEFFICIENTS BETWEEN YIELD AND ITS SELECTED COMPONENTS.



(0.91059) showed maximum correlation with weight of pod. Number of seeds per pod also showed positively significant correlation with other characters. Number of seeds per pod showed maximum correlation with yield of pod per plant (0.95056). Breadth of seed was positively significant with thickness of seed and yield of pod per plant. Breadth of seed showed maximum correlation with thickness of seed (0.95655). Thickness of seed was postively correlated with yield of pod per plant (0.66391).

Path coefficient analysis:

The path coefficient analysis in order to show the direct and indirect effects of selected yield components viz., number of pods per plant, weight of pod, number of seeds per pod, breadth of seed, thickness of seed, yield of pod per plant on yield of seed per plant was done the selection of component traits being based on the significance of genotypic correlation coefficients.

The genotypic correlations on seed yield per plant of its six selected attributes were partioned into direct and indirect contributions of the components on yield of seed per plant. Data are presented in Table XXII.

(TABLE XXII)

TABLE XXII

Direct and indirect genotypic effects of six component characters on seed yield

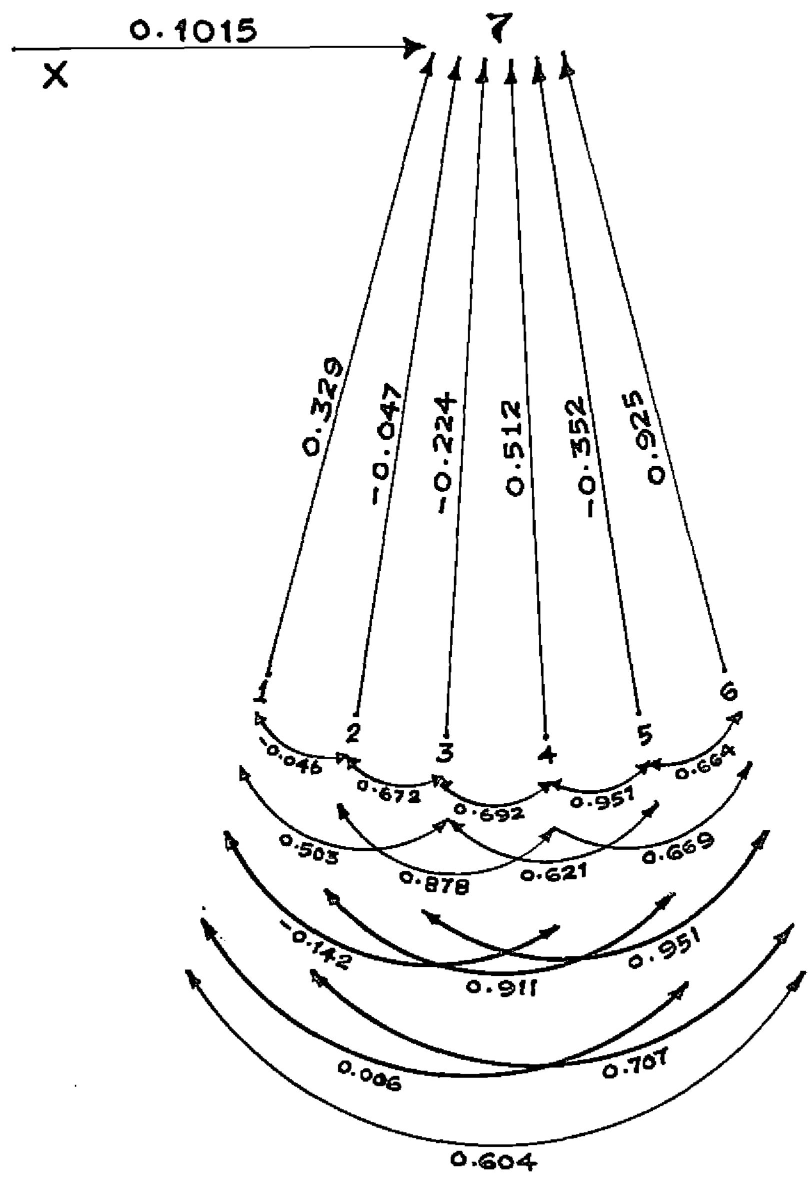
	rg	Number of pods per plant	Weight of pod	Number of seeds per pod	Breadth of seed	Thickness of seed	Yield of pod per plant
Number of pods per plant	0.70218	0.32921	0.00216	- 0.11273	- 0.07266	- 0.00215	0.55835
Weight of pod	0.57028	- 0.01505	- 0.04729	- 0.15069	0.44968	- 0.32060	0.65425
Number of seeds per pod	0.92455	0.16552	- 0.03179	- 0.22421	0.35445	- 0.21849	0.87907
Breadth of seed	0.55099	- 0.04670	- 0.04152	- 0.15515	0.51223	- 0.33678	0.61892
Thickness of seed	0.57167	0.00201	- 0.04307	- 0.13914	0.48997	- 0.35208	0.61398
Yield of pod per plant	0.98603	0.19877	- 0.03346	- 0.21312	0.34281	- 0.23375	0.92479

r_g = genotypic correlation

Figures underlined represent direct effect.

Residual effect = 0.1015

FIG. 3 - PATH DIAGRAM INDICATING DIRECT AND INDIRECT EFFECTS OF THE POSSIBLE COMPONENTS ON YIELD OF SEED PER PLANT.



→ PATH COEFFICIENTS.

↔ r(g) - GENOTYPE CORRELATION.

1. NUMBER OF PODS/PLANT.
2. WEIGHT OF POD.
3. NUMBER OF SEEDS/POD.
4. BREADTH OF SEED.
5. THICKNESS OF SEED.
6. YIELD OF PODS/PLANT.
7. YIELD OF SEEDS/PLANT.
X. RESIDUAL EFFECT.

The results reveal that the six component characters alone and in combinations contributed more than 90 per cent of the variability in seed yield per plant (R^2 = 0.9897).

The path coefficient analysis revealed that yield of pods per plant exerted the maximum direct effect than any other components (0.92479) on yield of seed per plant followed by breadth of seed (0.51223).

The direct effect on seed yield per plant was negatively influenced by weight of pod (- 0.04729), number of seeds per pod (- 0.22421) and thickness of seed (- 0.35208), though their total correlation with yield of seed per plant was postive and significant (r_g : 0.57028; r_g : 0.92455 and r_g: 0.57167 respectively) (Table XXII) (Vide Fig. 3).

The indirect effect of number of pods per plant through pod yield per plant on seed yield are worth mentioning. The highly significant correlation between number of seeds per pod and yield of seed per plant might have resulted from the high positive indirect effects on yield of seed per plant through yield of pod per plant and number of pods per plant. The indirect effect of number of pods per plant through weight of pod was positive and through number of seeds per pod, breadth of seed and thickness of seed was negative, but all these values were very low.

Selection index:

Selection index through discriminent function analysis was fitted to ascertain the extent of contribution of each factor towards seed yield per plant and also to predict the seed yield per plant based on the phenotypic performance of the six characters namely, number of pods per plant, weight of pod, number of seeds per pod, breadth of seed, thickness of seed and pod yield per plant. Thus the following selection index was obtained.

$$I = 0.493\ X_1 + 1.22\ X_2 - 4.69\ X_3 + 16.575\ X_4 + 17.291\ X_5 + 172.914\ X_6 + 0.576\ X_7.$$

Where I = Selection index.

X_1 = Yield of seed per plant.

X_2 = Number of pods per plant.

X_3 = Pod weight.

X_4 = Number of seeds per pod.

X_5 = Breadth of seed.

X_6 = Thickness of seed.

X_7 = Yield of pod per plant.

Using this criterian, index values for each variety were determined. The same in the discending order of magnitude is presented in Table XXIII.

(TABLE XXIII)

The results indicate that Pattambi local-1 has the highest index value (764.64) followed by C_{152} x New Era-I belonging to Cluster No.11 (672.91). The lowest index value of 392.25 has been recorded by Pusa Phalguni of Cluster No.3.

Constellation of 17 cowpea genotypes through metroglyps:

The 17 genotypes are pictorially represented through metroglyphs (Vide Fig. 4).

TABLE XXIII

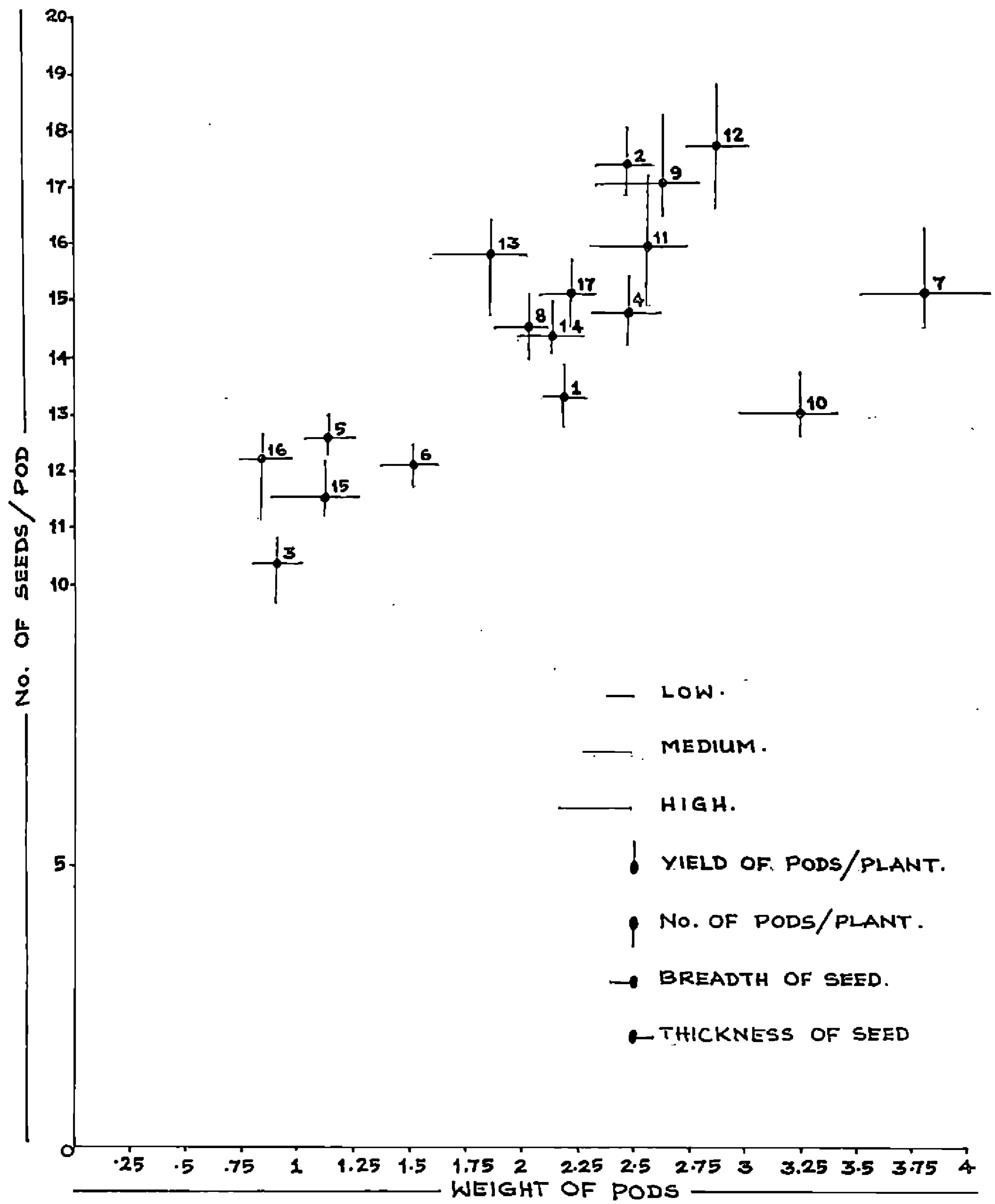
Ranking of the varieties based on the index value for selection

Sl. No.	Name of the variety	Cluster No.	Index value
1.	Pattambi local-I	12	764.24
2.	C_{152} x New Era-I	11	672.91
3.	GP. T. 536	9	667.85
4.	C_{152} x New Era-I	13	657.57
5.	GP. PLS. 63	2	647.96
6.	GP. MS. 9314	7	596.811
7.	Kolingipayar	8	583.28
8.	Mancheri-black	17	556.96
9.	Mancherimottled - dark	4	523.51
10.	Kolingipayar white	16	513.85
11.	Pannithodan early	14	494.78
12.	No. 62	1	490.21
13.	P_{118}	15	450.37
14.	IC. 20729	10	439.01
15.	GP. PLS. 139	5	421.05
16.	Pusaphalguni	3	392.25

Fig. 4. CONSTELLATION OF 17 COWPEA GENOTYPES BASED ON YIELD AND ITS COMPONENTS THROUGH METROGLYPHS.

Cluster Number	Name of the variety
1	No. 62
2	GP. PLS. 63
3	Pusa Phalguni
4	Mancheri Mottled-dark
5	GP. PLS. 139
6	Red seeded selection
7	GP. M.S. 9314
8	Kolingipayar
9	GP.T. 539
10	IC. 20729
11	C_{152} x New Era-1
12	Pattambi local-1
13	C_{152} x New Era-1
14	Pannithoden early
15	P_{118}
16	Kolingipayar white
17	Mancheri-black

FIG. 4. CONSTELLATION OF 17 COWPEA GENOTYPES BASED ON YIELD AND ITS COMPONENTS THROUGH METROGLYPHS.
(1 TO 17 REPRESENT CLUSTER NUMBERS)



Discussion

DISCUSSION

The prime objective of any plant breeding programme is the development of elite crop varieties through genetic upgrading of economic crops. This usually follows two pathways viz. "production breeding" and "defect elimination breeding" or "resistance breeding". Though these two pathways are termed differently they go side by side symbiotically. Production breeding with which the breeder is mainly concerned is usually followed for evolving varieties or improving the existing ones. The varieties thus evolved or synthesised should have a better genetic make up within a morphological frame work that will result in a better and an efficient absorption of plant food ingredients from the soil and also in the harvest of solar energy resulting in a better convertion of the above factors into the final harvestable produce.

The basic information which a breeder usually requires as a prerequisite to any breeding programme of a particular crop species is the extent of variability present in the available germplasm. Informations on heritability and estimates of genetic advance that could be obtained in the next cycle of selection are of vital importance to the breeder in deciding the appropriate method of breeding. A knowledge on the degree of association among quantitative characters would help the breeder to pinpoint a character or characters whose selection would automatically result in an overall progress of such characters which are positively correlated with yield and would also result in the elimination of such characters which are negatively correlated with the yield. Thus a thorough understanding of genetic diversity in the varietal spectrum is imperative for the breeder. The present investigations basically deal with obtaining the relevant genetic informations as a prerequisite to production breeding programme in a number of selected cowpea varieties. The results obtained are discussed in the following pages.

The seventeen cowpea varieties were observed to be significantly different for the sixteen characters studied, viz; plant height, number of primary branches, days to commence and complete flowering, flowering spread, number of flowers and pods per plant, length and weight of individual pod, number of seeds per pod, 100-seed weight, length, breadth and thickness of seed and pod as well as seed yields per plant.

Of the various estimates of quantitative variability, mean, range and variation around the means are the basic ones. Success in genetic improvement of a crop would, to a large extent, depend upon a wide genetic base resulting in a wider genetic variability. In the present investigation it may be seen that the range of variation for almost all the characters is large, particularly in respect of plant height, number of pods per plant, length of pod, weight of pod, 100-seed weight, pod as well as seed yields per plant etc. This indicated the presence of enough variability in the population under study. The investigation of Tikka et al. (1974) in cluster bean, and Saini et al. (1976) in peas, have shown that a wide range of variation was present for most of the characters considered in those crops.

The observed variation alone is not sufficient for the breeder. A knowledge of the extent and nature of genetic variability is all the more important. This necessitates the breeder to partition the overall or the total variability into heritable or genetic and non-heritable or environmental components, because of the high influence of environment on the expression of the quantitative characters. Variance estimates in the present investigation have shown that the total observed variance in fourteen out of sixteen characters studied are mainly due to genetic causes as indicated by the predominance of genotypic variance over environmental variance. Only in the case of flowering spread and number of flowers per plant the environmental variance has been more than the genotypic variance. This indicates that they are characters which are highly influenced by environmental effects like number of rainy days during the crop growth, length of the day, temperature of the atmosphere etc. A good amount of the variability observed in other characters like plant height height, days to complete flowering, number of pods per plant, weight of pod, etc. is also seen to be contributed by environmental effects. Similar results have been reported by Sanghi *et al.* (1964) in cluster bean.

The magnitude of the variance as such does not indicate the relative amount of variability for which coefficients of variations appear to be a better index. High genotypic coefficient of variation indicates that genotypic variability present in the crop for that character is high and enables us to compare with that present in other characters. The values estimated for the phenotypic and genotypic coefficients of variation in the present study have revealed that plant height, number of primary branches, number of pods per plant, length and weight of individual pods, 100-seed weight, length of seed, pod as well as seed yields per plant etc. have high estimates of over 20 per cent. This is suggestive of the fact that there is high degree of variability in the crop for these characters as compared to the rest and, therefore, the same can be utilized for crop improvement programmes. Reports by Anand and Torrie (1963) in soybean, Pande et al. (1975) in French bean, Tripathi and Lal (1975) in cluster bean, Laxmi and Goud (1977) in cowpea are in support of the above findings. Characters like number of flowers per plant, number of seeds per pod, breadth as well as thickness of seed etc. are observed to have moderate genotypic coefficients of variation (10 to 20 per cent), while days to commence and complete flowering and flowering spread have exhibited low values of genotypic coefficients of variation (below 10 per cent), thereby suggesting that these characters offer little scope for selection.

The magnitude of genotypic coefficient of variation alone will not help us to determine or ascertain the amount of variation that is heritable Gandhi et al.(1964). Heritability estimates alone will give an index of the heritable portion of variation. According to Burton (1952), genotypic coefficient of variation together with heritability estimates would give a true picture of the amount of progress to be expected by selection. Results of the present investigation have indicated that characters like length of pod, 100-seed weight, length of seed etc. have exhibited high genotypic coefficient of variation coupled with high heritability estimates. Heritability estimates are highest for length as well as breadth of seed (97 per cent) followed by length of pod (96 per cent) thickness of seed (93 per cent) and 100-seed weight (91 per cent). Other characters like number of primary branches, days to commence flowering, number of seeds per pod and pod yield per plant etc. have shown values of heritability exceeding 80 per cent. Hence these traits can be improved by selection since high heritability indicated the effectiveness with which selection of genotypes can be based on phenotypic performance (Johnson et al, 1955 a). Among the characters studied number of flowers per plant and flowering spread have exhibited the lowest estimates of heritability of 34 per cent and 39 per cent respectively, thereby indicating the limited scope of selection for these traits.

Heritability estimates alone provide no indication of the amount of the genetic progress that would result from selecting the best individuals. A better approach in such situation would be to consider heritability estimates and genetic advance jointly so as to arrive at a more reliable conclusion. Johnson et al. (1955 a) in their studies with soybean have suggested that heritability estimates along with genetic gain (Genetic advance expressed as percentage over the mean) are more useful than heritability estimates alone in predicting the resultant effects for selection of the best individuals. In the present study, genetic advance was estimated as absolute for each character and also the percentage of mean (Genetic gain) for comparing different characters.

Expected genetic advance estimated in absolute values for the various characters have indicated that under five per cent intensity of selection ie. by selecting five per cent superior plants from the available population, it will be possible to improve the seed yield by 64.15 g per plant, pod yield by 118.69 g per plant, plant height by 0.6 m, number of primary branches by 2.16, days to commence flowering by 8.38, days to complete flowering by 8.84, flowering spread by 3.21 days, number of flowers per plant by 39.43, number of pods per plant by 48.72, length of pod by 9.13 cm, weight of pod by 1.32 g, number of seeds per pod by 3.93, 100-seed weight by 6.55 g, length, breadth and thickness of seed by 0.33 cm, 0.16 cm and 0.12 cm respectively

The genetic gain estimate is maximum for seed yield per plant (80 per cent) followed by pod yield per plant and the same is minimum for days to complete flowering (11 per cent) and flowering spread (12 per cent). The rest of the characters studied are observed to possess values of genetic gain in between the two extremes. The results of the present investigations have indicated that characters like number of primary branches, number of pods per plant, weight of pod, 100-seed weight, length of seed, pod as well as seed yields per plant etc. exhibit high heritability (above 70 per cent) coupled with high or moderately high (above 40 per cent) genetic gain estimates thereby indicating additive gene effects for the expression of above traits (Panse, 1957) and as such those traits can be improved through straight selection. Characters like number of seeds per pod, breadth of seed and thickness of seed are found to have high heritability estimates coupled with low genetic gain values which may be attributed to the action of non-additive genes which include dominance and the epistasis (Panse, 1957). As such selection has limited scope for improving these traits.

A comparison of the available material for different economic traits has revealed that different types carry superiority with regard to various traits.

Hence there is possibility of combining the desirable attributes through an effective hybridization programme between types selected from the available materials.

Yield in any crop plant is a complex character determined by a number of genetic factors and environmental conditions occurring at various stages of the growth of the plant. Hence, selection for yield, merely on the basis of its phenotypic expression, is likely to give misleading results. For a rational approach to the improvement of yield, it would therefore be desirable to have some knowledge on the association between the different yield components and their relative contribution to the yield. A knowledge of such relationship is essential if selection for the simultaneous improvement of yield components and in turn yield to be effective. For this purpose a simple correlation study seems to be inadequate to measure the association, since different genotypes are susceptible to environments in varying degree. Robinson et al. (1951) have pointed out the usefulness of genotypic and phenotypic correlations in crop improvement programme. Genotypic correlation coefficients provide a measure of the degree of genotypic association between the characters and reveal such of those useful under consideration. With this in view, the phenotypic and genotypic correlation coefficients between yield and six of its selected components and the intercorrelations among them were worked out.

Results of the present study have indicated that within the limits of acceptable error the phenotypic and genotypic correlation coefficients for any of the six selected traits with seed yield seem to be of comparable magnitudes. However, the genotypic correlation coefficients are slightly higher than the phenotypic correlation coefficients, thereby indicating the preponderance of inherent relationship between the components and yield.

Yield in cowpea is peculiar in the sense, that both pod as well as seed yields are practically important in this crop. Pod yield assumes importance in vegetable cowpea, and seed yield-in grain cowpea. Both are equally important in cases of dual purpose cowpea. The association analysis in the present investigation has revealed that yields of both pod and seed are highly associated with number of pods per plant, weight of pod, number of seeds per pod, breadth and thickness of seed. Pod yield per plant is also strongly associated with seed yield. Association of the first five components with pod yield is also significant, either at one per cent level or at five per cent level, as evidenced by the significance of of both phenotypic and genotypic coefficients of correlation (Vide Table XXI) (Vide Fig.2). With reference to seed yield, all the six components having exhibited significant associations as shown by their genotypic correlation coefficients. But with reference to the phenotypic correlation coefficients only four out of six components have exhibited significant association with seed yield. In the case of weight of pod and also breadth of seed, the phenotypic correlation coefficients with seed yield are seen to be not significant. This may perhaps be due to the modifying effects of environmental factors in the expression of genetic components of those traits. The association of yield with its components alone is not adequate in any selection programme. A knowledge of their interrelationship is also needed. Doku (1970), based on his work in cowpea has suggested that intercorrelation among the yield components should be estimated, since in an actual breeding programme, rate of improvement in one component might or might not result in the improvement of other components. The estimates of inter correlations for the selected yield components in the present study have revealed that weight of pod, number of seeds per pod, breadth of seed and thickness of seed are strongly and positively associated with each other, thereby indicating that improvement through selection in one trait will take care of a simultaneous improvement in the other traits as well. Number of pods per plant is observed to be negatively correlated with weight of pod and breadth of seed. This suggests that improvement through selection of number of pods per plant is possible only at the expense of weight of pod and also breadth of seed.

The association analysis based on correlation coefficients of components with yield will not provide a true picture of the relative merits or demerits of each of the components to final yield, since an individual component may either have a direct influence in the improvement of yield or indirect role through other components in the improvement of yield, or both. Path coefficient analysis developed by Wright (1921) and applied for the first time in plants by Dewey and Lu (1959) furnished a means of the direct and indirect effects of individual components to final yield. Results of path coefficient analysis in the present study have revealed that, pod yield per plant has the maximum direct effect (0.92479) towards seed yield followed by breadth of seed (0.51223) and number of pods per plant (0.32921). The indirect effects of all but three characters through these traits are also positive and high. Hence it is to be understood that these three characters viz; pod yield per plant, breadth of seed and number of pods per plant form the important traits contributing to seed yield in cowpea (vide Fig.3).

The results of the present study have also indicated that the direct effects on seed yield of the traits viz., number of seeds per pod (- 0.22421), thickness of seed (- 0.35208), and weight of pod (- 0.04729) are negative, though, these traits have exhibited high significant genotypic correlation coefficients with seed yield. This situation is explainable by considering the positive indirect effect of these traits through other characters on seed yield. Thus for example, number of seeds per pod has been observed to have positive indirect effect on seed yield through number of pods per plant (0.16552), breadth of seed (0.35445), and pod yield per plant (0.87907). The same exaplanation holds good for the situation in the case of thickness of seed and ~~wt~~ weight of pod.

The residual effect calculated in the path coefficient analysis is only 0.1015. This indicates that about 90 per cent of yield in cowpea is contributed by the six component traits considered for the path analysis. This comparatively low value of residual effect obtained in the present study adequately supports the correct choice of yield components in cowpea for Path Coefficient Analysis.

Hence, from the results of Path Coefficient Analysis carried out in the present study, it can be concluded that greater emphasis has to be laid for improving pod yield per plant, breadth of seed and number of pods per plant which have exerted positive and high direct effects and through which other components have also exerted maximum indirect effects towards seed yield.

Finally, with a view to evolving a selection index for isolating superior genotypes from among those tested, a selection index through discriminant function analysis was worked out. Based on the index, the variety Pattambi local-1 (Cluster No.12) proved to be the best followed by C_{152} x New Era-I (Cluster No.11).

Summary

SUMMARY

Variability studies in cowpea (Vigna unguiculata L.) were undertaken in the Division of Agricultural Botany, College of Horticulture, Vellanikkara during 1979-1980. Seventeen different cowpea varieties belonging to seventeen district clusters were raised during the khariff season of 1979-80 in an randomised block design with four replications. Observations on sixteen economic character were recorded from 10 plants per treatments. The data were subjected to suitable statistical analyses for estimating the variability available in the material, for working out the heritable portion of the variability and for finding out the degree of association of the different components of yield with yield either directly or indirectly.

The important findings are summarised below:

1. The seventeen cowpea varieties showed significant differences with reference to the sixteen characters studied.

2. Estimates of phenotypic, genotypic and environmental variances have shown that a large proportion variability in all the characters except flowering spread and number of flowers per plant was due to genetic factors. Values of phenotypic and genotypic coefficient of variation

have confirmed the above conclusion.

3. Heritability in the bread sense was high (over 70 per cent) for twelve characters, moderately high (40 to 70 per cent) for two characters and low (below 40 per cent) for two characters.

4. Genetic advance estimated in absolute values was promising for all characters.

5. Genetic gain was the highest (80 per cent) for seed yield per plant and lowest (11 per cent) for days to complete flowering. Other characters exhibited estimates of genetic gain in between the two extremes.

6. Characters like number of primary branches, number of pods per plant, length and weight of pods, 100-seed weight, length of seed and pod as well as seed yields per plant have shown high heritability (over 70 per cent) and high or moderately high genetic gain (40 to 70 per cent) and as such they might be governed by additive genes. Hence, these characters can be improved through straight selection. Number of seeds per pod and breadth and thickness of seed have exhibited high heritability but low genetic gain thereby suggesting the action of non-additive genes including dominance and epistasis. Hence, straight selection has limited scope

for improving these traits.

7. Results of correlation studies have revealed that phenotypic and genotypic correlation coefficients for any pair of traits were of comparable magnitudes. However, genotypic correlation coefficients were slightly higher than phenotypic correlation coefficients in most of the cases.

8. Pod and seed yields per plant were strongly associated with number of pods per plant, weight of pod, number of seeds per pod, breadth and thickness of seed at both genotypic and phenotypic levels.

9. Inter correlations studied have shown that characters exhibiting significant association with seed yield per plant were also highly intercorrelated. Hence, weight of pod, number of seeds per pod, breadth and thickness of seed can be simultaneously improved.

10. Results of Path Coefficient Analysis have brought out that pod yield per plant, breadth of seed and number of pods per plant had high positive direct effects on seed yield, in that order. Thickness of seed, number of seeds per pod and weight of pod had negative direct effects on seed yield and the highly positive correlation coefficients exhibited by them with

seed yield were compensated by their indirect effects on seed yield through other traits.

11. The residual effect was 0.1015 indicating that about 90 per cent of the variation in yield were contributed by the six components considered in Path Coefficient Analysis.

12. A comparison of different varieties based on the index value has revealed the superiority of Pattambi local (Cluster No.12) over others.

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VARIABILITY STUDIES IN COWPEA

BY

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Agricultural Botany

COLLEGE OF HORTICULTURE

VELLANIKKARA - TRICHUR

1981

ABSTRACT

Studies were undertaken with seventeen cowpea varieties representing seventeen clusters, in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during 1979-80 to estimate the extent of genetic variability, association among the selected characters and its partition into direct and indirect effects through Path Coefficient Analysis. A discriminant function analysis was carried out with a view to isolating superior genotypes from among those studied.

The results have shown that the difference between types were highly significant for all the sixteen characters studied.

The estimates of variance components and coefficients of variation have indicated that the major portion of total variability in all characters, except for flowering spread and number of flowers per plant was due to genetic causes. Heritability in the broad sense was found to be quite high for all characters except for flowering spread and number of flowers per plant. Expected genetic advance has shown that, by selecting five per cent superior plants from the available population, yield could be increased by 64.15 g per plant.

Characters such as number of primary branches, number of pods per plant, length and weight of individual pods,

100-seed weight, length of seed, pod as well as seed yields per plant which exhibited parallelism in the high estimates of heritability and genetic gain might be due to the action of additive genes and could be improved straight away through selection. Variety Pattambi local-1 was found to be exceptionally high yielding.

Yield of seeds per plant was highly correlated with number of pods per plant, weight of pod, number of seeds per pod, breadth of seed, thickness of seed and yield of pods per plant. The correlation coefficients among the yield components were also highly significant.

Path coefficient analysis has shown that yield of pods per plant, breadth of seed, and number of pods per plant had high direct positive effects on yield of seeds per plant. Weight of pod, number of seeds per pod and thickness of seed exhibited low and negative direct effects on yield of seeds per plant.

The index values calculated based on discriminant function analysis, revealed the superiority of Pattambi Local-1 (Cluster No.12) followed by C_{152} x New Era-1 (Cluster No.11).

Appendix ii

ABSTRACT OF ANOVA

Sl. No.	Characters	Source	DF	SS	MS
1.	Plant height (in m)	Total	67	16.43	
		Varieties	16	10.90	0.68**
		Replication	3	0.49	0.163
		Error	48	5.04	0.105
2.	Number of primary bud	Total	67	107.085	
		Varieties	16	91.658	5.729**
		Replication	3	0.939	0.313
		Error	48	14.489	0.301
3.	Days to flowering commencement	Total	67	1657.42	
		Varieties	16	1387.60	86.73**
		Replication	3	36.43	12.145
		Error	48	233.38	4.86
4.	Days to flowering completion	Total	67	2648.14	
		Varieties	16	1957.06	122.32**
		Replication	3	60.18	20.06
		Error	48	630.90	13.14
5.	Flowering spread(in days)	Total	67	1078.59	
		Varieties	16	548.95	34.31**
		Replication	3	69.06	23.02
		Error	48	460.58	9.60

Sl. No.	Characters	Source	DF	SS	MS
6.	No. of flowers/plant	Total	67	258378.48	
		Varieties	16	102393.33	6399.90**
		Replication	3	35607.99	11869.33
		Error	48	100372.16	2091.09
7.	Number of pods/plant	Total	67	74200.07	
		Variety	16	53834.88	3364.68**
		Replication	3	6513.76	2171.25
		Error	48	13851.44	288.57
8.	Pod length	Total	67	1345.97	
		Varieties	16	1309.01	81.81**
		Replication	3	0.77	0.26
		Error	48	36.19	0.75
9.	Pod weight	Total	67	53.44	
		Varieties	16	41.34	2.58**
		Replication	3	0.237	0.08
		Error	48	11.87	0.25
10.	Number of seeds per pod	Total	67	342.89	
		Varieties	16	295.85	19.189**
		Replication	3	3.06	1.02
		Error	48	43.98	0.92 (0.706)
11.	100-seed weight	Total	67	785.41	
		Varieties	16	727.94	45.50**
		Replication	3	5.28	1.76
		Error	48	52.19	1.09

Sl. No.	Characters	Source	DF	SS	MS
12.	Seed length	Total	67	1.72	
		Varieties	16	1.67	0.10**
		Replication	3	.00639	.00213
		Error	48	.045	.00093
13.	Seed breadth	Total	67	0.547	
		Varieties	16	0.53	0.03**
		Replication	3	0.004	0.001
		Error	48	0.009	0.0002
14.	Seed thickness	Total	67	0.19	
		Varieties	16	0.18	0.011**
		Replication	3	0.0038	0.0013
		Error	48	0.0088	0.00018
15.	Pod yield/plant	Total	67	333026.18	
		Varieties	16	265895.47	16618.48**
		Replication	3	30277.77	10092.59
		Error	48	36853.94	767.737
16.	Seed yield per plant	Total	67	111805.65	
		Varieties	16	83179.15	5198.70**
		Replication	3	13473.11	4491.04
		Error	48	15153.38	315.70

** Statistical significance at 1% probability level (P : 0.01)