GENETIC STUDIES IN RED GRAM (*Cajanus cajan* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Genetic studies in Red gram (*Cajanus cajan* L.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or any other similar title, of any other University or Society.

Vellanikkara,
8--8--1988.

V.V.RADHAKRISHNAN

CERTIFICATE

Certified that this thesis entitled "Genetic studies in Red gram (*Cajanus cajan* L.)" is a record of research work done independently by Sri.V.V.RADHAKRISHNAN, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned, members of the Advisory Committee of Sri.V.V.RADHAKRISHNAN, e candidate for the degree of Doctor of Philosophy in Agriculture with major in Agricultural Botany, agree that the thesis entitled "Genetic studies in Red gram (Cajanus cajan L.)" may be submitted by Sri.V.V.RADHAKRISHNAN in partial fulfilment of the requirements for the degree.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Pulses are important as a major source of protein in the vegetarian diet of the people and also as a 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.

Red gram is the second most important pulse crop in India which accounts for more than 90 per cent of the total world production. Eventhough red gram constitutes the major portion of the pulses consumed by Keralites, the production in Kerala is only 1000 M.T. from an area of 2000 ha with an average yield of 500 kg/ha as compared to national production of 2.4 million tonnes from 3 million ha with an average yield of 800 kg/ha. Kerala has the lowest average yield of red gram among the Indian States.

Red gram, a prominent member of the genus *Cajanus* owing to appreciable amount of hardiness and the capacity to withstand prolonged drought, does well in a wide range of soil types seen in area like Palghat, Malappuram and

Trichur Districts of Kerala. In rice growing areas where irrigation is not available, grain legumes such as cowpea and black gram are grown in rice fallows on residual moisture. Pigeon pea could be another alternative in such situations because it has higher yield potential than many other pulses. In coconut gardens, it can be grown as an intercrop and is also recommended for sowing on the bunds of rice fields.

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 agroclimatic conditions. In red gram, these informations are lacking because of the fact that very little breeding or agronomic research has been carried out, particularly in Kerala.

Cajanus cajan (L) Mill sp. is predominantly self pollinated, with natural cross pollination ranging from 6 to 7 per cent, which is one of the reasons for genetic variability. Further, somatic variation also augments variability. Within the species there is considerable variability for plant and flowering habit and various yield attributes. Recombination between diverse flowering groups and yield attributes, together with reduction of excessive vegetative growth and duration could be rewarding. As a preliminary step in this direction, it is desirable to investigate the nature and degree of divergence in a population of different groups since information from such a study is useful for an understanding of the course of evolution of that group and also for classifying the population into sub units on the basis of this diversity. Such studies utilizing multivariate analysis have been successfully completed in several crops. Besides its use in taxonomic problems, such a study helps in choosing parents in the hybridisation programme for achieving specific breeding objectives. It is well established that exploitation of hybrid vigour and success in getting desirable segregants in any breeding programme depends to a large measure, on the degree of genetic divergence between the parents chosen. Informations on the source of variability for various factors contributing to yield, and the degree of diversity among the genotypes are inadequate in red gram and hence it is necessary to evaluate the available germplasm in this regard.

Primary aim of a plant breeder is to improve yield and quality by evolving superior genotypes. Selection of superior genotypes 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 such 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.

The association analysis based on correlation coefficients of components with yield, however, will not prove 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 both. Hence an assessment of the merit of each character by analysing the direct and indirect effects of the same towards final yield is of immense value in selecting the character for crop improvement.

For selecting suitable genotypes from a highly heterogenous mass population, the selection should always be based on the minimum number of characters. An estimation of discriminant function based on such most reliable and effective characters, is a valuable tool for the practical plant breeder. Selection of genotypes based on a suitable index is highly efficient in any breeding programme. Moreover discriminant function would ensure a maximum concentration of the desired genes in the plants or in the lines selected.

With this view in mind, the present investigations were undertaken with the following objectives:

1. To estimate the variability in the important economic characters among the genotypes of red gram.

2. To estimate the genetic divergence among the genotypes and to group them into clusters according to the magnitudes of genetic distances using Mahalonobis D^2 statistic.

3. To study the genetic variability in the expression of economic characters in the selected genotypes of red gfam.

4. To estimate the heritability, genetic advance and genetic gain for the different characters.

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

6. To partition the correlation coefficient into direct and indirect effects through the path coefficient analysis in order to get some idea of the casual system of the factors contributing to yield.

7. To evolve a selection index for isolating superior genotypes in red gram

Review of Literature

REVIEW OF LITERATURE

A review of literature on the subject is attempted in this chapter. Details of information available have been pooled and a brief review made covering genetic diversity, genetic variability, correlation of variables, heritability, coheritability and genetic advance, path coefficient analysis and discriminant function. In order to project the overall picture and magnitude of the problem, relevant informations relating to not only red gram but also other allied crops have been included in the review.

Genetic diversity

The importance of genetic diversity in selection of parents for hybridization has been stressed by many workers. Singh and Gupta (1968) working in upland cotton stated that the progenies derived from a set of diverse crosses exhibited a broad spectrum of variability. They emphasised the importance of genetic diversity of parents in hybrid breeding programme. According to them, the more diverse the parents were, within a reasonable range, the more would be the chance of improving the character in question.

Multivariate analysis by means of Mahalanobis' D^2 statistic has been found to be a powerful tool in the hands of plant breeders for quantifying the degree of divergence between biological populations, to understand the trend on evolutionary pattern, to assess the relative contribution of different characters towards total divergence and the associations between genetic divergence and geographic divergence.

Generally ecogeographic diversity has been considered as an index of genetic variability in crop plants. However, this may not be true for every case, as many workers have postulated that geographic diversity need not necessarily be related to genetic diversity. Varieties from widely separated localities are usually included in hybridization programmes presuming genetic diversity and greater likelihood of yielding better segregants. The validity of the above presumption depends upon the association between geographic diversity and genetic diversity (Singh and Bain, 1968). Results of Singh and Srivastava (1978) in castor were quite in agreement with the above. Many workers, however, have pointed out that genetic diversity need not necessarily be related to geographic diversity (Murthy and Qadri, 1965; Arunachalam and Jawahar Ram, 1967; Singh and Bain, 1968; Gupta and

Singh, 1970). The workers observed that many varieties forming one group were geographically diverse, while varieties obtained from the same region were genetically diverse.

Genetic diversity in red gram

Asawa (1979) studying the genetic diversity in selected population of pigeon pea (Cajanus cajan (L) Millsp.) reported that calculation of genetic distance in pigeon pea showed wide divergence which was not reflected in the geographical origin of the varieties. Height accounted for 73.6 per cent and the number of seeds per pod for 24.2 per cent of the divergence.

Bainiwal and Jatasra (1980) studied 29 genotypes of pigeon pea in two environments and showed that environmental conditions exerted considerable impact on the clustering pattern. Plant height followed by pod length and days to flower contributed the maximum to genetic divergence. They emphasized the need to conduct the genetic divergence studies over a range of environment. Hybridization between genetically distant types from diverse groups was recommended.

Dumbre and Deshmukh (1984a) conducted the cluster analysis studies in 54 genotypes of Cajanus cajan representing different parts of India. They reported that there was substantial genetic divergence. The clustering pattern of the varieties was not related to their geographic distribution. D^2 values ranged from 3.65 to 1211.5. Maximum intercluster distance was 39.24 and minimum 5.76.

Malik et al. (1985) studied the genetic diversity in 36 early pigeon pea genotypes and grouped them into 8 clusters. They reported that clustering was not related to geographical origin of the cultivars.

Hazarika and Singh (1986) while studying genetic divergence in some pigeon pea varieties and their hybrids for seed yield and 10 related characters, reported that divergence between parents was positively correlated with heterosis in the hybrids for seed yield. All the 44 genotypes studied were grouped into 11 clusters.

Genetic diversity in other pulses

Jain et al. (1982) grouped 32 divergent types of chick pea (Bengal gram) into eight clusters based on D^2 values of ten yield component characters. They reported that the pattern of clustering was highly influenced by environment. Srivastav and Gupta (1982) while studying genetic divergence in 49 chick pea varieties observed that number of pods contributed most to distinguishing groups. They grouped the varieties into nine clusters using Mahalanobis D^2 statistic. Adhikari and Panday (1983) studied genetic divergence in 36 chick pea varieties on seed yield and 16 yield related characters. All the genotypes were grouped into nine clusters. Dumbre and Deshmukh (1984 b) on the basis of Mahalanobis D^2 values obtained from analysis of data on seed yield per plant and seven yield related traits, grouped the seventeen varieties of chick pea into nine clusters. There were considerable differences between cluster means for seed size, yield per plant, pods per plant and growth period, indicating that these traits were involved in divergence. Genetic diversity and geographic diversity were unrelated. Srivastav et al. (1984) grouped 16 advanced chick pea genotypes into eight clusters based on yield and four yield related traits.

Das and Gupta (1984) using multivariate analysis in 23 black gram genotypes reported that no relationship was found between genetic divergence and geographical origin. All the 23 genotypes were grouped into nine clusters and observed that thousand grain weight made the greatest contribution to total divergence. Das Gupta and Das (1985) based on multivariate analysis on 40 strains of Vigna mungo grouped them into 17 different clusters regardless of their geographic origin.

Kumar *et al.* (1982) studied grain yield and nine quantitative characters on 50 genotypes of cow pea using D^2 statistic and grouped them into seven clusters. They observed that days to 50 per cent maturity, pod length, pod width and hundred grain weight contributed most to genetic divergence. Chikkadyavaiah (1985) studied genetic divergence on 324 genotypes of cow pea and reported that 23 stable genotypes formed one cluster. Jindal (1985) studied genetic divergence in 52 cow pea varieties for 10 characters and grouped them into eight clusters based on Mahalanobis D^2 values. The clustering did not reflect the geographical origins of the varieties.

Shanmugam and Rangaswamy (1982) studied the genetic diversity for yield and eight yield-related characters in 45 green gram genotypes and grouped them into 16 clusters. The grouping of genotypes into clusters was not related to geographical origin.

Ganeshaiah *et al.* (1984) conducted multivariate analysis for 18 characters of 100 varieties of horse gram and reported that plant maturity had contributed most to the divergence. No clear cut association between genetic diversity and geographic diversity was seen.

Chandel and Joshi (1981) studied eight yield component characters on 30 types of yellow seeded pea and grouped the varieties into 10 clusters. Types from different geographical regions fell into same cluster, indicating their close genetic similarity and possibly a common evolutionary trend.

Genetic variability

Bruton (1952) introduced a convenient procedure for the calculation of the phenotypic and genotypic coefficient of variations. Johnson et al. (1955) introduced a methodology for partitioning the total variance into that due to genotype, phenotype and error in the analysis of variance.

Genetic variability in red gram

Rathnaswamy et al. (1973) has reported on genetic variability of certain quantitative characters in red gram (*Cajanus cajan*). The characters viz., clusters per plant, seeds per plant, pods per plant, weight of pods, branches per plant, plant height and days to flowering were found to have high genotypic coefficient of variation.

Ram *et al.* (1976 b) reported highest genotypic coefficient of variability for clusters per plant and lowest for pods per cluster in red gram. Singh and Shrivastava (1977) observed high genotypic coefficient of variation for number of secondary branches per plant in pigeon pea.

Awatade *et al.* (1980 a) while estimating the genetic parameters in advanced generations of pigeon pea, found higher phenotypic coefficient of variation and a lower genotypic coefficient of variation for the characters like number of clusters per plant, yield per plant, number of pods per plant, height of the plant and hundred seed weight.

Asawa *et al.* (1981) reported in pigeon pea that seed and pod number together accounted for 47.73 per cent of the variability in yield.

Bainiwal *et al.* (1981) observed maximum variability for number of secondary branches followed by primary branches and seed yield in red gram (*Cajanus cajan*).

Dumbre and Deshmukh (1983) analysed the genetic variability in 54 varieties of *Cajanus cajan* for seed yield and eight related characters. Very high genetic variabilities were noticed for grain yield, number of primary branches and pods per plant.

Shoran (1983) observed very high range of phenotypic variability for all characters except seeds per pod in red gram. Higher genotypic coefficient of variation was seen for the characters like pods per plant, days to maturity, plant height and days to flowering in all environments.

Jag Shoran et al. (1985) reported high estimates of genotypic coefficient of variation for the characters like pods per plant, height, and days to maturity in pigeon pea. Lowest estimates of genotypic coefficient of variation were exhibited by length of pod and seeds per pod.

Genetic variability in other pulses

Patil and Phadnis (1977) based on their studies in bengal gram recorded high genetic variation for pods per plant, pod weight per plant and hundred seed weight.

Soundarapandian et al. (1975) observed high genotypic and phenotypic variances for number of pods per plant and height of plant in black gram. Goud et al.(1977)

recorded highest genetic variability for seed yield and lowest for length of pod in black gram.

Lakshmi and Goud (1977) recorded high coefficient of genetic variation for height of plant, seed yield, number of pods, length of pod and hundred seed weight in cowpea. Vaid and Singh (1983) studied eight yield related characters in 60 F_3 and 50 F_4 populations of cowpea and reported that branch number, cluster number and yield per plant gave high values for phenotypic and genotypic coefficient of variation. Patil and Baviskar (1987) reported that in cowpea maximum range of variation was for grain yield per plant followed by pods per plant, clusters per plant and days to maturity. The genotypic and phenotypic coefficients of variation were higher for clusters per plant, pods per plant, grain yield per plant and hundred grain weight.

Gupta and Singh (1969) while studying 36 varieties of green gram, recorded that yield per plant had high genetic variability. Malhotra and Singh (1974) reported that in green gram, number of clusters, number of pods and seeds per pod were the most important yield components accounting for 96 per cent of variability in yield.

Singh (1985) reported that in pea, grain yield, plant height, pods per plant and branches per plant showed a high degree of genetic variability and were highly amenable to selection as indicated by high genetic advance.

Correlation of variables

Galton (1889) conceived the idea of correlation of variables for the first instance.

Correlated variables in red gram

Joshi (1973) in correlation studies with pigeon pea reported that seed yield was positively and significantly correlated with the number of pods and number of branches. The pod length and numb r of seeds per pod were positively correlated. The number of branches and number of pods per plant were the main yield components.

Singh and Malhotra (1973) recorded significant and positive association of yield with number of clusters per plant, pods per plant and secondary branches in pigeon pea.

Veeraswamy et al. (1973 b) reported that in pigeon pea the numb r of clusters and pods per plant was found to be the most reliable and useful index because they had genotypic and phenotypic correlations with yield. The number of branches per plant was also an important factor in selection, because of high positive genetic association with number of clusters and pods per plant. The number of branches, clusters and pods per plant were the chief characters which contributed to the yield of red gram.

Pankaja Reddy et al. (1975) reported in pigeon pea that pod number and seed size were the most important components contributing to yield. As the duration increased, pod number, yield and seed size also increased.

Tiwari et al. (1978) with their correlation studies in pigeon pea reported that seed yield and harvest index were each positively correlated with plant spread and with each other. Height of the first branch was negatively correlated with number of pods per plant, seed yield and harvest index. The number of pods was positively correlated with the number of secondary branches and with seed yield.

Dani (1979) studied yield components in 24 varieties of pigeon pea and reported that seed yield was correlated with number of inflorescence, number of pods and number of seeds per plant.

Ram et al. (1976 b) estimated the correlation coefficients among the economic characters between themselves and towards yield. They reported that the number of primary branches showed positive association with clusters per plant, pods per cluster, harvest index and grain yield both at genotypic as well as phenotypic levels.

Asawa et al.(1981) studied the character correlations in pigeon pea and observed that yield proved to be positively correlated with height, number of secondary branches per plant, pod number per plant, seed number per plant and number of days to maturity.

Singh et al. (1981) while studying the yield components in F_4 progenies of pigeon pea reported that seed yield per plant was positively correlated with pod number per plant, plant height, number of days to 50 per cent flowering, seed number per pod and number of days to maturity.

Yadavendra et al. (1981) reported in pigeon pea that seed yield per plant was positively correlated with number of pods per plant.

Ekshinge et al. (1983) reported that in pigeon pea total dry matter and pod number per plant were significantly correlated with yield per plant.

Kumar and Reddy (1983) while studying genetic association in pigeon pea reported that pod number was the most important yield component. In short group, number of primary branches, pod bearing length and seed weight were important yield components.

Wagh *et al*. (1983) with their correlation studies in 79 varieties of pigeon pea reported that there were high significant values of correlations between grain yield per plant and plant height, number of effective pods per plant and hundred grain weight both at phenotypic and genotypic levels. Number of effective pods and thousand grain weight, however, showed negative phenotypic correlation.

Jagshoran (1985) obtained significant desirable association between seed yield per plant and pods per plant and days to maturity which in turn - suggested that seed yield could be increased in red gram by selecting plants with many pods and reasonable early maturity.

Correlated variables in other pulses

Kambal (1969) recorded strong and positive association of yield with number of pods per plant and negative association of seed weight with number of pods per plant and number of seeds per pod in field beans. Joshi (1971) obtained high positive correlation between yield and number of pods, number of seeds per pod and number of branches in Indian beans. He also observed a high genotypic correlation coefficient. Sharma _et al_. (1977) reported high genotypic correlation of yield with number of nodes bearing pods in french beans.

Gupta _et al_. (1972) with their correlation studies in bengal gram involving 46 varieties, recorded significant and positive phenotypic correlation of yield with days to 50 per cent flowering, number of pods per plant and number of seeds per pod. Khan and Chaudhary (1975) reported positive correlations between yield and height of plant, number of primary, secondary and tertiary branches and number of pods per plant and negative correlation between yield and seeds per pod and seed size in bengal gram. Katiyar _et al_. (1977) recorded positive correlation of yield with height of plant, number of branches per plant, number of pods per plant and days to maturity in chick pea. Narasimhaiah _et al_. (1977) observed high positive correlation between yield and number of branches, number of pods and number of seeds per plant and seed weight, while days to flowering and maturity showed negative correlation with yield in chick pea. Oraon _et al_. (1977) observed positive correlations of grain yield with number of pods per plant and number of seeds per pod in chick pea. They further noticed that genotypic correlations were slightly higher than phenotypic correlations. Katiyar et al. (1981) while studying seed yield and seven yield components in widely varied lines of chick pea found that genotypic correlations were in greater magnitude than phenotypic correlations. Adhikari and Panday (1982) reported that, in chick pea, seed yield was positively correlated with primary branches per plant, secondary branches per plant and number of pods per plant. Islam et al. (1984) in a correlation study in chick pea reported that yield per plant was highly and positively correlated with pods per plant and number of secondary branches per plant.

Verma and Dubere (1970) observed positive association of yield with number of pods per plant in black gram. Further, they observed that pods per plant, length of pod and hundred seed weight contributed much towards yield. Goud et al. (1977) recorded positive correlation of yield with height of plant, length of pods, seeds per pod and thousand seed weight in black gram. They have also recorded highest genetic variability for seed yield and lowest for length of pod. Muthieh and Sivasubramanian (1981) reported that in black gram (Vigna mungo) pod number, pod yield, cluster number, hundred seed weight etc. showed positive genotypic and phenotypic correlations with seed yield. Rani and Rao (1981) studied eight characters on 12 varieties of black gram and reported that number of pods per plant, hundred seed weight and number of seeds per pod showed high positive correlations and high direct effects on yield. Pod weight per plant and pod length were highly and positively correlated with yield but with high negative direct effects.

Singh and Mehndiratta (1969) found that grain yield was significantly correlated with number of branches, number of pods, number of seeds per pod and hundred grains weight in cowpea. Dumbre et al. (1982) in a study of the genotypic characters among 24 cultivars of Vigna sinensis observed that height and pods per plant were significantly correlated with yield. Jindal and Gupta (1984) in a component analysis of yield in cowpea observed that plant height, inflorescence per plant, pods per plant, pod length and seeds per pod were significantly and positively associated with seed yield. Chikkadyavaiah(1985) reported that in cowpea, seed yield was positively correlated with number of branches per plant, fruiting bunches per plant, pods per plant, seeds per pod and hundred seed weight. Patil and Bhapkar (1987) reported in cowpea that grain yield was positively and significantly correlated with pods per plant and grains per pod.

Singh and Malhotra (1970) while studying 75 strains of mung bean, recorded significant association of yield with number of branches, number of pods, length of pod, number of seeds per pod and seed size. They also observed that genotypic correlations were higher than phenotypic and environmental correlations. Tomas et al. (1973) while studying four yield components in 22 genetic stocks of mung bean, recorded positive correlation, of yield with number of pods per plant, length of pod, hundred seed weight and number of seeds per pod. Choudhary and Singh (1974) recorded strong association of yield with days to flower, height of plant, number of pods per plant and number of seeds per pod in mung beans. Malhotra and Singh (1974) studied the yield components in 60 strains of green gram and reported strong correlation of yield with number of branches, number of pods, number of clusters, number of seeds per pod and days to flowering. These characters were significantly associated together. They have also reported that number of clusters, number of pods and seeds per pod were the most important yield components accounting for 96 per cent of variability in yield. Shamsuzzaman et al. (1983) reported in mung bean that pods per plant, primary branches per plant and seeds per pod were positively correlated with yield per plant. Khan (1985) studied the yield components in mung bean and reported that number of fertile branches and number of pods had high heritability and were positively correlated with yield.

Agarwal and Kang (1976) observed significant correlations between yield and pods per plant, hundred grain weight, length of pod, height of plant and number of branches in horse gram. Shivashankar et al. (1977) while studying hundred varieties of horse gram, observed positive correlations of yield with height of plant, number of pods per plant, number of seeds per pod and number of pods per plant. Patil and Deshmukh (1983) reported that seed yield was positively correlated with number of pods per plant, number of secondary branches and hundred seed weight in horse gram.

Singh and Singh (1969) reported a close resemblance between phenotypic and genotypic correlations, although genotypic correlations were slightly higher than phenotypic correlations in field pea. They also recorded that grain yield was significantly associated with number of pods per plant and hundred seed weight. Sangha *et al.* (1971) observed that weight of green pods per plant and number of pods per plant contributed much to grain yield in pea. Narasinghani *et al.* (1978 b) while studying 65 diverse genotypes of pea, recorded that the seed yield per plant was positively associated with number of days to flower, maturity period, height of plant, number of branches, number of pods per plant and number of seeds per pod. Singh *et al.* (1985) reported in pea that days to 50 per cent flowering, days to maturity, plant height, pods per plant and primary branches per plant were positively associated with grain yield as well as with each other.

Kaw and Menon (1972) studied yield components in 37 varieties of soyabean and reported strong correlation of yield with number of pods, number of seeds, height of plants, days to 50 per cent flowering and maturity. They have also reported that genotypic correlation coefficients were mostly higher than the phenotypic correlation coefficients.

Heritability, co-heritability and genetic advance

Genetic parameters like heritability, coheritability and genetic advance have been often found to be of great use for assessing the relative importance of the inherited and correlated variables. Hanson et al. (1956) proposed the mathematical relationship of various estimates on computation of heritability. Lush (1949) and Johnson et al. (1955) devised a procedure for the calculation of genetic advance under specified intensity of selection. This attribute is generally expressed as the percentage and in the broad sense it refers to the proposition of variances due to genotype over the variance due to the phenotype.

Heritability, coheritability and genetic advance in red gram

Hiremath and Talawar (1971) in a study on genetic variability in pigeon pea observed high heritability with low genetic gain in respect of primary branches, pods per plant, length of pod and weight of thousand seed, where as high heritability with high genetic gain was observed in case of plant height, pods per plant and yield per plant.

Rathnaswamy et al. (1973) reported in pigeon pea that plant height, branches per plant, clusters per plant, pods per plant, days to flowering had high heritability and similar genetic gain.

Ram _et al_. (1976 a) observed highest value of heritability for clusters per plant followed by grain yield per plant, primary branches and pods per cluster. The clusters per plant showed the highest amount of genetic advance.

Singh and Shrivastava (1978) reported in pigeon pea that heritability estimates were highest for days to flowering, followed by days to maturity, harvest index, seed yield per plant and height of the primary branch. Plant spread, number of secondary branches, height and days to flowering combined high heritability estimates with high genetic advance.

Awatade _et al_. (1980 b) observed highest heritability estimates for the character height followed by hundred seed weight in pigeon pea. The number of clusters per plant, yield per plant and number of pods per plant had high heritability estimates and high genetic advance.

Bainiwal _et al_. (1981) reported high genetic advance for seed yield, secondary branches, plant height and primary branches in pigeon pea.

Singh and Srivastav (1981) reported the highest broad sense heritability in pigeon pea for hundred seed weight.

Yadavendra *et al*. (1981) observed maximum heritability in pigeon pea for test weight (91.76 per cent) followed by number of seeds per pod (90.41%). The expected genetic advance expressed as a percentage of the mean ranged from 13.86 for pod length to 32.62 for number of pods per plant.

Dumbre and Deshmukh (1983) reported in pigeon pea that broad sense heritability estimates were high for days to first flowering, maturity and hundred grain weight and higher heritability with high genetic advance was observed for the characters like plant height, pods per plant, days to maturity and days to first flowering.

Shoran (1983) reported high heritability estimates and moderate to high genetic advance for pods per plant, days to maturity, plant height and days to flowering in all environments.

Suresh Kumar and Reddy (1983) observed high heritability coupled with high genetic advance in pigeon pea for the characters seed weight, pod clusters per plant, days to flower, days to maturity, plant height and pod number.

More *et al*. (1984) suggested the effectiveness of selection in pigeon pea for the character pods per plant which showed moderate heritability with higher genetic advance.

Heritability, coheritability and genetic advance in other pulses

Cyone (1968) reported that heritability was very low for total seed yield in field beans.

Sandha and Chandra (1969) made heritability studies in bengal gram, and found high heritability values for primary and secondary branches. Gupta et al. (1972) observed high heritability values for number of seeds per pod and hundred seed weight in bengal gram. Joshi (1972) reported high heritability and genetic advance for number of pods per plant in bengal gram. Singh et al. (1973) observed high heritability for hundred seed weight and low heritability for number of secondary branches in bengal gram. Narasimhaiah et al. (1977) recorded high genetic advance for yield of pods, number of pods per plant and yield of seed in chick pea. Dumbre et al. (1984) observed high heritability values of 80 per cent with relatively high genetic advance for the characters like seed per pod, seed yield per plant and hundred seed weight in chick pea. Khorgade et al. (1985) observed high heritability (90%) for the characters seed index (100 seed mass) seeds per pod and time to 50 per cent flowering in chick pea.

Soundrapandian *et al.* (1975) observed high heritability for length of pod and height of plant in black gram. Patil and Shah (1982) observed high heritability in conjunction with low genetic advance for seeds per pod, hundred seed weight and pod per clusters in black gram.

Lakshmi and Goud (1977) recorded high heritability for number of seeds, height of plant, length of pod and hundred seed weight in cow pea. Vaid and Singh (1983) while studying eight yield related characters in cow pea, observed high heritability and expected genetic advance values for branch number, cluster number and yield per plant. Dharmalingam and Kadambavanasundaram (1986) reported in cow pea that pod length, hundred seed weight and harvest index showed the highest heritability. Patil and Baviskar (1987) reported in cow pea that heritability estimates were highest for hundred grain weight followed by days to maturity and pod length. The expected genetic advance was also high for clusters per plant, pods per plant, hundred grain weight and grain yield per plant.

Gupta and Singh (1969) while studying 36 varieties of green gram, recorded that yield per plant had high genetic variability and medium heritability but low expected genetic advance. Srivastav et al. (1977) observed high heritability for days to flowering, length of pod and width of pod in green gram. They have also observed high genetic advance for number of seeds per pod. Veeraswamy et al. (1973 a) observed high heritability for days to flower, height of plant, number of clusters and number of branches in green gram. They have also observed high genetic advance for number of clusters, number of branches per plant, height of plant and number of pods. Length of pod and number of seeds per pod showed moderate to high heritability and low genetic advance.

Sreekantaradhya et al. (1975) while studying 48 varieties of horse gram, recognised high heritability and genetic advance for number of nodes, number of branches, number of pods, height of plant and yield of seed. Agarwal and Kang (1976) observed high genetic advance for pods per plant, hundred grain weight and grain yield per plant in horse gram. Shivashankar et al. (1977) while studying hundred varieties of horse gram, recorded that primary branches, secondary branches, days to 50 per cent flowering, number of nodes per plant and hundred seed weight were highly heritable, while height of plant, number of seeds per pod, number of pods per plant and yield showed low heritability. Patil and Deshmukh (1982) reported in horse gram that seed yield, number of secondary and primary branches and pods per plant showed high heritability and high expected genetic advance in two successive years. Ganeshaiah et al. (1984) reported in horse gram that days to flowering showed the highest heritability (94.23%).

Koranne and Singh (1974) reported high heritability for flowers per peduncle, pods per peduncle, pods per plant, length of pod and hundred seed weight, while very low heritability for yield in pea.

Path coefficient analysis

The path coefficient analysis devised by Wright (1921) is an effective means of examining the direct and indirect relationships permitting a critical examination of the specific factors that produce a given correlation.

Dewey and Lu (1959) recommended the path coefficient analysis as a potent method for resolving the accurate and dependable criteria in selection procedures in breeding programmes.

Path coefficient analysis in red gram

Singh and Malhotra (1973) while studying yield components in pigeon pea stated that number clusters per plant was the main yield component in pigeon pea.

Pokle and Mohatkar (1975) reported that pod number per plant had a higher direct effect in pigeon pea.

Veeraswamy _et al._ (1975) while studying path analysis recorded that the number of branches showed maximum influence both directly and indirectly on seed yield.

Wakankar and Yadav (1975) while measuring the direct and indirect effects of yield components in arhar, observed that pod number had the highest positive direct effect on seed yield, followed by number of secondary branches and hundred seed weight. They have also concluded that selection for seed yield should be based on high number of pods, secondary branches and a high seed index and a nonspreading habit.

Ram _et al._ (1976 a) while studying path analysis reported in pigeon pea that the primary branches, cluster per plant and pods per cluster contributed directly as well as indirectly to grain yield.

Awatade _et al._ (1980 a) reported in pigeon pea that when seed yield and seven yield components were investigated, only number of clusters per plant and 100 seed weight were found to affect yield directly.

Malik *et al.* (1981) while studying path coefficient analysis in pigeon pea observed that days to maturity, plant spread, clusters per plant and pods per plant proved to be the chief characters contributing to seed yield.

Singh and Shrivastava (1981) reported in red gram that the number of pods per plant had a slight positive and direct effect on seed yield but had a marked positive and indirect effect through 100 seed weight and the number of primary branches. Pod bearing length also had a marked indirect effect through hundred seed weight and the number of pods per plant. The number of primary branches had a strong positive and direct effect on yield but strong netative and indirect effects through pod bearing length and hundred seed weight.

Kumar *et al.* (1982) observed in path coefficient analysis studies in red gram that pod number, plant height and number of primary branches had large positive direct effects on yield per plant.

Shoran (1982) reported in arhar that pods per plant had the highest direct effect on seed yield followed by hundred seed weight, seeds per pod and days to flowering.

Balyan and Sudhakar (1985) observed while estimating the path coefficients in arhar that days to maturity, number of pods per plant, number of seeds per pod and hundred seed weight were found to have high direct effects on yield.

Bainiwal and Jatasra (1985) in a path coefficient analysis of seed yield per plant and nine quantitative characters based on data from 29 red gram genotypes, revealed that seed yield was positively and significantly correlated with days to flowering, plant height and primary branch number per plant; plant height having the strongest direct effect on yield.

Path coefficient analysis in other pulses

Phadris <u>et al</u>. (1970) studied 45 chick pea varieties and reported that the number of pods per plant, number of seeds per plant and hundred seed weight were the major factors determining yield. Katiyar <u>et al</u>. (1977) recorded that number of branches per plant had higher positive direct effect on grain yield followed by number of pods per plant in chick pea. The direct effect of height of plant and days to maturity on grain yield was high and negative. Jatasra <u>et al</u>. (1978) conducted path analysis in chick pea and recorded that seeds per pod and hundred seed weight should be given due emphasis while selection for high yield. Katiyar et al. (1981) reported in chick pea that number of days to flowering had a high negative direct effect on seed yield. Adhikari and Pandey (1982) studied 16 characters on 36 chick pea genotypes and reported that days to complete flowering, pods per plant and hundred seed weight had important direct effect on yields. Singh et al. (1985) in a path coefficient analysis in chick pea, recorded that seeds per pod had the highest direct effect on yield, while most of the other characters affected yield directly via pods per plant.

Soundarapandian et al. (1976) studied path coefficient analysis in black gram and reported that height of plant and number of clusters had direct and indirect effect on seed yield. Sandhu et al. (1980) while attempting path analysis in 268 strains of urd bean affirmed strongly that selection criteria should be based on early flowering lesser plant height, higher fruiting nodes and larger pods. Muthiah and Sivasubramanian (1981) recorded in black gram, that pod yield and pod number were the most important traits determining seed yield per plant. Rani and Rao (1981) showed through path coefficient analysis in black gram that selections should be based on large seeds, number of pods per plant and number of seeds per pod.

Singh and Mehndiratta (1970) showed that pods per plant, grains per pod and hundred grain weight directly contributed to grain yield in cow pea. Kumar et al. (1976) with their path coefficient studies in cow pea, recorded that number of clusters per plant, number of pods per plant and hundred seed weight had high direct effect on pod yield. They have also suggested these characters as reliable selection indices in cow pea. Jana et al. (1983) while studying path analysis of pod yield components in cow pea indicated that pod number per plant had the highest direct effect on pod yield per plant. Kumar et al. (1983) reported in cow pea that selection for pods per pedunicle, pod length and width, peduncle length and days to 50 per cent maturity would increase seed yield. Jindal and Gupta (1984) observed in cow pea that bunches of pods per plant, seeds per pod and length were the major components contributing directly to seed yield. Padhye et al. (1984) reported in cow pea that pods per plant and seeds per pod showed the highest positive direct phenotypic and genotypic effects respectively on yield. Chikkadyavaiah (1985) reported in cow pea that plant spread, pods per plant and seeds per pod had direct effect on seed yield. Choulwar and Borikar (1985) while studying path analysis in cow pea observed that number of seeds per pod and length of pod had greatest direct effects on seed yield per plant. Obiseran (1985) reported in cow pea that most important yield components were number of pods per plant, 100 seed weight and number of seeds per pod.

Singh and Malhotra (1970) who conducted path coefficient analysis with 75 strains of mung bean reported that pods per plant, seeds per pod and seed size were the yield components. Further, they reported that seed size had negative indirect effect on yield through seeds per pod and pods per plant and vice versa. Giriraj and Vijayakumar (1974) while applying path coefficient analysis in mung bean, observed that length of pod, days to flower and height of plant had positive direct effect on seed yield. Height of plant and days to flower had negative indirect effect through length of pod and hundred seed weight. They concluded that maximum weightage should be given to length of pod, days to flower and height of plant while formulating selection indices for seed yield in mung bean. Malhotra and Singh (1974) while examining yield components in green gram, reported that pods per plant had the highest direct and indirect effect on seed yield. Singh _et al_. (1977) with their path coefficient studies in green gram reported that number of primary branches, number of cluster per plant, number of pods per cluster and number of pods per plant had significant association with grain yield. Number of seeds per pod showed lack of association with yield. Primary branches and number of clusters per plant exhibited indirect contribution to grain yield. The pods per cluster and pods per plant contributed direct and indirect effects on grain yield. They have also concluded that number of pods per cluster and number of pods per plant were to be considered as major yield components. Boomikumaran and Rathinam (1981) while studying eight yield characters among 49 lines of green gram observed that height, number of pods per cluster and number of clusters per plant had the most important effects on seed yield. Malik and Singh (1983) while studying multiple correlation and regression analysis on 81 green gram genotypes indicated that a combination of branch per plant, pods per plant and seeds per pod was better than any single one for effecting improvement on seed yield. Thandapani and Rao (1984) in a path coefficient analysis in green gram showed that clusters per plant had the greatest direct effect on yield, while pod length and seed weight were also directly associated with yield. Thulasidas (1984) in a multiple regression analysis in green gram observed that pods per plant, days to maturity, pod length and hundred seed weight in that order were relatively important for their contributions to yield. Vidhyadhar et al. (1984) in an analysis of data on yield and ten yield related and other quantitative traits from 36 green gram genotypes revealed that number of pod clusters per plant and seeds per pod and hundred seed weight had direct effects on seed yield. Khan (1985) in a path coefficient analysis of yield components in mung bean indicated that number of pods had a high positive direct effect on yield while number of fertile branches had a negative direct effect.

Agarwal and Kang (1976) while applying path coefficient analysis in horse gram, observed that pods per plant contributed much for seed yield.

Singh and Singh (1969) with their path coefficient studies in 40 field pea varieties, found that number of branches, number of pods per plant, number of seeds per pod and hundred seed weight were the important factors determining grain yield. Chandel and Joshi (1976) recorded that number of seeds per pod, number of pods per plant and hundred seed weight had positive direct effect on seed yield and the number of days to flower had a negative direct effect on yield in yellow grained peas. Kalloo and Dhankar (1977) concluded from path coefficient analysis of 64 varieties of pea, that number of pod clusters, number of pods per plant and number of branches per plant were the major yield components. Narasinghani *et al*. (1978 a) while studying path analysis in pea indicated that hundred seed weight had positive direct effect on grain yield.

Gupta and Kataria (1971) based on results from path analysis in soyabean, recorded that maximum weightage should be given to days to maturity and leaves per plant for the improvement of soyabean by selection. Lal and Haque (1971) studied 36 varieties of soyabean and reported that hundred seed weight and number of pods had high positive direct effect on seed yield. Further they observed that hundred seed weight had negative indirect effect on seed yield via number of leaves, total leaf area, plant height, number of nodes and number of pods. Kaw and Menon (1972) while studying 37 varieties of soyabean, stated that the yield components were number of pods and days to maturity. Choudhary and Singh (1974) while measuring the direct and indirect effects of yield components in soyabean, recorded that number of pods per plant and seed size had high direct effects towards yield. Veeraswamy and Ratnaswamy (1975) reported number of pods per plant as the major yield contributing character in soyabean, followed by hundred seed weight and number of nodes. Patirana and Gushov (1979) while studying 11 varieties of soyabean, observed that number of seeds per pod and single seed weight were the major yield components and concluded that selection for these two characters would be an effective method for increasing seed yield.

Discriminant function

Discriminant function technique was developed by Fisher (1936) and Smith (1936) wherein, it was shown that selection for yield could be made more efficient, if the basis of component traits that went to make up the crop yield and the relationship between those characters and yield were studied. This formed the basis for the formulation of selection index.

Discriminant function in red gram

Gunaseelan and Rao (1976) while studying the discriminant function in arhar recorded that the major components that exerted maximum influence on yield in pigeon pea was plant height and number of pods.

Malhotra and Sodhi (1977) conducted discriminant function techniques in pigeon pea and reported that number of branches, number of pods and number of clusters should be given due weightage for an effective selection.

Sharma and Asawa (1977) while studying path coefficient analysis and selection indices for segregating population of arhar, observed that most efficient selection criteria was pods per plant.

Shrivastava et al. (1977) estimated selection efficiency using discriminant function in pigeon pea. They reported that direct selection for yield in pigeon pea was superior to selection based on any component alone or in combination. Further they recorded that the efficiency of selection was highest when selection was based on combination of yield with number of primary branches and pod bearing length or with number of primary and secondary branches with pod bearing length and number of pods per plant or with pod bearing length and hundred seed weight.

Reddy et al. (1979) while studying the combining ability and selection index in F_2 generation of pigeon pea crosses observed that plant height was an important attribute and was effective as yield. Plant height, seed weight, length of pod bearing branch and number of pod bearing branches furnished criteria for selection.

Discriminant function in other pulses

Panagua and Pinchinat (1976) reported that improved seed yield in french beans could be achieved by selection for a high number of pods per plant, seeds per pod and nodes per plant. Davis and Evans (1977) after studying 112 breeding lines of field beans, reported that efficiency of selection would not be improved by including information of yield components. But they have concluded that 10 per cent improvement was predicted if informations on total number of nodes, number of inflorescences and hypocotyl diameter were included. Singh end Singh (1972) constructed selection indices in field beans by studying yield and yield related characters in 48 genotypes. A maximum relative efficiency of 28 per cent over straight selection for yield was achieved when all characters were taken into consideration. The data showed that number of pods per plant, number of seeds per pod length were the major yield components.

Mital and Thomas (1969) recorded that number of branches and total number of pods when taken together, would form the best index in bengal gram.

Banerjee et al. (1976) during their discriminant function studies with 16 varieties of black gram recorded that an index based on a combination of yield and days to flowering and number of pods were more efficient. Singh et al. (1976) studied 36 strains of black gram and reported that use of discriminant function based on a single character was not superior to direct selection for yield. The relative efficiency of selection was highest when discriminant function was based on number of primary branches, number of clusters per plant, number of pods per cluster and grain yield per plant.

Tikka et al. (1977) reported in cow pea that selection based on single characters would not be more efficient, then direct selection for seed yield except in the case of number of pods per plant. They have also concluded that the most efficient selection index included height, pods per plant and 100 seed weight. Tikka and Asawa (1978) while studying selection indices in 17 varieties of cowpea, recorded 100 seed weight as the stable selection component for increased yield. Murthy (1982) constructed a selection index in cow pea consisting of traits - pod number of plant, pod length, seed number per pod, test weight and yield, and found that this was more effective than selection for seed alone.

Singh and Mehndiratta (1970) studied yield components in 40 strains of cow pea and observed that discriminant function on two yield components viz., grains per pod and hundred seed weight and three yield components viz., grains per pod, hundred seed weight and pods per plant, were superior in selection for yield.

Malhotra and Singh (1974) recorded that selection for yield in green gram based on number of clusters, number of pods and number of seeds per pod was 30 per cent superior. Singh et al. (1977) while studying 53 lines of mung bean, reported that an index based on number of primary branches per plant, number of clusters per plant, number of pods per plant and number of seeds per pod would be most efficient for yield improvement. Malik et al. (1982) while studying seven traits on 50 genotypes of green gram observed that simultaneous selection for pods per plant, seeds per pod and seed weight was superior to selection for yield alone and also resulted in the greatest genetic advance. Misra (1985) while constructing selection indices in green gram observed that criterion for the choice of characters for inclusion in the indices was their direct effect on yield, assessed by path analysis. The most effective index comprised pods per plant, 1000 seed weight, seeds per pod, reproductive period, cluster per plant and yield per plant.

Singh and Singh (1972) based on results from discriminant function studies in 40 varieties of field pea, recorded that selection based on combination of certain characters would be more effective than that based on a single character.

Wu (1966) while studying discriminant function in eleven characters of nine varieties of soyabean, concluded that height of plant was the best and number of branches, the worst character for descrimination on between any two varieties. Malhotra (1973) while attempting discriminant function technique in soyabean suggested that a function based on pods per plant, primary branches and seeds per pod was best for the selection of high yielding lines.

Materials and Methods

MATERIALS AND METHODS

The studies reported herein, were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara, during the period 1983-86. The experimental farm attached to the College is located at an altitude of 22.5 m above M.S.L. and is situated between 10° 32" N latitude and 76° 10" E longitude Geographically it falls in the warm humid tropical climatic zone. The soil type of the experimental site is sandy loam.

A. Materials

One hundred and twelve genotypes of Red gram (*Cajanus cajan* L. Millsp) exhibiting wide diversity in the expression of various economic characters constituted the material for this study. Of these 112 genotypes, 86 were obtained from the germplasm collection maintained at the Regional Centre of the National Bureau of Plant Genetic Resources, Vellanikkara and 26 - from Tamil Nadu Agricultural University, Coimbatore. Particulars of the genotypes included in the study are furnished in Table 1.

Table 1. Particulars of the one hundred and twelve genotypes of red gram used in the study

Accession Number	N.B.P.G.R. accession number	Varietal name if any	Source
1	2	3	4
V_1	NBPGR No.115	PLA-600	Delhi collection
V_2	-	H-72-44	T.N.A.U.Coimbatore
V_3	NBPGR No.114	PLA-550	Delhi collection
V_4	" 78	Kerala local	Local collection from Kerala
V_5	" 53	"	"
V_6	" 63	"	"
V_7	" 13	IC 16211	Delhi collection
V_8	" 109	PLA 459	"
V_9	" 77	Kerala local	Local collection from Kerala
V_{10}	--	S.14	T.N.A.U.Coimbatore
V_{11}	--	E.E.76	"
V_{12}	NBPGR-55	Kerala local	Local collection from Kerala
V_{13}	NBPGR-2	ICRISAT-7414	ICRISAT
V_{14}	" 20	IC 16204	Delhi collection
V_{15}	" 49	Kerala local	Local collection from Kerala
V_{16}	-	DL-78-1	T.N.A.U.Coimbatore
V_{17}	NBPGR-12	Kerala local	Collected from Kerala
V_{18}	NBPGR-19	IE-16211	Delhi collection

(Contd.)

Table 1 (contd.)

1	2	3	4
V_{19}	-	UPAS-120	T.N.A.U.Coimbatore
V_{20}	NBPGR-10	ICRISAT-8395	ICRISAT
V_{21}	NBPGR-101	PLA 215	Delhi collection
V_{22}	-	ICPL-1	T.N.A.U.Coimbatore
V_{23}	-	DPI-711	"
V_{24}	NBPGR-81	ICRISAT-3795	ICRISAT
V_{25}	NBPGR-74	Kerala local	Collected from Kerala
V_{26}	-	ICPL-85	T.N.A.U.Coimbatore
V_{27}	NBPGR-35	Kerala local	Collected from Kerala
V_{28}	NBPGR-5	ICRISAT-8345	ICRISAT
V_{29}	NBPGR-86	Karnataka local	Collected from Karnataka
V_{30}	" 59	Kerala local	Collected from Kerala
V_{31}	-	H-76-19	T.N.A.U.Coimbatore
V_{32}	NBPGR-60	Kerala local	Collected from Kerala
V_{33}	-	CORG-1	T.N.A.U.Coimbatore
V_{34}	NBPGR-28	Kerala local	Collected from Kerala
V_{35}	" 128	ICRISAT-8386	ICRISAT
V_{36}	-	TAT-10	T.N.A.U.Coimbatore
V_{37}	NBPGR-57	Kerala local	Collected from Kerala
V_{38}	-	H-77-216	T.N.A.U.Coimbatore
V_{39}	NBPGR-106	PLA-37	Delhi collection
V_{40}	NBPGR-69	Kerala local	Collected from Kerala

(Contd.)

Table 1 (Contd.)

1	2	3	4
V_{41}	-	Prabhat	T.N.A.U.Coimbatore
V_{42}	NBPGR-15	IC-15709	Delhi collection
V_{43}	NBPGR-102	PLA-309	Delhi collection
V_{44}	" 83	Karnataka Local	Collection from Kernataka
V_{45}	" 61	Kerala local	Collected from Kerala
V_{46}	" 43	"	"
V_{47}	" 119	PLA 639	Delhi collection
V_{48}	" 16	IC-15720	"
V_{49}	" 48	Kerala local	Collected from Kerala
V_{50}	" 23	IC-33521	Delhi collection
V_{51}	" 52	Kerala local	Collected from Kerala
V_{52}	" 110	PLA-465	Delhi collection
V_{53}	" 129	Gurupura	"
V_{54}	" 42	Kerala local	Collected from Kerala
V_{55}	" 124	PLA-345-1	Delhi collection
V_{56}	" 27	Kerala local	Collected from Kerala
V_{57}	" 94	Karnataka local	Collected from Karnataka
V_{58}	-	H-76-18	T.N.A.U.Coimbatore
V_{59}	NBPGR-40	Kerala local	Collected from Kerala
V_{60}	" 1	ICRISAT-7385	ICRISAT

(Contd.)

Table 1. (Contd.)

1	2	3	4
V_{61}	NBPGR-54	Kerala local	Kerala state
V_{62}	" 87	Karnataka local	Karnataka state
V_{63}	" 24	ICRISAT-3795	ICRISAT
V_{64}	" 76	Kerala local	Kerala state
V_{65}	" 39	Kerala local	Kerala state
V_{66}	" 123	Kerala local	Kerala state
V_{67}	" 18	IC-16193	Delhi collection
V_{68}	" 8	ICRISAT-8362	ICRISAT
V_{69}	" 107	PLA-379	Delhi collection
V_{70}	-	H-76-46	T.N.A.U., Coimbatore
V_{71}	-	H-76-48	"
V_{72}	NBPGR-93	Karnataka local	Karnataka state
V_{73}	" 58	Kerala local	Kerala state
V_{74}	" 84	Karnataka local	Karnataka state
V_{75}	-	H-76-20	T.N.A.U., Coimbatore
V_{76}	" 21	IC-16211	Delhi collection
V_{77}	" 7	ICRISAT-Var	ICRISAT
V_{78}	" 99	PLA-191-1	Delhi collection
V_{79}	-	CORG-5	T.N.A.U., Coimbatore
V_{80}	NBPGR-117	PLA-6091	Delhi collection
V_{81}	" 6	ICRISAT-8349	ICRISAT

(Contd.)

Table 1.(Contd.)

1	2	3	4
V_{82}	NBPGR-46	Kerala local	Collected from Kerala
V_{83}	-	H-77-169	T.N.A.U., Coimbatore
V_{84}	NBPGR-84	Karnataka local	Karnataka State
V_{85}	" 75	Kerala local	Kerala State
V_{86}	" 103	PLA-345	Delhi collection
V_{87}	" 116	PLA-606	"
V_{88}	" 25	Kerala local	Kerala State
V_{89}	" 51	Kerala local	Kerala State
V_{90}	" 79	"	"
V_{91}	" 30	"	"
V_{92}	-	H-77-208	T.N.A.U., Coimbatore
V_{93}	-	CORG-2	"
V_{94}	NBPGR-105	PLA-349	Delhi collection
V_{95}	-	H-76-32	T.N.A.U., Coimbatore
V_{96}	NBPGR-14	IC-15708	Delhi collection
V_{97}	-	VL-23	T.N.A.U., Coimbatore
V_{98}	NBPGR-113	PLA-529	Delhi collection
V_{99}	" 108	PLA-439	"
V_{100}	-	H-77-215	T.N.A.U., Coimbatore
V_{101}	NBPGR-11	EC-10046-1	Delhi collection
V_{102}	" 37	Kerala local	Kerala State

(Contd.)

Table 1. (Contd.)

1	2	3	4
V_{103}	NBPGR-37	Karnataka local	Karnataka State
V_{104}	" 29	Kerala local	Kerala State
V_{105}	" 98	PLA-194	Delhi collection
V_{106}	" 112	PLA-591	"
V_{107}	" 121	PLA-654	"
V_{108}	" 104	PLA-3451	"
V_{109}	" 34	Kerala local	Kerala State
V_{110}	" 56	Kerala local	Kerala State
V_{111}	-	H-76-51	T.N.A.U., Coimbatore
V_{112}	"	Co-2	"

B. Methods

Experiment Number 1

With a view to finding out the genetic diversity in Red gram, a field experiment was laid out in June 1983 incorporating the 112 genotypes mentioned above. The experiment was laid out in 112 x 2 R.B.D., each of the genotypes constituting one treatment. The spacing adopted was 1 m between rows and 50 cm between plants in a row with 12 plants per genotype. Seeds were dibbled on raised beds in a row on 24.6.1983 at the rate of 2 seeds per hole and subsequently it was thinned to one seedling per hole. The crop received timely management care as per the recommendation given in the Package of Practices of K.A.U.1981.

All the observations were confined to 10 plants per genotype leaving one plant on both the sides for eliminating the border effects. Thus observations on the following eleven economic characters were recorded from 112 x10 x 2 = 2240 plants.

1. Height of plant at harvest (x_1)

Height of plants at harvest was measured from the ground level to the tip of plant and expressed in cm.

2. Number of primary branches at harvest (x_2)

All the primary branches in each plant were counted and recorded at the time of harvest.

3. Number of secondary branches at harvest (x_3)

Total number of secondary branches of each plant at harvest was counted and recorded.

4. Number of clusters per plant (x_4)

All the productive clusters of pods in each plant were counted and recorded.

5. Number of pods per plant (x_5)

All the seed bearing pods in each plant were counted and recorded.

6. Length of pod bearing branches (x_6)

The length of individual productive branch (pod bearing branch) was measured in cm and the total length of all productive branches per plant was calculated. This was divided by the number of pod bearing branches in a plant and the mean value in cm arrived at.

7. Number of days from sowing to 50% flowering (x_7)

The day on which 50% of the plants in each row flowered was noted and the duration in days from the day of sowing to this day was worked out for each genotype.

8. Number of days from sowing to harvest (x_8)

The number of days taken by individual plants from sowing to harvest was noted, all the plants constituting in the sample in each plot being harvested on the same day.

9. Number of seeds per pod (x_9)

A random sample of 100 pods per plant was taken for estimation of this trait. In case of plants having less than 100 pods all the pods were taken. They were then shelled and the total number of seeds obtained was divided by the number of pods for arriving at the number of seeds per pod.

10. Hundred seed weight (x_{10})

Weight of hundred seeds chosen at random from individual plants in a treatment was found out and the same expressed in g.

11. Seed yield (y)

Seed yield obtained from each plant was estimated after normal drying and the same was expressed in g.

Statistical analysis

The data in respect of eleven metric traits were collected from all the 112 genotypes (treatments) at the rate of 10 individual observations from the 10 plants in a genotype. The genotype/treatment mean was then arrived at and these means were utilized for further analysis.

The genetic distance among 112 red gram genotypes was calculated considering all the 11 quantitative characters. The method suggested by Mahalanobis (1928) was used to estimate D^2 with $X_1, X_2, X_3 \ldots\ldots X_{11}$ as the multiple measurements available on each genotype and $d_1, d_2, d_3 \ldots\ldots d_{11}$ as $x_1^{-1} - x_1^{-2}$, $x_2^{-1} - x_2^{-2}$, $x_3^{-1} - x_3^{-2} \ldots\ldots x_{11}^{-1} - x_{11}^{-2}$ being the differences in the means of two genotypes where power denoted genotypes and suffix denoted characters.

The D^2 value obtained for a pair of populations was taken as the calculated value of X^2 and was tested against the tabulated value of X^2 for 'P' degrees of freedom, where P is the number of characters considered.

Grouping of varieties to clusters was done by Tochers' method (Rao, 1952).

Experiment 2

All the 112 genotypes of the 1st experiment were found to fall into five clusters based on the D^2 values estimated. Based on the intracluster distances, 20 genotypes representing the broad spectrum of variability present in the crop were selected and utilized in the second experiment. The particulars of genotypes selected and utilized in this experiment are given in Table 2.

In order to keep the viability of seeds, the above 20 genotypes were grown in nonreplicated study plots of 1 m x 10 m during 1984.

This experiment was laid out in a 20 x 4 Randomized Block Design, adopting a spacing of 1 m x 0.5 m and a plot size of 5 m x 3.5 m. Seeds were dibbled in raised beds on 19.7.1985 in rows spaced 1 m apart at a distance of 50 cm between plants in a row. Each plot contained five rows of six plants in each row. The crop received all timely management care and practices as per the recommendations given in the Package of Practices of K.A.U. 1981.

Observations on eleven economic attributes listed earlier were recorded from the middle twelve plants of each plot leaving one row all around for avoiding border effect.

Table 2. Particulars of genotypes selected for the second experiment

Tr. No.	Acc. No.	Cluster No.	Name of the variety	Characters for which selected
T_1	V_{55}	III	NBPGR 124-PLA-345-1-Delhi collection	Higher number of seeds per pod; longer duration.
T_2	V_{49}	III	NBPGR 48 - Kerala local	Increased primary and secondary branches; longer pod bearing branch.
T_3	V_{70}	II	H-76-46 (Tamil Nadu Agrl. University)	Tall plant habit; higher number of seeds per pod; longer duration.
T_4	V_{79}	II	CORG-5 (")	Higher number of clusters per plant; higher number of pods per plant; low 100 seed weight.
T_5	V_{25}	III	NBPGR 74 - Kerala local	Medium plant height; medium 100 seed weight; higher number of seeds per pod.
T_6	V_{64}	III	NBPGR 76 - Kerala local	Long flowering duration; medium yield per plant.
T_7	V_{12}	I	NBPGR 55 - Kerala local	Tall plant habit; medium number of primary branches and secondary branches; medium 100 seed weight; short duration.
T_8	V_{66}	I	NBPGR 123 - Kerala local	Tall plant habit; high yield; long flowering duration

(Contd.)

Table 2. (Contd.)

Tr. No.	Acc. No.	Cluster No.	Name of the variety	Characters for which selected
T_9	V_{101}	I	NBPGR 11-EC-10046-1 Delhi collection	Medium primary and secondary branches; higher number of pods.
T_{10}	V_{111}	II	H-76-51- Tamil Nadu Agrl.University	Medium primary and secondary branches; long pod bearing branches; higher number of seeds per pod; short duration.
T_{11}	V_{73}	I	NBPGR 58 - Kerala local	Medium height; lower number of primary branches; medium 100 seed weight; short duration.
T_{12}	V_{110}	I	NBPGR - 56 Kérala local	Short pod bearing branch; higher number of seeds per pod; short flowering duration.
T_{13}	V_1	V	NBPGR 115-PLA-600 Delhi collection	Tall plant height; medium number of primary and secondary branches; long pod bearing branch; long flowering duration.
T_{14}	V_{95}	II	H-76-32 Tamil Nadu Agrl. University	Medium number of clusters per plant; short duration.
T_{15}	V_{93}	II	CORG-2 "	Medium 100 seed weight; medium yield; short flowering duration.

(Contd.)

Table 2 (Contd.)

Tr. No.	Acc. No.	Cluster No.	Name of the variety	Characters for which selected
T_{16}	V_{83}	II	H-77-169 Tamil Nadu Agrl. University	Higher 100 seed weight
T_{17}	V_{58}	II	H-76-18 "	Short duration
T_{18}	V_{71}	II	H-76-48 "	Long flowering duration, medium 100 seed weight.
T_{19}	V_{3}	IV	NBPGR, 114-PLA-550 Delhi collection	Low number of primary branches
T_{20}	V_{45}	I	NBPGR-61 Kerala local	Dwarf plant habit; low number of secondary branches, clusters per plant, and pods per plant; short pod bearing branch; few seeds per pod; low yield; short flowering duration.

Thus total number of plants from which observations were recorded worked out to 12 x 20 x 4 = 960.

Statistical analyses

The data collected in respect of eleven metric traits were tabulated and subjected to the following statistical analyses.

1. Analysis of variance

Analysis of variance was worked out for all the eleven characters, to find out whether there were significant differences between the genotypes in respect of the characters.

For the analysis of variance, the procedures described by Panse and Sukhatme (1957) were used.

2. Estimation of variability, heritability, genetic advance and genetic gain

a) Variability

Variability existing in the various characters under observation was estimated as per the procedure suggested by Burton (1952). The formulae used in the estimation of genotypic and phenotypic variances are as follows.

$$\text{Genotypic variance (GV)} = \frac{\text{TM-EM}}{\text{Number of replications}}$$

where TM is the treatment mean square and EM is the error mean square from the analysis of variance.

Genotypic standard deviation $= \sigma g = \sqrt{GV}$

Genotypic coefficient of variation (GCV) $= \dfrac{\sigma g \times 100}{\text{Mean}}$

Phenotypic variance (PV) $=$ GV + EM

Phenotypic standard deviation $\sigma P = \sqrt{PV}$

Phenotypic coefficient of variation PCV $= \dfrac{\sigma P \times 100}{\text{Mean}}$

b) Heritability

The heritability in broad sense was estimated as suggested by Burton and Dewane (1953) as shown below.

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

c) Genetic advance (GA)

The expected genetic advance of the available germplasm at 5 per cent intensity of selection was calculated as per the method suggested by Lush (1949) using the intensity of selection 'i' as 2.06 as given by Allard (1960).

$$GA = i \times h^2 \times \sigma p$$

d) Genetic gain

The method described by Johnson *et al.* (1955) was used.

$$\text{Genetic gain} = \frac{GA \times 100}{\overline{X}}$$

where $\overline{X}$ = Mean of the character under study

3. Estimation of correlations

The genotypic and phenotypic correlations were estimated, using the formulae suggested by Searb (1961) as given below:

$$r_{xy} = \frac{\text{Cov } x\, y\, (g)}{\sqrt{GV\,(x).\ GV\,(y)}}$$

where

$$\text{Cov } x\, y^{(g)} = \frac{TSP - ESP}{\text{Number of replications}}$$

TSP is the mean treatment sum of products and ESP is the mean error sum of products between characters x and y on the analysis of variance and GV (x) and GV (y) are the genotypic variances for characters x and y. Phenotypic correlation between characters x and y was estimated by

$$r_{xy} = \frac{\text{Cov } x\, y^{(P)}}{\sqrt{PV\,(x) \times PV\,(y)}}$$

$\text{Cov } x\ y^{(P)} = \text{Cov } x\ y^{(g)} + \text{ESP}$ and

PV (x) and PV (y) are phenotypic variances for characters x and y.

4. Path coefficient analysis

In the path coefficient analysis, the genotypic correlations among causes and effects are partitioned into direct and indirect effects of causal factors on the effect factor. All the ten yield contributing characters along with yield were considered for the path coefficient analysis.

The estimates of direct and indirect effects in such a closed system of variables were calculated by the path coefficient analysis as suggested by Dewey and Lu (1959). The following set of simultaneous equations were formed and solved for estimating the various direct and indirect effects.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + r_{14}P_{4y} + \ldots\ldots\ r_{1k}P_{ky}$$

$$r_{2y} = P_{2y} + r_{21}P_{1y} + r_{23}P_{3y} + r_{24}P_{4y} + \ldots\ldots\ r_{2k}P_{ky}$$

$$r_{3y} = P_{3y} + r_{31}P_{1y} + r_{32}P_{2y} + r_{34}P_{4y} + \ldots\ldots\ r_{3k}P_{ky}$$

$$r_{4y} = P_{4y} + r_{41}P_{1y} + r_{42}P_{2y} + r_{43}P_{3y} + \ldots\ldots r_{4k}P_{ky}$$

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$$r_{ky} = P_{ky} + r_{k1}P_{1y} + r_{k2}P_{2y} + r_{k3}P_{3y} + \ldots r_{k(k-1)} P_{(K-1)y}$$

where r_{1y} to r_{ky} denote genotypic correlation between independent characters 1 to k and dependent character y, r_{12} to $r_{k(k-1)}$ denote genotypic coefficient of correlation between all possible combinations of independent characters and P_{1y} to P_{ky} denote direct effects of characters 1 to k on character y.

The above equations can be written as presented below.

$$A = BC$$

where $A = (r_{1y}, r_{2y} \ldots\ldots r_{ky})$

$B = (r_{ij})_{kxk}$

and $C = (P_{1y}, P_{2y} \ldots\ldots\ldots P_{ky})$

Residual factor 'R' which measures the contribution of the characters which are not considered in the causal scheme was obtained as follows.

$$\text{Residual factor } h = (1-R^2)^{\frac{1}{2}}$$

where $$R^2 = \sum_{i=1}^{k} r_{iy} P_{iy}$$

5. Estimation of selection indices

A series of selection indices were obtained by discriminant function analysis using different combination of component characters.

The method suggested by Robinson et al. (1951) was used for constructing selection indices and computing genetic advance. The following set of simultaneous equations were solved to obtain weights in the selection index based on yield and the independent component characters.

$$a_1 + b_1 \; t_{11} + b_2 \; t_{12} + b_3 \; t_{13} + \ldots\ldots + b_k t_{1k} + by \; t_{1y} = g_{1y}$$
$$a_2 + b_1 \; t_{21} + b_2 t_{22} + b_3 \; t_{23} + \ldots\ldots\ldots + b_k t_{2k} + b_y t_{2y} = g_{2y}$$
$$a_3 + b_1 \; t_{31} + b_2 t_{32} + b_3 \; t_{33} + \ldots\ldots\ldots + b_k t_{3k} + b_y t_{3y} + g_{3y}$$

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$$ak + b_1 \; t_{k1} + b_2 \; t_{k2} + b_3 \; t_{k3} + \ldots\ldots + b_k t_{kk} + b_y \; t_{ky} + g_{ky}$$
$$a_y + b_1 \; t_{y1} + b_2 \; t_{y2} + b_2 \; t_{y2} + \ldots\ldots + b_k t_{yk} + b_y t_{yy} = g_{yy}$$

where t_{kk} and t_{km} represent phenotypic variance and covariance respectively and bk is the unknown weight. g_{ky} and g_{yy} are genotypic covariances and variances respectively. Genetic advance by discriminant function

$$GA(D) = i \left(\sum b_k \, g_{ky} \right)^{\frac{1}{2}}$$ where 'i'

stands for intersity of selection when top 5 per cent of the population is selected (2.06). Genetic advance by straight selection for yield is given by

$$GA(S) = i \frac{g_{yy}}{(t_{yy})^{\frac{1}{2}}}$$

The relative efficiency of selection through discriminant function over straight selection was calculated as suggested by Paroda and Joshi (1970).

$$\left.\begin{array}{l}\text{Relative efficiency over} \\ \text{straight selection}\end{array}\right\} = \frac{GA(D) - GA(S) \times 100}{GA(S)}$$

The scope for improvement of the index by inclusion of additional measurement was calculated as described by Falconer (1982).

$$\left.\begin{array}{l}\text{The room for improvement of the}\\ \text{index by inclusion of additional}\\ \text{measurement}\end{array}\right\} = 1 - r^2_{1A}$$

where $r^2_{IA} = \dfrac{\sigma_I^2}{\sigma_A^2}$

σ_I^2 = Variance of index value

σ_A^2 = Genotypic variance

Results

RESULTS

Experiment 1:

Observations recorded from 10 plants in each of the 112 genotypes of red gram on eleven economically important characters are statistically analysed and presented in the following pages.

Variability in red gram genotypes

Results of observations pertaining to ghe range in means of genotypes and the overall means for the eleven characters included in the study are presented in Table 3. Table 4 gives the abstract of analysis of variance for different characters and Table 5, the phenotypic genotypic and environmental variances and heritability for the different characters.

The results reveal the presence of high amount of variability in the material studied. There exists a wide gap between the maximum and minimum values with respect to each of the eleven traits studied.

A further scrutiny of the result revealed the following.

Table 3. Extremes in means of genotypes and the overall means for the different characters

Sl. No.	Characters	Extremes and the genotypes showing the maximum and minimum value				Mean
		Maximum value	Genotype	Minimum value	Genotype	
1	Height of plant at harvest (cm)	354.00	V_{51}	129.00	V_{11}	290.08
2	Number of primary branches at harvest	20.80	V_{10}	5.70	V_{62}	12.77
3	Number of secondary branches at harvest	286.40	V_{84}	18.70	V_{33}	48.43
4	Number of clusters per plant	322.40	V_{25}	9.85	V_{33}	121.19
5	Number of pods per plant	1481.55	V_{25}	34.80	V_{33}	530.10
6	Length of pod bearing branches (cm)	218.50	V_{17}	73.00	V_{11}	167.15
7	Number of days from sowing to 50% flowering	105.00	V_{84}	71.00	V_{38}	95.24
8	Number of days from sowing to harvest	186.00	V_{33}	178.00	V_{58}	181.43
9	Number of seeds per pod	4.90	V_{109}	3.20	V_{16}	3.98
10	100 seed weight (g)	10.25	V_{53}	5.55	V_{102}	7.03
11	Seed yield (g)	297.40	V_{58}	6.80	V_{11}	70.32

Table 4. Abstract of analysis of variances for different characters

Sl. No.	Characters	Mean square values: Cultivars df = 111	Mean square values: Error df = 111	F value for cultivars
1	Height of plant at harvest (cm)	5159.870	564.990	9.13**
2	Number of primary branches at harvest	12.330	6.300	1.96**
3	Number of secondary branches at harvest	673.250	558.390	1.21
4	Number of clusters per plant	5643.010	1385.190	4.07**
5	Number of pods per plant	112881.480	34210.380	3.30**
6	Length of pod bearing branches (cm)	1982.860	767.260	2.58**
7	Number of days from sowing to 50% flowering	349.720	44.810	7.80**
8	Number of days from sowing to harvest	330.470	333.330	0.99
9	Number of seeds per pod	0.097	0.096	1.01
10	100 Seed weight (g)	2.220	0.773	2.89**
11	Seed yield (g)	1933.090	567.430	3.40**

* Significant at 5% level
** Significant at 1% level

Table 5. Phenotypic, genotypic and environmental variances (PV, GV and EV) and heritability (H^2) for the different characters

Sl. No.	Characters	PV	GV	EV	H^2
1	Height of plant at harvest (cm)	2862.430	2297.440	564.99	0.803
2	Number of primary branches at harvest	9.312	3.017	6.30	0.324
3	Number of secondary branches at harvest	615.820	57.430	558.39	0.093
4	Number of clusters per plant	3514.100	2128.910	1385.19	0.606
5	Number of pods per plant	73545.930	39335.550	34210.38	0.535
6	Length of pod bearing branches (cm)	1375.060	607.800	767.26	0.442
7	Number of days from sowing to 50% flowering	197.270	152.450	44.82	0.773
8	Number of days from sowing to harvest	331.899	-1.430	333.32	0.004
9	Number of seeds per pod	0.097	0.001	0.096	0.010
10	100 Seed weight (g)	1.500	0.727	0.773	0.486
11	Seed yield (g)	1250.260	682.830	567.43	0.546

Height of plant at harvest (cm)

The mean values for height of plant at harvest (cm) of red gram genotypes under study varied from 129.0 to 354.00. V_{51} recorded the maximum height (354.00 cm) whereas V_{11} showed the minimum height (129.00 cm) (Table 3). The differences among the genotypes were highly significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 2862.43 which could be apportioned into genotypic variance (GV) and environmental variance (EV) as 2297.44 and 564.99 respectively, indicating a low amount of environmental effect on this character. A comparatively high amount of heritability for this character (H^2 = 0.803) also indicated the predominant genotypic influence for height of plant at harvest (Table 5).

Number of primary branches at harvest

With a general mean of 12.77, the mean values for number of primary branches at harvest of red gram genotypes showed a range of variability from 5.70 to 20.80. V_{10} recorded the maximum number of primary branches (20.80) whereas V_{62} showed the minimum number of 5.70 (Table 3).

The differences among the genotypes were highly significant (Table 4).

The estimated phenotypic variance (PV) for this character was 9.312 which could be apportioned into genotypic variance (GV) and environmental variance (EV) as 3.017 and 6.30 respectively, indicating a high amount of environmental effect on this character. A comparatively moderate amount of heritability for this character (H^2 = 0.324) also indicated the predominant environmental influence for number of primary branches at harvest (Table 5).

Number of secondary branches at harvest

A range of variability from 18.70 to 286.40 was observed in the mean values for number of secondary branches at harvest. V_{84} recorded the maximum number of secondary branches (286.40) and V_{33} showed the minimum number (18.70) with a general mean of 48.43 (Table 3). The differences among the genotypes were not significant (Table 4).

The estimated phenotypic variance (PV) was 615.82 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as 57.43 and 558.39 respectively, indicating a high amount of environmental effect. A comparatively low amount of heritability for this character (H^2 = 0.093) also indicated the predominance of environmental effect for number of secondary branches at harvest (Table 5).

Number of clusters per plant

In the mean value for number of clusters per plant of red gram genotypes under study, a range from 9.85 to 322.40 with a general mean of 121.19 was noticed. V_{25} recorded the maximum number of clusters (322.40) whereas V_{33} showed the minimum number of 9.85 (Table 3). The differences among the genotypes were highly significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 3514.10 which could be apportioned into genotypic variance (GV) and environmental variance (EV) as 2128.91 and 1385.19 respectively, indicating a comparatively low amount of environmental effect on this character. A high amount of heritability (H^2 = 0.606) also indicated the predominant genotypic influence for number of clusters per plant (Table 5).

Number of pods per plant

The mean values for number of pods per plant of red gram genotypes under study varied from 34.80 to 1481.55

with a general mean of 530.10. V_{25} recorded the maximum number of pods per plant (1481.25) whereas V_{33} showed the minimum number of 34.80 (Table 3). The differences among the genotypes were highly significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 73,545.93 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as 39,335.55 and 34,210.38 respectively indicating comparatively a low amount of environmental effect on this character. A comparatively high amount of heritability ($H^2 = 0.535$) also indicated the predominant genotypic influence for number of pods per plant (Table 5).

Length of pod bearing branches (cm)

The mean values for length of pod bearing branches of red gram genotypes under study varied from 73.00 to 218.50 with a general mean of 167.15. V_{17} recorded the maximum length of 218.50 cm and V_{11} showed the minimum length (73.00 cm) (Table 3). The differences among the genotypes were highly significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 1375.06 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as 607.80 and 767.26 respectively indicating genotypic and environmental on this character more or less equal. This is also indicated by a heritability value (H^2 = 0.442) (Table 5).

Number of days from sowing to 50 per cent flowering

The mean values for number of days from sowing to 50 per cent flowering of red gram genotypes under study varied from 71.00 to 105.00 recorded by V_{38} and V_{84} respectively with a general mean of 95.24 (Table 3). The differences among the genotypes were significant for this character.

The estimated phenotypic variance (PV) for this character was 197.27 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as 152.45 and 44.82 respectively indicating a high genotypic influence on this character. A comparatively high amount of heritability (H^2 = 0.773) also indicated the predominant genotypic influence for the number of days from sowing to 50 per cent flowering (Table 5).

Number of days from sowing to harvest

The mean values for number of days from sowing to harvest of red gram genotypes under study varied from 178.00

to 186.00 recorded by V_{33} and V_{58} respectively (Table 3) with a general mean of 181.43. The differences among the genotypes were not significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 331.899 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as -1.430 and 333.32 respectively indicating a very high amount of environmental effect on this character. A very low amount of heritability (H^2 = 0.004) also indicated the predominant environmental influence for number of days from sowing to harvest (Table 5).

Number of seeds per pod

The mean values for number of seeds per pod ranged from 3.20 to 4.50 with a general mean of 3.98. V_{109} recorded the maximum number of seeds per pod of 4.90 and V_{16} recorded the minimum of 3.20 (Table 3). The differences among the genotypes were not significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 0.097 which could be apportioned into genotypic variance (GV) and environmental variance (EV) as 0.001 and 0.096 respectively indicating a low genotypic effect on this character. This is also indicated by a low amount of heritability (H^2 = 0.010) (Table 5).

100 Seed weight (g)

The mean values for hundred seed weight of red gram genotypes under study varied from 5.55 to 10.25 with a general mean of 7.03. V_{53} recorded the maximum weight (10.25 g) whereas V_{102} showed the minimum weight (5.55 g) (Table 3). The differences among the genotypes were highly significant (Table 4).

The estimated phenotypic variance (PV) was 1.50 which could be paritioned into genotypic variance (GV) as 0.727 and environmental variance (EV) as 0.773 indicating the genotypic and environmental effects more or less equal. This is also indicated by a heritability value (H^2 = 0.486) (Table 5).

Seed yield (g)

The mean values for seed yield of red gram genotypes under study varied from 6.80 to 297.40 with a general mean of 70.32. V_{58} recorded the maximum weight

(297.4 g) whereas V_{11} showed the minimum weight (6 80 g) (Table 3). The differences among the genotypes were highly significant for this character (Table 4).

The estimated phenotypic variance (PV) for this character was 1250.26 which could be partitioned into genotypic variance (GV) and environmental variance (EV) as 682.83 and 567.43 respectively indicating a slightly high amount of genotypic effect on this character. A comparatively high amount of heritability (H^2 = 0.546) also indicated the predominant genotypic influence on seed yield.

Genetic divergence among the genotypes

The one hundred and twelve red gram genotypes included in the study were found to fall into five clusters, each one having different number of genotypes (Table 6).

The results presented revealed that 80 genotypes constituted Cluster I, 26 genotypes Cluster II, 4 genotypes - Cluster III, one genotype - Cluster IV and one genotype - Cluster V.

Results of observations pertaining to the extremes in means of genotypes and overall mean for

Table 6. Details of red gram genotypes constituting different clusters

Cluster number	Total numbers	Genotypes included									
I	80	V_{4},	V_{5},	V_{6},	V_{7},	V_{8},	V_{9},	V_{12},	V_{13},	V_{14},	V_{15},
		V_{17},	V_{18},	V_{20},	V_{21},	V_{24},	V_{27},	V_{28},	V_{29},	V_{30},	V_{32},
		V_{34},	V_{35},	V_{37},	V_{39},	V_{40},	V_{42},	V_{43},	V_{44},	V_{45},	V_{46},
		V_{47},	V_{48},	V_{50},	V_{51},	V_{52},	V_{53},	V_{54},	V_{56},	V_{57},	V_{59},
		V_{60},	V_{61},	V_{62},	V_{63},	V_{65},	V_{66},	V_{67},	V_{68},	V_{69},	V_{72},
		V_{73},	V_{74},	V_{76},	V_{77},	V_{78},	V_{80},	V_{81},	V_{82},	V_{85},	V_{86},
		V_{87},	V_{88},	V_{89},	V_{90},	V_{91},	V_{94},	V_{96},	V_{98},	V_{99},	V_{101},
		V_{102},	V_{103},	V_{104},	V_{105},	V_{106},	V_{107},	V_{108},	V_{109},	V_{110},	V_{84}.
II	26	V_{36},	V_{93},	V_{70},	V_{100},	V_{38},	V_{83},	V_{79},	V_{111},	V_{75},	V_{95},
		V_{41},	V_{71},	V_{2},	V_{10},	V_{11}, 9	V_{16},	V_{22},	V_{23},	V_{26},	V_{97},
		V_{19},	V_{112},	V_{31},	V_{33},	V_{92},	V_{58}.				
III	4	V_{64},	V_{49},	V_{25},	V_{55}.						
IV	1	V_{3}									
V	1	V_{1}									

different characters in Cluster I, II, III, IV and V are presented in Tables 7 to 10.

The results revealed the following.

Height of plant at harvest (cm)

In Cluster I, the maximum mean value of 354.00 cm for this character was expressed by the genotype V_{51} and the minimum of 278.50 cm by the genotype V_{82} with a cluster mean of 314.33 cm (Table 7).

The corresponding values for cluster II were seen to be 258.00 cm (V_{92}), 129.00 cm (V_{11}) and 206.70 cm (Table 8) and those for cluster III were 343.50 cm (V_{55}), 318.00 cm (V_{25}) and 330.75 cm (Table 9).

Since the clusters IV and V were represented by one genotype only, their means were 325.25 cm and 319.90 cm respectively (Table 10).

Among the five clusters, the highest cluster mean of 330.75 cm was recorded by cluster III and the lowest of 206.70 cm by Cluster II.

Table 7. Extremes in means of genotypes - in cluster I and overall mean for different characters

Sl. No.	Characters	Extremes and the genotypes showing the maximum and minimum value				Mean
		Maximum value	Genotype	Minimum value	Genotype	
1	Height of plant at harvest (cm)	354.00	V_{51}	278.50	V_{82}	314.33
2	Number of primary branches at harvest	15.90	V_{96}	5.70	V_{62}	12.93
3	Number of secondary branches at harvest	286.40	V_{84}	24.20	V_{61}	51.88
4	Number of clusters per plant	230.50	V_{46}	71.10	V_{14}	133.85
5	Number of pods per plant	980.60	V_{46}	315.85	V_{52}	595.46
6	Length of pod bearing branches (cm)	218.50	V_{17}	133.00	V_{57}	178.95
7	Number of days from sowing to 50% flowering	105.00	V_{84}	100.00	V_{50} & V_{104}	102.09
8	Number of days from sowing to harvest	183.00	V_{17}, V_{42}, V_{82}, V_{89}, V_{94}, V_{107}	180.00	V_5, V_9, V_{12}, V_{13}, V_{14}, V_{21}, V_{39} etc.	181.25
9	Number of seeds per pod	4.90	V_{109}	3.40	V_{29}	4.00
10	100 Seed weight (g)	10.25	V_{53}	5.55	V_{102}	6.96
11	Seed yield (g)	132.00	V_{54}	34.10	V_{98}	78.17

Table 8. Extremes in means of genotypes in Cluster II and overall mean for different characters

Sl. No.	Characters	Extremes and the genotypes showing the maximum and minimum value				Mean
		Maximum value	Geno-type	Minimum value	Geno-type	
1	Height of plant at harvest (cm)	258.00	V_{92}	129.00	V_{11}	206.70
2	Number of primary branches at harvest	20.80	V_{10}	6.80	V_{33}	12.32
3	Number of secondary branches at harvest	79.30	V_{100}	18.70	V_{33}	39.69
4	Number of clusters per plant	121.50	V_{92}	9.85	V_{33}	60.17
5	Number of pods per plant	544.20	V_{92}	34.80	V_{33}	247.69
6	Length of pod bearing branches (cm)	194.20	V_{95}	73.00	V_{11}	126.88
7	Number of days from sowing to 50% flowering	73.50	V_{92}	71.00	V_{38}	72.46
8	Number of days from sowing to harvest	186.00	V_{33}	178.00	V_{58}	181.60
9	Number of seeds per pod	4.20	V_{11}	3.20	V_{16}	3.90
10	100 seed weight (g)	9.55	V_{23}	5.95	V_{112}	7.35
11	Seed yield (g)	297.40	V_{58}	6.80	V_{11}	41.78

Table 9. Extremes in means of genotypes in cluster III and the overal mean for different characters

Sl. No.	Characters	Extremes and the genotypes showing the maximum and minimum value				Mean
		Maximum value	Genotype	Minimum value	Genotype	
1	Height of plant at harvest (cm)	343.50	V_{55}	318.00	V_{25}	330.75
2	Number of primary branches at harvest	12.10	V_{49}	8.10	V_{55}	10.08
3	Number of secondary branches at harvest	52.70	V_{25}	22.35	V_{55}	27.22
4	Number of clusters per plant	322.40	V_{25}	215.80	V_{64}	251.99
5	Number of pods per plant	1481.55	V_{25}	1003.00	V_{55}	1133.25
6	Length of pod bearing branches (cm)	190.00	V_{49}	177.50	V_{55}	183.00
7	Number of days from sowing to 50% flowering	103.00	V_{55}, V_{49}	102.00	V_{25}, V_{64}	102.50
8	Number of days from sowing to harvest	182.00	V_{64}	181.00	V_{55}	181.50
9	Number of seeds per pod	4.00	V_{64}, V_{55}	3.80	V_{25}	3.95
10	100 Seed weight (g)	6.65	V_{55}	5.70	V_{25}	6.25
11	Seed yield (g)	126.85	V_{55}	91.30	V_{49}	107.32

Table 10. Means of different characters of clusters IV and V

Sl.No.	Characters	Means	
		Cluster IV	Cluster V
1	Height of plant at harvest (cm)	325.25	319.90
2	Number of primary branches at harvest	18.30	16.50
3	Number of secondary branches at harvest	93.30	39.95
4	Number of clusters per plant	210.95	82.00
5	Number of pods per plant	411.60	349.80
6	Length of pod bearing branches (cm)	208.00	165.50
7	Number of days from sowing to 50% flowering	103.00	103.00
8	Number of days from sowing to harvest	182.00	181.50
9	Number of seeds per pod	4.00	4.50
10	100 Seed weight (g)	6.45	5.25
11	Seed yield (g)	66.00	41.00

Number of primary branches at harvest

The mean values for number of primary branches at harvest in cluster I ranged from 5.70 (V_{62}) to 15.90 (V_{96}) with a cluster mean of 12.93 (Table 7).

In cluster II, the genotype V_{10} showed the maximum mean value of 20.80 and V_{33} recorded the minimum mean value of 6.80 with a cluster mean of 12.32 (Table 8) whereas in Cluster III, the genotypes and the values were V_{49} (12.10), V_{55} (8.10) and 10.08 respectively (Table 9).

Cluster IV and V which were represented by one genotype only, exhibited means 18.30 and 16.50 respectively (Table 10).

Maximum cluster mean value for this character was 18.30 shown by cluster IV and the minimum of 10.08 shown by cluster III.

Number of secondary branches at harvest

For this character a range from 24.20 to 286.40 expressed by genotypes V_{61} and V_{84} respectively were noticed in cluster I with a cluster mean of 51.88 (Table 7).

The corresponding values for cluster II were seen to be 18.70 (V_{33}), 79.30 (V_{100}) and 39.69 (Table 8) and those for Cluster III were 22.35 (V_{55}) and 52.70 (V_{25}) and 27.22 (Table 9).

The means of cluster IV and V were 93.30 and 39.95 respectively (Table 10).

Cluster IV showed the maximum mean of 93.30, whereas cluster III showed the minimum mean of 27.22.

Number of clusters per plant

In cluster I, the maximum mean value of 230.50 for this character was expressed by V_{46}, while the minimum value of 71.10 by V_{14} with a cluster mean of 133.85 (Table 7).

V_{92} recorded the maximum mean value (121.50) and V_{33} showed the minimum of 9.85 in cluster II, which had a cluster mean of 60.17 (Table 8). The corresponding values for Cluster III were 322.40 (V_{25}), 215.80 (V_{64}) and 251.99 (Table 9).

The means of cluster IV and V were 210.95 and 82.00 respectively (Table 10).

Among the five clusters, the highest cluster mean of 251.99 was recorded by Cluster III and the lowdst of 60.17 by Cluster II.

Number of pods per plant

The mean values for number of pods per plant in Cluster I ranged from 315.85 (V_{52}) to 980.60 (V_{46}) with a cluster mean of 595.46 (Table 7).

In cluster II, the genotype V_{92} showed the maximum mean value of 544.20 and V_{33} showed the minimum of 34.80 with a cluster mean of 247.69 (Table 8), whereas in cluster III the corresponding values were V_{25} (1481.55), V_{55} (1003.00) and 1133.25 (Table 9).

The means of Cluster IV and V were 411.60 and 349.80 respectively (Table 10).

It is seen from the above that the highest cluster mean of 1133.25 was shown by cluster III and lowest of 247.69 - by cluster II.

Length of pod bearing branches (cm)

A range from 133.00 cm (V_{57}) to 218.50 cm (V_{17}) with a cluster mean of 178.95 cm were noticed in cluster I for this character (Table 7).

Corresponding values for Cluster II and III were 73.00 cm (V_{11}), 194.20 cm (V_{95}), 126.88 cm (Table 8) and

177.50 cm (V_{55}), 190.00 (V_{49}) and 183.00 cm respectively (Table 9).

In Table 10 the cluster means of cluster IV and V were given as 208.00 cm and 165.50 cm respectively.

Among the five clusters the maximum cluster mean of 208.00 cm was shown by cluster IV and minimum of 126.88 cm - by cluster II.

Number of days from sowing to 50 per cent flowering

The maximum mean value for this character in Cluster I was expressed by V_{84} as 105.00 and the minimum by V_{50} and V_{104} as 100.00 with a cluster mean of 102.09 (Table 7).

The corresponding values for Cluster II were seen to be 73.50 (V_{92}), 71.00 (V_{38}) and 72.46 (Table 8) and those for cluster III were 103.00 (V_{55} and V_{49}), 102.00 (V_{25} and V_{64}) and 102.50 (Table 9).

The clusters IV and V exhibited the same mean value of 103.00 (Table 10).

The highest cluster mean of 103.00 was recorded by clusters IV end V and the lowest of 72.46 - by cluster II.

Number of days from sowing to harvest

The mean values for the character in cluster I ranged from 180.00 (V_5, V_9, V_{12}, V_{13}, V_{14}, V_{21} and V_{39}) to 183.00 (V_{17}, V_{42}, V_{82}, V_{89}, V_{94} and V_{107}) with a cluster mean of 181.25 (Table 7).

In Cluster II, the maximum value expressed by V_{33} was 186.00 and the minimum by V_{58} - 178.00 with a cluster mean of 181.60 (Table 8) whereas in Cluster III the corresponding values were V_{64} (182.00), V_{55} (181.00) and 181.50 (Table 9).

The means of clusters IV and V were 182.00 and 181.50 respectively (Table 10).

Among the five clusters, cluster IV showed the highest cluster mean value of 182.00 and Cluster I showed the lowest value of 181.25.

Number of seeds per pod

In Cluster I the highest mean value for this character was recorded by V_{109} (4.90) and lowest by V_{29} (3.40) with a cluster mean of 4.00 (Table 7) whereas in Cluster II the corresponding values were V_{11} (4.20), V_{16} (3.20) and 3.90 (Table 8).

Cluster III showed a range from 3.80 (V_{25}) to 4.00 (V_{64}, V_{55} and V_{49}) with a cluster mean of 3.95 (Table 9).

Cluster IV and V showed a cluster mean of 4.00 and 4.50 respectively (Table 10).

100 Seed weight (g)

The maximum mean value for this character in cluster I was expressed by the genotype V_{53} as 10.25 g and minimum by V_{102} as 5.55 g with a cluster mean of 6.96 g (Table 7).

In cluster II maximum mean value of 9.55 g was expressed by V_{23} and minimum of 5.95 g by V_{112} with a cluster mean of 7.35 g (Table 8). The corresponding values for cluster III were 6.65 g (V_{55}), 5.70 g (V_{25}) and 6.25 g (Table 9).

Cluster IV and V recorded the cluster mean of 6.45 g and 5.25 g respectively (Table 10).

Cluster II showed the highest cluster mean value (7.35 g) and cluster V - the lowest (5.25 g).

Seed yield

The maximum mean value for seed yield in Cluster I was expressed by the genotype V_{54} as 132.00 g and minimum by V_{98} as 34.10 g with a cluster mean of 78.17 g (Table 7).

In Cluster II maximum mean value of 297.40 g was expressed by V_{58} and minimum of 6.80 g by V_{11} with a cluster mean of 41.78 g (Table 8). The corresponding values for Cluster III were 126.85 g (V_{55}), 91.30 g (V_{49}) and 107.32 g (Table 9).

Cluster IV and V recorded the cluster mean of 66.00 g and 41.00 g respectively (Table 10).

Among the clusters, the maximum cluster mean value of 107.32 g was shown by cluster III and minimum of 41.00 g by cluster V.

The intra and inter cluster D^2 and D values of the five clusters worked out, have been presented in Tables 11 and 12 respectively.

From the result, it could be observed that the intra cluster D^2 values were lower than the corresponding inter cluster D^2 values.

The average intra cluster distances in the five clusters ranged from 0 (Cluster IV and V) to 6.47 (Cluster II), the other clusters possessing values in between the two extremes (Table 12).

Cluster V was found to show the maximum average inter cluster distance with any other cluster and it was found to be the cluster showing maximum distance in all

Table 11. Average intra and inter cluster D^2 values

Cluster No.	I	II	III	IV	V
I	22.93	3336.81	596.18	196.91	5846.72
II		41.75	3655.97	3644.62	3844.00
III			14.25	145.47	5954.58
IV				0	5972.64
V					0

Table 12. Average intra and inter cluster distances ($\sqrt{D^2}$ values)

Cluster No.	I	II	III	IV	V
I	4.79	57.77	24.42	14.04	76.42
II		6.47	60.47	60.37	62.00
III			3.78	12.07	77.17
IV				0	77.28
V					0

combinations it could make. Cluster IV showed the lowest average inter cluster distances (Table 12).

Experiment 2

Results of observations recorded from 12 plants per plot in each of the selected 20 genotypes of red gram included in the second field experiment on eleven economically important characters are presented in the following pages.

The abstract of analysis of variance for the different characters is presented in Table 13.

Observations pertaining to the extremes, mean, range as percentage of mean and standard error of mean for the different characters are presented in Table 14. Tables 15 to 25 give the ranking of genotypes for the eleven characters studied.

Table 26 gives the phenotypic, genotypic, and environmental variances and phenotypic and genotypic coefficient of variation for the different characters. Heritability, genetic advance, and genetic gain for the different characters are presented in Table 27.

Table 13. Abstract of analysis of variance for different characters

Sl. No.	Characters	Mean square values		F value
		Genotypes df = 19	Error df = 57	
1	Height of plant at harvest (cm)	2567.9473	742.0439	3.4606**
2	Number of primary branches at harvest	19.7782	12.4356	1.5904
3	Number of secondary branches at harvest	759.6028	488.8281	1.5539
4	Number of clusters per plant	8852.5000	2902.4080	3.0501**
5	Number of pods per plant	112015.6900	38708.8790	2.8938**
6	Length of pod bearing branches (cm)	512.9700	316.1184	1.6227
7	Number of days from sowing to 50% flowering	1732.8158	12.0406	143.9150**
8	Number of days from sowing to harvest	28.2500	0.8860	31.8861**
9	Number of seeds per pod	0.0935	0.1093	0.8554
10	100 Seed weight (g)	0.9921	0.5127	1.9445*
11	Seed yield (g)	1249.0099	262.6151	4.7561**

* Significant at 1% level
** Significant at 5% level

Table 14. Extremes, mean, range as percentage of mean and standard error of mean for the different characters in red gram

Sl. No.	Characters	Extremes		Mean	Range as percentage of mean	S.E. of mean
		Maximum	Minimum			
1	Height of plant at harvest (cm)	277.150	186.675	243.521	37.15	± 13.620
2	Number of primary branches at harvest	21.200	12.600	18.520	46.43	± 1.763
3	Number of secondary branches at harvest	72.350	23.850	46.556	104.18	± 11.055
4	Number of clusters per plant	249.350	91.800	189.579	83.11	± 26.937
5	Number of pods per plant	755.450	201.450	547.106	101.26	± 98.373
6	Length of pod bearing branches (cm)	150.175	104.250	124.292	36.95	± 8.890
7	Number of days from sowing to 50% flowering	126.750	78.500	110.575	43.64	± 1.735
8	Number of days from sowing to harvest	166.000	160.000	163.800	3.66	± 0.471
9	Number of seeds per pod	4.500	3.950	4.210	13.06	± 0.165
10	Hundred seed weight (g)	8.225	6.180	7.160	28.51	± 0.358
11	Seed yield (g)	89.825	24.030	58.810	111.87	± 8.103

Table 15. Ranking of the genotypes for height of plant at harvest (cm)

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_8	I	277.15
2	T_7	I	267.25
3	T_{20}	I	266.00
4	T_{14}	II	263.75
5	T_{12}	I	263.50
6	T_1	III	261.50
7	T_{13}	V	259.55
8	T_4	II	258.25
9	T_6	III	255.25
10	T_{15}	II	253.76
11	T_2	III	253.75
12	T_{19}	IV	242.32
13	T_9	I	239.80
14	T_4	II	239.68
15	T_{11}	I	235.25
16	T_{18}	II	231.00
17	T_{17}	II	214.00
18	T_{16}	II	207.00
19	T_3	II	195.00
20	T_{10}	II	186.68
		General Mean	243.521
		C.D.	38.52

Table 16. Ranking of genotypes for number of primary branches at harvest

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_9	I	21.20
2	T_{13}	V	21.05
3	T_6	III	21.00
4	T_{20}	I	20.77
5	T_4	II	20.57
6	T_{12}	I	20.40
7	T_1	III	20.20
8	T_{18}	II	19.85
9	T_8	I	19.65
10	T_{11}	I	19.35
11	T_{15}	II	19.15
12	T_{16}	II	18.06
13	T_{19}	IV	17.92
14	T_2	III	17.75
15	T_7	I	17.60
16	T_{14}	II	17.25
17	T_5	III	17.10
18	T_3	II	14.70
19	T_{10}	II	14.20
20	T_{17}	II	12.60
		General Mean	18.52
		C.D.	2.137

Table 17. Ranking of genotypes for number of secondary branches at harvest

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_6	III	72.35
2	T_{13}	V	71.75
3	T_9	I	64.80
4	T_{19}	IV	57.55
5	T_{20}	I	57.10
6	T_8	I	53.75
7	T_2	III	50.20
8	T_4	II	48.20
9	T_{12}	I	46.95
10	T_1	III	46.85
11	T_{18}	II	46.10
12	T_5	III	44.15
13	T_7	I	42.70
14	T_{11}	I	42.00
15	T_{15}	II	39.35
16	T_{16}	II	38.00
17	T_{17}	II	31.46
18	T_{14}	II	27.40
19	T_{10}	II	26.60
20	T_3	II	23.85
		General Mean	46.58
		C.D.	31.267

Table 18. Ranking of genotypes for number of clusters per plant

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_{18}	II	249.35
2	T_{14}	II	232.40
3	T_{2}	III	228.75
4	T_{5}	III	228.35
5	T_{6}	III	222.10
6	T_{19}	IV	220.35
7	T_{20}	I	218.55
8	T_{15}	II	214.15
9	T_{1}	III	212.70
10	T_{12}	I	210.25
11	T_{4}	II	200.35
12	T_{8}	I	193.95
13	T_{13}	V	190.05
14	T_{9}	I	181.65
15	T_{11}	I	175.50
16	T_{7}	I	175.30
17	T_{16}	II	154.72
18	T_{17}	II	97.80
19	T_{3}	II	92.50
20	T_{10}	II	91.80
		General Mean	169.58
		C.D.	76.189

Table 19. Ranking of genotypes for number of pods per plant

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_5	III	755.45
2	T_1	III	677.90
3	T_{18}	II	663.05
4	T_{12}	I	656.45
5	T_{19}	IV	653.60
6	T_{15}	II	639.90
7	T_2	III	629.40
8	T_4	II	614.15
9	T_6	III	602.00
10	T_8	I	601.50
11	T_{20}	I	599.55
12	T_{13}	V	583.55
13	T_9	I	532.25
14	T_{11}	I	492.00
15	T_{14}	II	473.90
16	T_{16}	II	456.00
17	T_7	I	448.00
18	T_{10}	II	207.92
19	T_{17}	II	204.00
20	T_3	II	201.45
		General Mean	547.11
		C.D.	275.390

Table 20. Ranking of genotypes for length of pod bearing branches (cm)

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_{20}	I	150.18
2	T_{14}	II	138.25
3	T_5	III	134.45
4	T_{19}	IV	134.25
5	T_8	I	130.50
6	T_7	I	130.25
7	T_9	I	130.25
8	T_{15}	II	130.25
9	T_{13}	V	129.00
10	T_{18}	II	125.50
11	T_6	III	123.00
12	T_{12}	I	121.75
13	T_{17}	II	120.32
14	T_1	III	118.50
15	T_2	III	118.50
16	T_4	II	116.55
17	T_3	II	113.00
18	T_{11}	I	112.25
19	T_{16}	II	106.67
20	T_{10}	II	104.25
		General Mean	124.59
		C.D.	25.144

Table 21. Ranking of genotypes for number of days from sowing to 50% flowering

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_6	III	126.75
2	T_{14}	II	126.00
3	T_{19}	IV	124.75
4	T_9	I	124.50
5	T_8	I	124.00
6	T_{13}	V	123.50
7	T_2	III	123.25
8	T_7	I	123.25
9	T_{12}	I	122.50
10	T_{11}	I	122.50
11	T_1	III	122.25
12	T_{20}	I	120.75
13	T_5	III	120.50
14	T_4	II	120.25
15	T_3	II	82.25
16	T_{15}	II	80.50
17	T_{10}	II	79.50
18	T_{18}	II	79.00
19	T_{16}	II	79.00
20	T_{17}	II	78.50
		General Mean	110.58
		C.D.	1.023

Table 22. Ranking of genotypes for number of days from sowing to harvest

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_1	III	166.00
2	T_{14}	II	166.00
3	T_5	III	166.00
4	T_{12}	I	166.00
5	T_{19}	IV	166.00
6	T_6	III	166.00
7	T_7	I	165.75
8	T_8	I	165.50
9	T_{13}	V	165.25
10	T_2	III	165.25
11	T_{11}	I	165.00
12	T_{20}	I	165.00
13	T_9	I	164.50
14	T_4	II	160.00
15	T_{16}	II	160.00
16	T_{18}	II	160.00
17	T_{10}	II	160.00
18	T_3	II	160.00
19	T_{17}	II	160.00
20	T_{15}	II	160.00
		General Mean	163.800
		C.D.	1.331

Table 23. Ranking of genotypes for number of seeds per pod

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_5	III	4.50
2	T_7	I	4.45
3	T_{20}	I	4.35
4	T_{13}	V	4.35
5	T_1	III	4.30
6	T_2	III	4.30
7	T_{12}	I	4.30
8	T_6	III	4.30
9	T_9	I	4.25
10	T_{15}	II	4.25
11	T_{19}	IV	4.20
12	T_{18}	I	4.20
13	T_{17}	II	4.07
14	T_{16}	II	4.06
15	T_{11}	II	4.06
16	T_4	II	4.05
17	T_{14}	II	4.05
18	T_8	I	4.05
19	T_{10}	II	4.00
20	T_3	II	3.95
		General Mean	4.210
		C.D.	0.4674

Table 24. Ranking of genotypes for hundred seed weight (g)

Rank	Genotype	Cluster to which it belongs	Mean value
1	T_7	I	8.22
2	T_{17}	II	7.71
3	T_{16}	II	7.70
4	T_{15}	II	7.62
5	T_3	II	7.51
6	T_1	III	7.40
7	T_8	I	7.38
8	T_{20}	I	7.37
9	T_{14}	II	7.36
10	T_6	III	7.20
11	T_9	I	7.15
12	T_{13}	V	7.15
13	T_5	III	7.10
14	T_2	III	6.93
15	T_{10}	II	6.75
16	T_{19}	IV	6.72
17	T_{18}	II	6.71
18	T_{11}	I	6.71
19	T_{12}	I	6.33
20	T_4	II	6.18
		General Mean	7.163
		C.D.	1.0106

Table 25. Ranking of genotypes for seed yield (g)

Rank	Genotype	Cluster to which it belongs	Mean values
1	T_9	I	89.81
2	T_1	III	81.69
3	T_2	III	77.71
4	T_{15}	II	76.93
5	T_{14}	II	75.44
6	T_5	III	74.37
7	T_8	I	68.98
8	T_{20}	I	62.74
9	T_{13}	V	61.79
10	T_{12}	I	61.41
11	T_{19}	IV	58.10
12	T_6	III	57.46
13	T_{16}	II	51.24
14	T_7	I	49.48
15	T_4	II	47.55
16	T_{18}	II	45.51
17	T_{11}	I	43.43
18	T_{10}	II	37.55
19	T_3	II	31.13
20	T_{17}	II	24.02
		General Mean	58.80
		C.D.	22.927

Table 26. Phenotypic, genotypic and environmental variances (PV, GV and EV) and phenotypic and genotypic coefficient of variations (PCV and GCV) for the different characters in red gram

Sl.No.	Characters	PV	GV	EV	PCV	GCV
1	Height of plant at harvest (cm)	1198.520	456.48^{0}	742.04^{0}	55.12	8.77
2	Number of primary branches at harvest	14.270	1.84^{0}	12.44^{0}	20.40	7.32
3	Number of secondary branches at harvest	556.520	67.69^{0}	488.83^{0}	50.67	17.67
4	Number of clusters per plant	4389.930	1487.52^{0}	2902.41^{0}	41.18	20.34
5	Number of pods per plant	57035.580	18326.70^{0}	38708.88^{0}	43.65	24.74
6	Length of pod bearing branches (cm)	365.330	49.21^{0}	316.12^{0}	15.34	5.63
7	Number of days from sowing to 50% flowering	442.230	430.19^{0}	12.04^{0}	19.02	18.76
8	Number of days from sowing to harvest	7.727	6.84^{0}	0.887	1.70	1.60
9	Number of seeds per pod	0.105	-0.004	0.109	7.70	1.50
10	100 Seed weight (g)	0.634	0.121	0.513	11.12	4.80
11	Seed yield (g)	509.21 0	246.60^{0}	262.61^{0}	38.37	26.70

Table 27. Heritability (H^2), Genetic Advance (GA) and Genetic Gain (GG) for the different characters in red gram

Sl.No.	Characters	Heritability	Genetic advance	Genetic Gain
1	Height of plant at harvest (cm)	0.381	27.172	11.16
2	Number of primary branches at harvest	0.113	0.996	5.38
3	Number of secondary branches at harvest	0.122	0.929	12.73
4	Number of clusters per plant	0.339	46.265	24.40
5	Number of pods per plant	0.321	157.923	28.87
6	Length of pod bearing branches (cm)	0.135	5.315	4.27
7	Number of days from sowing to 50% flowering	0.973	42.090	38.19
8	Number of days from sowing to harvest	0.885	5.068	3.09
9	Number of seeds per pod	-0.038	-0.025	-0.59
10	100 Seed weight (g)	0.191	0.313	4.36
11	Seed yield (g)	0.484	22.499	38.26

A scrutiny of the results presented in the above tables revealed the following.

Height of plant at harvest (cm)

The differences among the genotypes were highly significant for the height of plant at harvest (Table 13). The mean height ranged from 186.6 cm to 277.15 cm with a general mean of 243.52 cm. The range expressed as percentage of mean was 37.15 indicating a wide range of variability for this character (Table 14). T_8 belonging to cluster I recorded the maximum mean height (277.15 cm) and T_{10} belonging to Cluster II recorded the minimum mean height (186.68 cm) (Table 15).

The estimated phenotypic variance (PV) for this character was 1198.52 and the same could be apportioned into genotypic variance (GV) and environmental variance (EV) as 456.48 and 742.04 respectively indicating a higher influence of environmental effect on this character. The phenotypic and genotypic coefficients of variation (PCV = 55.12 and GCV = 8.77) also confirmed the above fact (Table 26). Heritability (0.381) and genetic gain as percentage of mean (11.16%) were found to be moderate (Table 27).

Number of primary branches at harvest

The statistical analysis showed that the differences among genotypes under study for number of primary branches at harvest were not significant (Table 13). The maximum mean value of 21.20 for this character was recorded by T_9 belonging to cluster I with a general mean of 18.52, whereas the minimum mean value of 12.60 was recorded by T_{17} belonging to Cluster II (Table 16). The range as percentage of mean was 46.43 (Table 14).

The phenotypic, genotypic and environmental variances for this character were 14.27, 1.84 and 12.44 respectively, thereby showing that this character was highly influenced by environment. This is also confirmed by phenotypic and genotypic coefficients of variation which were 20.40 and 7.32 respectively. The heritability and genetic gain were observed to be 0.113 and 5.38 per cent respectively.

Number of secondary branches at harvest

The general mean for number of secondary branches at harvest was 46.56 with a range from 23.85 to 72.35 and the range expressed as percentage of mean was 104.18 (Table 14), indicating a wide range of variability. From the analysis of variance, it could be seen that this character did not differ significantly among the genotypes (Table 13). The maximum value of 72.35 was recorded by T_6 belonging to the cluster III while the minimum value (23.650) by T_3 belonging to the cluster II (Table 17).

The phenotypic, genotypic and environmental variances for this character were estimated to be 556.52, 67.69 and 488.83 respectively. Phenotypic and genotypic coefficients of variation were 50.67 and 17.87 respectively indicating predominant influence of environment on the variability of this character (Table 26). This is confirmed by a low heritability value of 0.122 and low genetic gain of 12.73 per cent (Table 27).

Number of clusters per plant

In the abstract of analysis of variance (Table 13) it could be seen that the differences for the number of clusters per plant among the genotypes were highly significant. The character under study showed a mean range from 91.80 to 249.35 with a general mean of 189.58 and range as percentage of mean of 83.11, indicating a wide range of variability (Table 14). The maximum mean value of 249.35 was recorded by T_{18} belonging to the cluster II and minimum mean value 91.80 was recorded by T_{10} also belonging to the same cluster II (Table 18).

The total phenotypic variance of 4389.93 could be apportioned into genotypic and environmental variances as 1487.52 and 2902.41 respectively and the PCV, and GCV, as 41.18 and 20.34 respectively showing moderate environmental influence on the expression of this character. This is supported by moderate heritability (0.339) and genetic gain (24.40%) (Table 27).

Number of pods per plant

From the abstract of analysis of variance, the differences among the genotypes for number of pods per plant were seen to be highly significant (Table 13). Maximum value of 755.45 was recorded by T_5 belonging to cluster III where as minimum number of 2041.45 was recorded by T_3 belonging to cluster III. Range as percentage of mean was 101.26 with a general mean of 547.11 showing a wide range of variability in the expression of the character (Table 14 and 19).

Phenotypic, genotypic and environmental variance and PCV and GCV were 57035.58, 18326.70, 38708.88, 43.65 and 24.74 respectively showing a comparatively high contribution of environment in the expression of this character (Table 26). This is also confirmed by heritability and genetic gain which were 0.321 and 28.87 per cent respectively (Table 27).

Length of pod bearing branches (cm)

The statistical analysis showed that the varietal differences for length of pod bearing branches were not significant (Table 13). The character showed a range from 104.25 to 150.18 with a mean value of 124.59. The range expressed as percentage of mean was 36.95 (Table 14). The maximum value (150.175) was recorded by T_{20} belonging to cluster I while the minimum value was shown by T_{10} belong to cluster II (Table 2[illegible]).

The phenotypic variance (365.33), genotypic variance (49.212) and environmental variance (316.12) have shown the environmental effect on the expression of the character. The genotypic coefficient of variation (5.63) and phenotypic coefficient of variation (15.34), heritability (0.135) and genetic gain (4.27%) also confirmed the predominant environmental effect in the total variability.

Number of days from sowing to 50% flowering

Number of days from sowing to 50 per cent flowering showed very high significant differences among the genotypes (Table 13). The maximum mean value for this character was recorded as 126.75 and minimum value as 78.50 with a general mean value of 110.58. The range as percentage of mean was estimated as 43.64 (Table 14). The above maximum and minimum values were recorded by T_6 belonging to the cluster III and T_{17} belonging to the cluster II respectively (Table 21).

Genetic components appeared to contribute very highly to the total variation for this character. The phenotypic and genotypic variance were 442.23 and 430.19 respectively while environmental variance was only 12.04. This is also confirmed by phenotypic coefficient of variation (19.02), genotypic coefficient of variation (18.76), heritability (0.973) and genetic gain (38.19%) (Table 26 and 27).

Number of days from sowing to harvest

From the abstract of analysis of variance for number of days from sowing to harvest it was seen that the differences among genotypes were highly significant (Table 13). The character showed a very low range of mean from 160 to 166, with a general mean of 163.80 and 3.66 as the range expressed as percentage of mean (Table 14). The maximum value (166) was recorded by T_1 belonging to cluster III and minimum (160) by T_{15} belonging to cluster II (Table 22).

Major part of the variation for this character was found to be genetic (PV = 7.727, GV = 6.84). The phenotypic and genotypic coefficients of variation were 1.70 and 1.60 respectively. Heritability (0.885) and genetic gain as percentage of mean (3.09%) also confirmed the above.

Number of seeds per pod

Number of seeds per pod showed little differences among the genotypes studied (Table 13). The maximum mean value was recorded as 4.50 and minimum mean value 3.95 with a general mean of 4.21 and range as percentage of mean as 13.06 (Table 14). T_5 belonging to cluster III showed the maximum value and T_3 belonging to cluster II showed the minimum.

In the total variation, environmental effect was predominant (PV = 0.105, GV = -0.004 and EV = 0.109 and PCV = 7.70, GCV = 1.50) (Table 26). The heritability (-0.038) and genetic gain (-0.587) also confirmed the above.

100 Seed weight

The statistical analysis for 100 seed weight showed that the differences among the genotypes were highly significant (Table 13). The maximum seed weight (8.225) and the minimum (6.18) with a general mean of 7.163 and a range as percentage of mean as 28.51 were observed (Table 14). T_7 belonging to cluster I showed the maximum value whereas T_4 belonging cluster II showed the minimum value (Table 24). For this character the environment had a predominant part in the total variance (PCV = 0.634) GV = 0.021, EV = 0.513, PCV = 11.12 and GCV = 4.80) (Table 26). A low heritability of 0.191 and a genetic gain of 4.36 per cent also indicated low genetic effect (Table 27).

Seed yield

The genotypes differed significantly in seed yield (Table 13). The character showed a wide range of variability with a maximum of 89.82 and minimum of 24.031 with a general mean of 58.81. The range as percentage of mean was 111.87 which was the highest among the characters studied (Table 14). The maximum value was recorded by T_9 belonging to the cluster I whereas T_{17} belonging to the cluster II recorded the minimum value.

The total variance of seed yield was shared more or less equally by genotypic and environmental variance. The respective variances were PV = 509.21, GV = 246.60, EV = 262.61. The phenotypic and genotypic coefficient of variations were 38.37 and 26.70 respectively. A comparatively moderate heritability of 0.484 and genetic gain of 38.26 confirmed the above.

Correlation between yield and yield components

The genotypic and phenotypic correlation coefficients were estimated based on genotypic and phenotypic variances and co-variances of the characters (Table 28 and 29).

For all the characters the phenotypic covariances were higher than the genotypic covariances. Except hundred seed weight, the genetic components of covariance between yield and its component characters were predominent. This was confirmed by the indication of a higher coheritability between yield and its component characters except hundred seed weight (Table 30).

The correlation coefficients between yield and its component characters and inter correlations among the yield components both at genotypic and phenotypic levels are furnished in Tables 31 and 32.

Table 28. Estimates of genotypic variances and covariances for different characters in redgram (Components of variances in brackets)

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	y
Height of plant at harvest (x_1)	(456.476)	20.637	137.444	792.072	2790.057	139.860	402.055	55.029	1.857	0.940	278.330
Number of primary branches at harvest (x_2)		(1.836)	12.863	36.666	146.026	1.680	21.359	2.550	0.106	0.332	16.217
Number of secondary branches at harvest (x_3)			(67.694)	236.180	749.432	29.409	164.606	21.289	0.828	0.644	84.938
Number of clusters per plant (x_4)				(1487.523)	5286.421	209.023	552.754	73.186	3.155	-4.546	523.833
Number of pods per plant (x_5)					(18326.703)	814.947	2106.695	285.965	8.014	-17.586	2118.042
Length of pod bearing branches (x_6)						(49.212)	109.555	14.866	0.826	0.919	95.843
Number of days from sowing to 50% flowering (x_7)							(430.194)	54.335	1.513	-2.157	208.917
Number of days from sowing to harvest (x_8)								(6.841)	0.246	-2.237	95.749
Number of seeds per pod (x_9)									(-0.004)	0.001	1.147
100 - Seed weight (x_{10})										(0.121)	0.064
Seed yield (y)											(246.599)

Table 29. Estimates of phenotypic variances and covariances for different characters in red gram (Components of variances in brackets)

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	y
Height of plant at harvest (x_1)	(1198.52)	42.566	345.065	1271.862	4901.829	407.947	411.362	48.836	4.317	0.415	368.477
Number of primary branches at harvest (x_2)		(14.271)	47.140	122.873	394.905	14.818	20.344	2.240	0.144	-0.796	30.583
Number of secondary branches at harvest (x_3)			(556.522)	637.131	2229.349	159.339	160.681	17.733	2.037	--3.227	173.942
Number of clusters per plant (x_4)				(4389.931)	14575.711	601.220	572.086	72.862	6.552	-11.299	654.154
Number of pods per plant (x_5)					(57035.582)	1755.579	2201.204	262.868	30.101	-42.812	2450.138
Length of pod bearing branches (x_6)						(365.331)	130.842	14.691	0.070	1.808	102.255
Number of days from sowing to 50% flowering (x_7)							(442.234)	54.258	1.491	-1.892	203.128
Number of days from sowing to harvest (x_8)								(7.727)	0.167	-0.287	25.493
Number of seeds per pod (x_9)									(0.105)	0.030	1.687
100 - Seed weight (x_{10})										(0.634)	0.512
Seed yield (y)											(509.214)

Table 30. Heritability and coheritability among seed yield and its ten components in redgrams. (Components of heritability in brackets)

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	y
Height of plant at harvest (x_1)	(0.381)	0.485	0.398	0.623	0.569	0.343	0.977	1.127	0.430	0.267	0.755
Number of primary branches at harvest (x_2)		(0.129)	0.277	0.298	0.370	0.113	1.050	1.138	0.735	0.417	0.530
Number of secondary branches at harvest (x_3)			(0.122)	0.371	0.336	0.185	0.124	1.201	0.406	0.199	0.488
Number of plusters per plant (x_4)				(0.339)	0.363	0.348	0.966	1.004	0.482	0.402	0.801
Number of pods per plant (x_5)					(0.321)	0.464	0.957	1.088	0.266	0.411	0.864
Length of pod bearing branches (x_6)						(0.135)	0.837	1.012	0.038	0.508	0.937
Number of days from sowing to 50% flowering (x_7)							(0.973)	1.001	1.015	1.140	1.028
Number of days from sowing to harvest (x_8)								(0.885)	1.472	0.826	1.010
Number of seeds per pod (x_9)									(-0.037)	0.038	0.680
100 - Seed weight (x_{10})										(0.191)	0.125
Seed yield (y)											(0.484)

Table 31. Genotypic correlations among different characters in red gram

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	y
Height of plant at harvest (x_1)	1.000	0.713**	0.782**	0.961**	0.965**	0.933**	0.907**	0.985**	1,383**	0.126	0.830**
Number of primary branches at harvest (x_2)		1.000	1.154**	0.702**	0.796**	0.177*	0.760**	0.719**	1,245**	-0.704**	0.762**
Number of secondary branches at harvest (x_3)			1.000	0.744**	0.673**	0.510**	0.965**	0.989**	1.601**	-0.225*	0.657**
Number of clusters per plant (x_4)				1.000	1.012**	0.773**	0.691**	0.726**	1.302**	-0.339**	0.865**
Number of pods per plant (x_5)					1.000	0.858**	0.750**	0.808**	0.942**	-0.373**	0.996**
Length of pod bearing branches (x_6)						1.000	0.753**	0.810**	1.873**	0.376**	0.870**
Number of days from sowing to 50% flowering (x_7)							1.000	1.002**	1.161**	-0.299**	0.642**
Number of days from sowing to harvest (x_8)								1.000	1.497**	-0.261*	0.627**
Number of seeds per pod (x_9)									1.000	0.054	1.163**
100 - Seed weight (x_{10})										1.000	0.012
Seed yield (y)											1.000

* Significant at 5% level
** Significant at 1% level

Table 32. Phenotypic correlations among different characters in red gram

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	y
Height of plant at harvest (x_1)	1.000	0.325**	0.423**	0.554**	0.593**	0.617**	0.565**	0.507**	0.384**	0.015	0.472**
Number of primary branches at harvest (x_2)		1.000	0.529**	0.491**	0.483**	0.205*	0.256*	0.213*	0.118	-0.265*	0.359**
Number of secondary branches at harvest (x_3)			1.000	0.408**	0.396**	0.353**	0.324**	0.270*	0.266*	-0.172	0.327**
Number of clusters per plant (x_4)				1.000	0.921**	0.475**	0.411**	0.396**	0.305**	-0.214*	0.438**
Number of pods per plant (x_5)					1.000	0.385**	0.438**	0.396**	0.388**	-0.225*	0.455**
Length of pod bearing branches (x_6)						1.000	0.326**	0.277**	0.124	-0.119	0.237*
Number of days from sowing to 50% flowering (x_7)							1.000	0.928**	0.218 *	-0.113	0.428**
Number of days from sowing to harvest (x_8)								1.000	0.185	-0.130	0.406**
Number of seeds per pod (x_9)									1.000	0.118	0.230*
100 - Seed weight (x_{10})										1.000	0.029
Seed yield (y)											1.000

* Significant at 5% level
** Significant at 1% level

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. Here after the word correlation would denote the genotypic correlation. All the yield component characters except hundred seed weight showed significant correlation at one per cent level with seed yield (Table 31). Among these, number of seeds per pod (1.163) followed by number of pods per plant (0.996), length of pod bearing branches (0.870), number of clusters per plant (0.865), height of plant at harvest (0.830), number of primary branches at harvest (0.762), number of secondary branches at harvest (0.657), number of days from sowing to 50 per cent flowering (0.642) and number of days ffom sowing to harvest (0.627) showed positive significant correlation with yield.

Number of seeds per pod showed significant positive correlation with all the yield components. Number of pods per plant showed significant positive correlation with all other characters except 100 seed weight to which it was negative. Length of pod bearing branches indicated significant positive correlation with all other characters except number of primary branches at harvest. Association of number of clusters per plant with all other characters except hundred seed weight was significantly positive, while with hundred seed weight it was significantly negative. Height of plant at harvest showed significantly positive association with all other characters except hundred seed weight. Number of primary branches at harvest indicated significant positive association with all other characters except length of pod bearing branches and hundred seed weight. Association of this character with hundred seed weight was significantly negative. Number of secondary branches at harvest showed significant positive association with all other characters except hundred seed weight, to which it was significantly negative. Association of number of days from sowing to 50 per cent flowering with all other yield components were significantly positive except with a significantly negative association to hundred seed weight. Number of days from sowing to harvest showed significantly positive association with all other characters except significantly negative association with hundred seed weight. Hundred seed weight showed significant negative association with all other characters except height of plant at harvest, length of pod bearing branches and number of seeds per pod. Association of hundred seed weight with length of pod bearing branches was the only one which was significantly positive that it could make.

The phenotypic correlation of yield with all other components of yield showed the same trend i.e. significantly positive association of yield with its components, except hundred seed weight. But the magnitude of association was lightly lesser than the genotypic association.

Path coefficient analysis

In order to show the direct and indirect effect of yield components on yield, the path coefficient analysis was done considering all the characters. The genotypic correlations of seed yield and its attributes were partitioned into direct and indirect contributions of the components on seed yield. Data represented in Table 33.

The results showed that more than 92 per cent of the variability in seed yield per plant was contributed by the 10 component characters alone and in combinations (Residual effect = $\sqrt{0.07227}$). It is seen from the table that maximum positive direct effect on seed yield was for number of pods per plant (4.8914) followed by hundred seed weight (1.6868) where as maximum negative direct effect was for number of clusters per plant (-2.7588) followed by

Table 33. Direct and indirect genotypic effects of ten contributing characters on seed yield in red gram

	Direct effect on seed yield	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	Total correlation
Height of plant at harvest (x_1)	-1.4718	-	0.8601	0.5832	-2.7284	3.5512	-0.1065	-0.0358	-0.667	-0.5180	1.3630	0.830
Number of primary branches at harvest (x_2)	0.8732	-1.0490	-	0.9361	-1.9366	3.8936	0. 0722	-0.0434	0.0001	-0.7960	-1.1875	0.762
Number of secondary branches at harvest(x_3)	0.8112	-1.1510	1.0077	-	-2.0525	3.2919	0. 2081	-0.0550	0.0001	1.0239	-0.3795	0.657
Number of clusters per plant (x_4)	-2.7588	-1.4144	0.6130	0.6035	-	4.9501	0.3154	-0.0394	0.0001	-0.8327	-0.5718	0.865
Number of pods per plant (x_5)	4.8914	-1.4203	0.6951	0.5459	-2.7919	-	0.3501	-0.0428	0.0001	-0.6024	-0.6292	0.996
Length of pod bearing branches (x_6)	0.4081	0.1546	0.4137	-0.1325	4.1968	0.4081	-	-0.0662	-0.3528	-0.6395	0.6342	0.870
Number of days from sowing to 50% flowering (x_7)	-0.0570	-1.3349	0.6637	0.7828	-1.9063	3.6686	0.3703	-	-0.2362	-0.7425	-5.5044	0.641
Number of days from sowing to harvest (x_8)	-0.2357	-1.4497	0.6279	0.8023	-2.0029	3.9523	0.3305	0.0001	-	-0.9514	-0.4403	0.627
Number of seeds per pod (x_9)	-0.6395	-2.0355	1.0872	1.2987	-3.5919	4.6077	-0.6395	-0.0662	-0.3528	-	0.0911	1.163
100 - Seed weight (x_{10})	1.6868	-0.1864	-0.6148	-0.1825	0.9352	-1.8245	-0.6342	0.0170	0.0612	-0.0345	-	0.012

Residual effect = $\sqrt{0.07227}$

height of plant at harvest (-1.4718). The direct effect of number of primary branches at harvest was estimated as 0.8732 indicating a positive effect on yield for this character. The same positive direct effect on seed yield was also indicated by number of secondary branches at harvest with an estimated value of 0.8112. The least positive direct effect on seed yield was for length of pod bearing branches (0.4081). Number of seeds per pod showed a negative direct effect on seed yield (-0.6395) followed by number of days from sowing to harvest (-0.2357). The least negative direct effect on seed yield was number of days from sowing to 50 per cent flowering (-0.0570).

The highly significant correlation between number of pods per plant and seed yield (0.996) was resulted from the high positive direct effect (4.8914) whereas maximum significant correlation between number of seeds per pod and seed yield (1.163) might have resulted from the high positive indirect effects on yield by number of seeds per pod through number of pods per plant (4.6077). The high significant positive genotypic correlation between yield and number of cluster per plant (0.865) was mainly due to the maximum positive indirect effect of number of cluster per plant on yield through number of pods per plant (4.9501). The maximum negative indirect effect of number of days from sowing to 50 per cent flowering on yield was through hundred seed weight (-5.5044).

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 based on the phenotypic performance of the selected characters viz., seed yield, height of the plant at harvest, number of primary branches at harvest, number of clusters per plant, number of pods per plant, number of seeds per pod and hundred seed weight. These characters were selected based on the direct and indirect effects and genotypic correlations. The discriminent function for the different combinations is presented in Table 34. Table 35 gives the genetic advance through the various combinations, its efficiency over direct selection and scope for further inclusion of characters.

Maximum efficiency of 1.098 over direct selection was for the selection index constituting seven characters viz., yield, number of seeds per pod, hundred seed weight, height of the plant at harvest, number of primary branches,

Table 34. Discriminant function for the different combinations

Sl.No.	Combinations	Discriminant function
1	y, x_9	$0.47326\ y + 3.32009\ x_9$
2	y, x_9, x_5	$0.38654\ y - 1.38115\ x_9 + 0.021259\ x_5$
3	y, x_9, x_5, x_{10}	$0.382103\ y - 1.24758\ x_9 + 0.01938\ x_5 + 0.0648\ x_{10}$
4	y, x_5, x_{10}	$0.38083\ y + 0.018756\ x_5 + 0.0656\ x_{10}$
5	$y, x_9, x_5. x_{10}, x_4$	$0.38548\ y - 2.08084\ x_9 + 0.0337\ x_5 + 0.06915\ x_{10} - 0.06845\ x_4$
6	$y, x_9, x_5. x_{10}, x_4, x_1$	$0.3749\ y - 2.6478\ x_9 + 0.0337\ x_5 + 0.06915\ x_{10} - 0.0634\ x_4 + 0.03232\ x_1$
7	$y, x_9, x_5. x_{10}, x_4, x_1, x_2$	$0.38264y - 2.8379\ x_9 + 0.03277\ x_5 + 0.0629\ x_{10} - 0.0537\ x_4 + 0.03603\ x_1 - 0.027215\ x_2$

y = seed yield
x_1 = height of the plant at harvest
x_2 = number of primary branches at harvest
x_3 = number of cluster/plant
x_5 = number of pods/plant
x_9 = number of seeds/podt
x_{10} = 100 seed weight

Table 35. Genetic advance (GA) through selection index, efficiency over direct selection and scope for further inclusion of characters $(1- r^2_{1A})$

Sl. No.	Character combination	G.A. through selection index	Efficiency over direct selection	Gain in efficiency (%)	$I-r^2_{1A}$
1	y, x_9	22.6139	1.0045	(0.5)	0.5113
2	y, x_9, x_5	24.2661	1.0780	(7.8)	0.4373
3	y, x_9, x_5, x_{10}	24.3797	1.0830	(8.3)	0.4320
4	y, x_5, x_{10}	24.4053	1.0840	(8.4)	0.4308
5	y, x_9, x_5, x_{10}, x_4	24.6140	1.0938	(9.4)	0.4210
6	$y, x_9, x_5, x_{10}, x_4, x_1$	24.6560	1.0953	(9.5)	0.4191
7	$y, x_9, x_5, x_{10}, x_4, x_1, x_2$	24.7200	1.0980	(9.8)	0.4160
	Direct selection	22.4995	1.0000	-	

y = yield
x_9 = number of seeds/pod
x_{10} = 100 Seed weight
x_1 = height of the plant at harvest
x_2 = number of primary branches at harvest
x_4 = number of clusters/plant
x_5 = number of pods/plant

number of clusters per plant and number of pods per plant and its gain in efficiency was 9.8 per cent. Scope for further inclusion of character for improving the selection index was only 41 per cent. i.e. 59 per cent of the genetic improvement through selection could be achieved through the above combination. Though the gain inefficiency was slightly lower (8.4%) the selection index constituting the characters yield, number of pods/plant and hundred seed weight was also promising since it included only three characters. The efficiency of this combination over direct selection was 1.084. The genetic advance of the above two combinations of selection was 24.72 and 24.41 respectively.

Estimates of the selection index using characters, viz., seed yield, number of pods per plant and hundred seed weight and the ranking given to the genotypes according to the selection index and yield are given in Table 36.

Based on the above discriminant function, the genotype T_9 which has an estimated selection index of 44.66 secured 1st rank in both i.e. based on selection index and yield. In the case of T_1 which has an estimated

Table 36. Estimates of the selection index using characters seed yield (y) Number of pods per plant (x_5) and 100 seed weight (x_{10})

Genotype	Selection index	Rank according to	
		Selection index	Yield
T_1	44.3100	2	2
T_2	41.8566	4	3
T_3	16.1284	19	19
T_4	30.0420	14	15
T_5	42.9595	3	6
T_6	33.6473	12	12
T_7	27.7889	16	14
T_8	37.9298	7	7
T_9	44.6600	1	1
T_{10}	18.6460	18	18
T_{11}	26.2077	17	17
T_{12}	36.1171	8	10
T_{13}	34.9458	10	9
T_{14}	38.1035	6	5
T_{15}	41.8024	5	4
T_{16}	28.5718	15	13
T_{17}	13.4817	20	20
T_{18}	30.2094	13	16
T_{19}	34.8296	11	11
T_{20}	35.6244	9	8

Relative efficiency = 8.4%
Over direct selection

selection index of 44.31 received 2nd rank in both based on selection index and yield. The genotype T_2 which got 3rd rank in ranking based on yield, got 4th rank based on selection index. T_5 which got 3rd rank in ranking based on selection index, secured 6th rank based on yield. Likewise a changed set of genotypes was formed in ranking based on selection index and yield.

Estimates of selection index which showed the maximum relative efficiency over direct selection (9.8%) using characters seed yield, number of seeds per pod, number of pods per plant, hundred seed weight, number of clusters per plant, height of the plant at harvest and number of primary branches are presented in Table 37.

Ranks were given to the genotypes T_1 .... T_{20} based on the above selection index and yield.

Based on selection index 1st rank was given to T_1 (selection index = 39.188) while based on yield 1st rank was gone to T_9. In the selection index ranking, T_9 secured only 2nd rank. In the case of ranking based on yield, 1st rank to T_9 and 2nd rank to T_1. Likewise T_2 got 3rd rank based on yield while it was T_{15} which got the 3rd rank based on selection index.

The mean values of eleven characters of 112 genotypes of red gram are presented in Appendix I. D^2 values considering all the eleven characters simultaneously are given in Appendix II.

Table 37. Estimates of selection index using characters seed yield (y), number of seeds/pod (x_9) number of pods/plant (x_5), 100-Seed weight (x_{10}), number of clusters per plant (x_4), height of the plant at harvest (x_1) and number of primary branches at harvest (x_2).

Genotype	Selection index	Rank according to	
		Selection index	Yield
T_1	39.188	1	2
T_2	34.600	5	3
T_3	9.472	19	19
T_4	24.541	13	15
T_5	37.468	4	6
T_6	26.663	12	12
T_7	21.242	16	14
T_8	34.006	6	7
T_9	38.506	2	1
T_{10}	11.668	18	18
T_{11}	19.715	17	17
T_{12}	30.856	8	10
T_{13}	29.444	10	9
T_{14}	29.921	9	5
T_{15}	38.306	3	4
T_{16}	22.147	14	13
T_{17}	6.914	20	20
T_{18}	22.039	15	16
T_{19}	28.567	11	11
T_{20}	31.210	7	8

Relative efficiency over direct selection = 9.8%

Discussion

DISCUSSION

In any plant breeding programme, the main objective 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 and are complementary. 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 conversion 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.

The importance of genetic diversity of parents in hybridisation programme has been emphasised by many workers. The more diverse the parents within a reasonable range, the more would be the chances of improving the characters in question. Mahalanobis D^2 statistics has been found to be a powerful tool in the hands of plant breeders to assess the degree of relationship among the genotypes and to group them based on their phenotypic expression.

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.

The association analysis based on correlation coefficients of components with yield will not prove 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 may have influence through other components or both. Hence an assessment of the merit of each character by analysing the direct and indirect effects of each character towards yield is a valuable information in selecting the characters for crop improvement.

For selecting suitable genotypes from a highly heterogenous mass population, the selection should always be based on the minimum number of characters. An estimation of discriminant function based on such most reliable and effective characters, is a valuable tool for the practical plant breeder. Selection of genotypes based on a suitable index is highly efficient in any breeding programme (Hazel, 1943). More over, discriminant function would ensure a maximum concentration of the desired genes in the plants or in the lines selected.

Thus the objectives and methodology of the present investigations which basically deal with obtaining the relevant genetic informations as a prerequisite for production breeding programme in a number of red gram genotypes are fully justified. The results obtained are discussed in the following pages.

Variability in red gram genotypes

The one hundred and twelve red gram genotypes were observed to be significantly different for eight out of eleven characters studied, viz. height of plant at harvest, number of primary branches at harvest, number of clusters per plant, number of pods per plant, length of pod bearing branches, number of days from sowing to 50 per cent flowering, hundred seed weight and seed yield.

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, depends upon a wide genetic base resulting in a wider genetic variability. In the present investigation it is seen that the range of variation for almost all the characters is large particularly in respect of height of plant at harvest (129.00 to 354.00 cm), number of primary branches at harvest (5.70 to 20.80), number of secondary branches at harvest (18.70 to 286.40), number of clusters per plant (9.85 to 322.40), length of pod bearing branches (73.00 to 218.50 cm), number of days from sowing to 50 per cent flowering (71.00 to 105.00), 100 seed weight (5.55 to 10.25 g) as well as seed yield (6.80 to 297.40 g). This indicated the presence of enough variability in the population under study. The investigations of Rathnaswamy et al. (1973), Ram et al. (1976), Awatade et al. (1980), Asawa et al. (1981), Bainiwal et al. (1981), Dumbre and Deshmukh (1983), Shoran (1983) and Jagshoran et al. (1985) have also shown that a wide range of variation was present for most of the characters considered in this crop.

More than the total observed variation, it is the nature of that variation which is more important. The total variability can be divided into heritable and nonherital components. Variance estimates in the present study have indicated the influence of both genetic and environmental factors.

Among the characters, height of the plant at harvest showed the maximum heritability (0.803), followed by number of days to 50 per cent flowering (0.773), number of cluster per plant (0.606), seed yield (0.546) and number of pods per plant (0.535) thereby suggesting that these traits are mainly governed by genetic causes and are reliable characters for selection. The heritability of the characters like number of secondary branches at harvest (0.093), number of days from sowing to harvest (0.004), and number of seeds per pod (0.010) are highly influenced by environment.

Genetic divergence among the red gram genotypes

One of the main objectives of the present investigation was to assess the genetic diversity among the genotypes of red gram and to group them into clusters based on the genetic distance. On the basis of genetic distance computed with reference to eleven economic characters, the 112 genotypes of red gram could be grouped into five clusters. The distribution of genotypes into various clusters showed no regularity. Cluster I contains eighty genotypes, cluster II contains twenty six genotypes, cluster III contains four and cluster IV and V one each. One hundred and six genotypes were found to comprise just in two clusters in the present study. Such irregular pattern of distribution has been reported by Malik _et al_. (1985), and Hazarika and Singh (1986).

It is interesting to note that the clustering pattern did not follow the geographic pattern. Within the cluster, the genotypes showed wide geographic diversity. In cluster I, 29 genotypes belonged to Delhi collection, 10 genotypes belonged to ICRISAT, 33 genotypes to the local collection from Kerala and eight genotypes to the collection from Karnataka. In cluster II all the 26 belonged to the improved genotypes from TNAU Coimbatore. Among the four genotypes included in the cluster III, one genotype belonged to Delhi collection and the rest to local collections from Kerala. Clusters IV and V contained only one genotype each received from Delhi. These results indicated that genotypes of the same region of origin could fall into different clusters. These findings are in agreement with the results of Asawa (1979), Dumbre and Deshmukh (1984) and Malik *et al*. (1985).

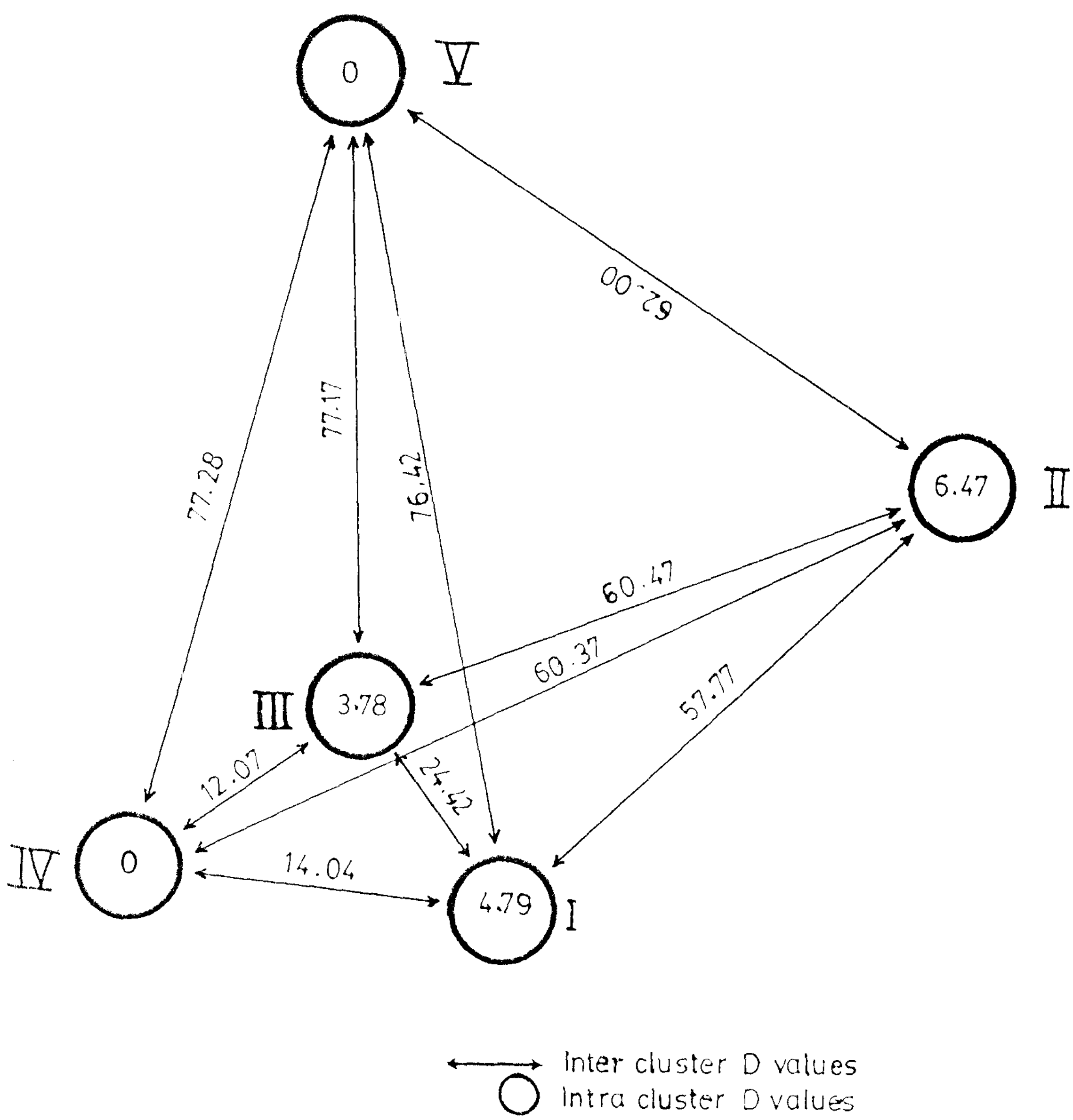
Among the five clusters studied, cluster III showed high mean values for many of the desirable characters like yield, height of the plant at harvest, number of cluster per plant, number of pods per plant, length of pod bearing branches, number of days from sowing to 50 per cent flowering etc. indicating that cluster III is superior to the rest of the clusters in respect of desirable attributes. Generally low values are attributed to cluster II in most of the characters showing that cluster II is inferior among the rest. Cluster IV is superior for characters like number of primary branches at harvest and number of days from sowing to harvest. Rest of the clusters are intermediary in position.

D^2 and D values presented in Table 11 and Table 12 have indicated that the minimum genetic distance was between cluster III and IV and maximum between cluster IV and V. Rest of the clusters were found to occupy intermediary positions as regard to their genetic distance with other clusters. Thus it is to be concluded that cluster III and cluster IV are genetically closer while cluster IV and V are wider.

A cluster diagram showing all the five clusters along with their intercluster distances is furnished in Fig.1. This diagram gives an overall picture of the distribution of the five clusters. It is also seen that clusters I, III and IV are relatively close while II and V are distant between themselves and also from the rest.

The maximum intracluster distance was shown by cluster II (6.47) followed by cluster I (4.79) and cluster III (3.78), thereby indicating a higher degree of variability in cluster II as compared to clusters I and III. This fact fully justified the selection of eight genotypes from cluster II, six genotypes from cluster I, four from cluster III one each from clusters IV and V for further detailed study. Further, these 20 genotypes truly represented the wide spectrum of variability present in the population studied, since among the twenty, there were genotypes representing high, medium, and low values for all the 11 parameters based on which the variability in the population

FIG. 1. CLUSTER DIAGRAM OF ONE HUNDRED AND TWELVE GENOTYPES IN RED GRAM



was studied. These twenty selected genotypes also represented the different geographic origin, since seven genotypes belonged to local collection from Kerala, one genotype to Karnataka, four genotypes to Delhi collection, and eight from TNAU, Coimbatore.

Among the 20 genotypes compared for the eleven characters in the second field experiment, the genotype T_8 belonging to the cluster I, was found to top all others in the height of the plant at harvest. With regard to number of primary branches at harvest and seed yield, T_9 belonging to the same cluster was found to top. The genotype T_7 belonging to the above cluster was found to be on top among the genotypes for the character 100 seed weight and when the genotype T_6 belonging to cluster III showed the maximum value with respect of number of secondary branches at harvest, it was T_{18} of cluster II which showed the maximum number of clusters per plant. Among the characters like number of pods per plant, number of days from sowing to 50 per cent flowering, number of days from sowing to harvest and number of seeds per pod, the maximum values were recorded by T_5, T_6, T_1 and T_5 respectively and all these genotypes belonged to Cluster I. T_{20} and T_7 belonging to cluster I showed the maximum value in respect of characters like length of pod bearing branches and hundred seed weight respectively. These facts clearly indicated that wide spectrum of variability was present in the material. Hence choice of the 20 genotypes for the second field experiment is fully justifiable.

Variability in the selected genotypes

The twenty selected red gram genotypes evaluated for eleven economic attributes were observed to be significantly different for seven characters viz., height of plant at harvest, number of clusters per plant, number of pods per plant, number of days from sowing to 50 per cent flowering, number of days from sowing to harvest, hundred seed weight and seed yield. In the case of characters like number of primary branches at harvest, number of secondary branches at harvest, length of pod bearing branches and number of seeds per pod, the results did not satisfy the test of significance.

Of the various estimates of quantitative variability, mean, range, and variation around the mean are the basic ones. Success in the genetic improvement of any crop would, to a large extent, depends upon a wide genetic base resulting in a wider genetic variability. In the present

Plate 1. A genotype of red gram representing cluster I.

Plate 2. A genotype of red gram representing cluster II.

Plate 1

Plate 2

Platå 3. A genotype of red gram representing cluster III.

Plate 4. A genotype of red gram representing cluster IV.

Plate 3

Plate 4

Plate 5. A genotype of red gram representing cluster V

Plate 6. Cluster of pods representing different groups

Plate 5

Plate 6

Plate 7. Variation in size and colour of seeds of genotypes of red gram included in the study.

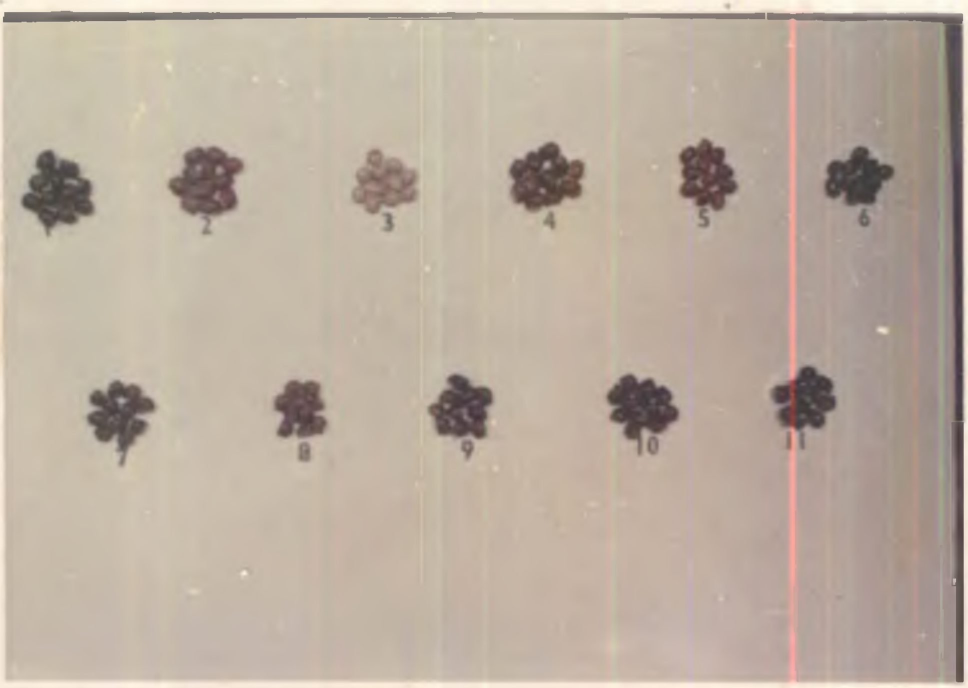


Plate 7

investigation it may be seen that the range of variation for all most all the parameters except number of days from sowing to harvest is fairly large (Fig.2). This is particularly shown in respect of number of secondary branches at harvest, number of clusters per plant, number of pods per plant, seed yield etc. This indicated the presence of enormous amount of variability in the selected population under study. This is in agreement with the results reported by Ratnaswamy et al. (1973), Ram et al. (1976 b), Singh and Srivastav et al. (1977), Jagshoran (1985) etc. in red gram.

The observed wide variability alone is not sufficient for the breeder. A knowledge of the extent and nature of genetic variability is all the more important. This makes the breeder to partition the total variability into heritable or genetic and nonheritable components because of the high influence of environment on the expression of almost all the quantitative traits. Variance estimates in the present investigation have shown that the total observed variance in two out of eleven characters studied are mainly due to genetic causes as indicated by the predominant genotypic variance over environmental variance. In nine out of eleven cases, the environmental variance is seen to

x_1 = Height of plant at harvest

x_2 = Number of primary branches at harvest

x_3 = Number of secondary branches at harvest

x_4 = Number of clusters per plant

x_5 = Number of pods per plant

x_6 = Length of pod bearing branches

x_7 = Number of days from sowing to 50% flowering

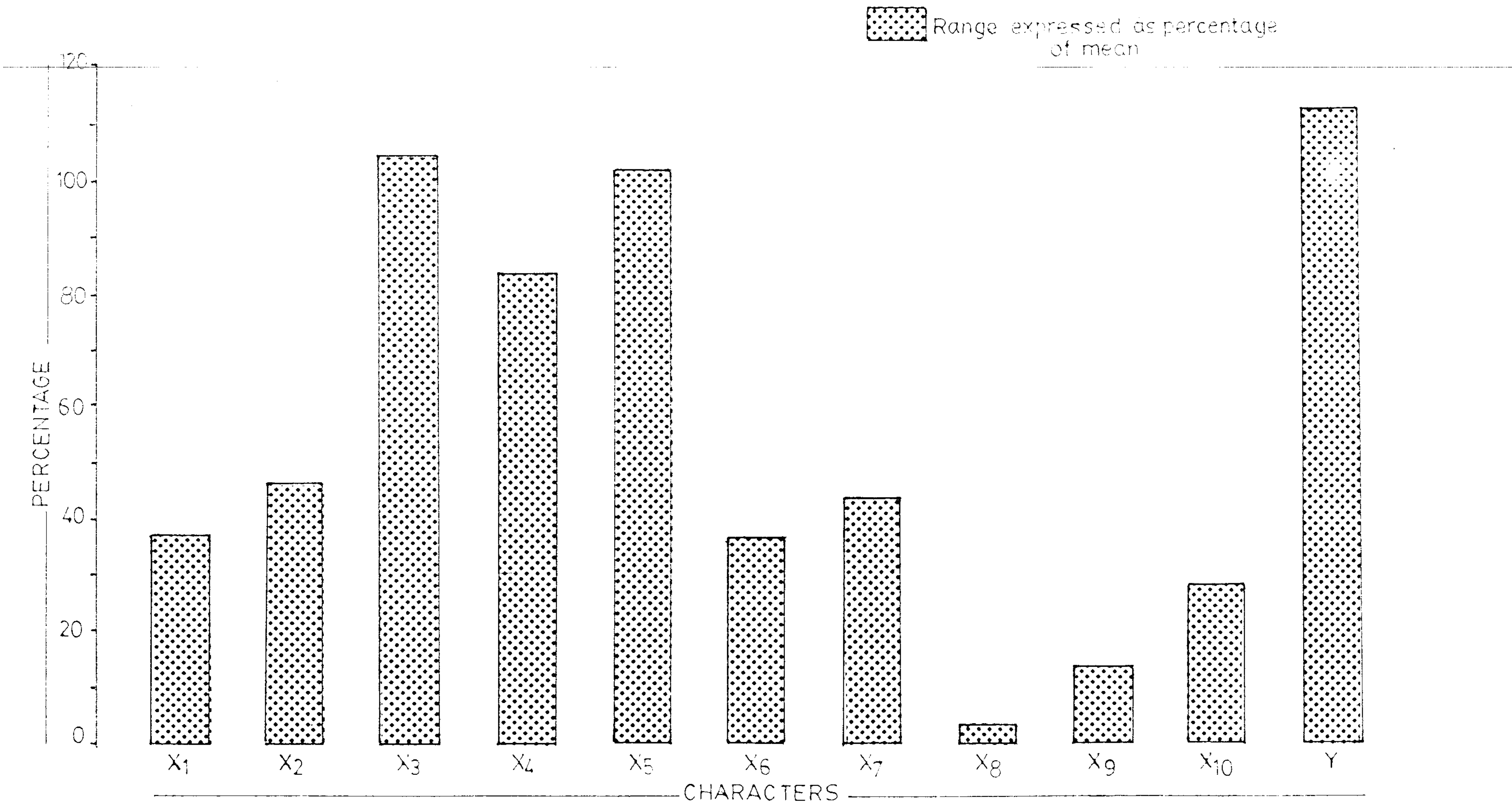
x_8 = Number of days from sowing to harvest

x_9 = Number of seeds per pod

x_{10} = 100 - Seed weight

y = Seed yield

FIG. 2. RANGE EXPRESSED AS PERCENTAGE OF MEAN OF ELEVEN CHARACTERS IN RED GRAM



surpass the genotypic variance thereby indicating that in those cases the expression is highly influenced by fluctuating environment.

The magnitude of variance as such does not indicate the relative amount of variability for which coefficients of variation appear to be a better index when the characters of different units of measurement are to be compared. High genotypic coefficient of variation indicates that genotypic variability present in the material is high and enables one to compare with that present in other traits or characters. The values estimated for phenotypic and genotypic coefficient of variation in the present study have revealed that characters like number of clusters per plant, number of pods per plant and seed yield 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 samecan be utilised for crop improvement programme. Characters like number of secondary branches at harvest, number of days from sowing to 50 per cent flowering etc. are observed to have moderate genotypic coefficient of variation (10 to 20%) while the rest of the characters like height of plant at harvest, number of primary branches at harvest, length of pod bearing branches, number of days from sowing to harvest, number of seeds per pod and hundred seed weight have exhibited low values of genotypic coefficient of variation (below 10%) there by suggesting that these characters offer little scope for selection (Fig.3).

The magnitude of genotypic coefficient of variation alone will not help the breeder to determine the amount of variation that is heritable (Gandhi et al., 1964). Heritability estimates will give an index of that portion of variation that willbe transmissible to the progeny. 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 obtained in the present investigation have indicated that the character number of days to 50 per cent flowering has moderate genotypic coefficient of variation (18.76%) coupled with high heritability (0.973) and the character seed yield has high genotypic coefficient of variation (26.70%) together with moderate heritability (0.484). Heritability estimates are the highest for number of days from sowing to 50 per cent flowering (0.973) followed by number of days from sowing to harvest (0.885). Other characters like height of the plant at harvest, number

x_1 = Height of plant at harvest

x_2 = Number of primary branches at harvest

x_3 = Number of secondary branches at harvest

x_4 = Number of clusters per plant

x_5 = Number of pods per plant

x_6 = Length of pod bearing branches

x_7 = Number of days from sowing to 50% flowering

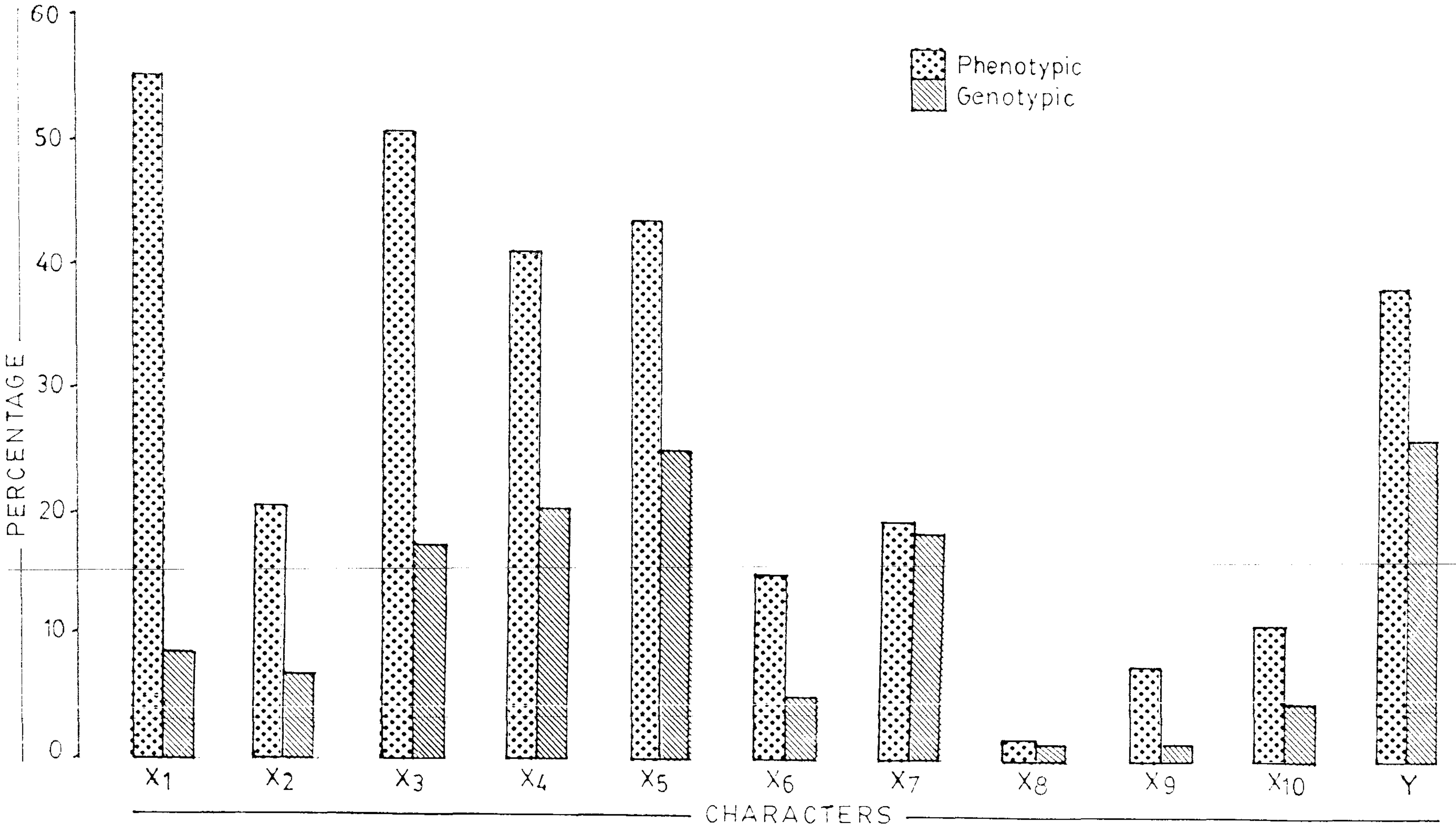
x_8 = Number of days from sowing to harvest

x_9 = Number of seeds per pod

x_{10} = 100 - Seed weight

y = Seed yield

FIG. 3. PHENOTYPIC AND GENOTYPIC COEFFICIENT OF VARIATION OF ELEVEN CHARACTERS IN RED GRAM



of clusters per plant, number of pods per plant, seed yield etc. have given values of heritability ranging from 30 per cent to 50 per cent and hence these characters can be improved by selection to a certain degree since magnitude of heritability indicates the effectiveness with which the selection of genotypes can be based on phenotypic performance (Johnson et al. 1955). Other characters like number of primary branches at harvest, number of secondary branches at harvest, length of pod bearing branches, number of seeds per pod, hundred seed weight etc. have recorded low heritability estimates ranging from 3 to 19 per cent thereby indicating the limited scope for selection for these traits.

Heritability estimates alone will not provide a complete picture of the amount of genetic progress that would result from selecting the best individuals. Alternatively better and more realistic approach in such a situation would be to consider the heritability estimates and genetic advance jointly so as to arrive at a more reliable conclusion. In the present investigation genetic advance was estimated in absolute values for each character and also percentage of mean (genetic gain) for comparying the different characters. Expected genetic advance, estimated in absolute values for the different characters has indicated that under 5 per cent intensity of selection i.e. by selecting 5 per cent of superior plants from the available population it will be possible to improve height of plant at harvest by 27.172 cm, number of primary branches at harvest by 0.996, number of secondary branches at harvest by 0.929, number of clusters per plant by 157.923, length of pod bearing branches by 5.135 cm, number of days from sowing to harvest by 5.068, number of seeds per pod by -0.025, 100 seed weight by 0.313 g and seed yield by 22.499 g respectively.

The genetic gain estimate is maximum for seed yield (38.26%), followed by number of days from sowing to 50 per cent flowering (36.19%) and number of pods per plant (28.87%). The same is found to be negative for number of seeds per pod (-0.59%). The other characters studied are found to possess values of genetic gain in between the two extremes.

According to Panse and Sukhatme (1957) high heritability coupled with high genetic gain indicates additive gene effects while high heritability with low genetic gain indicates non additive gene effects which include dominance and epistasis. Results of present investigation have indicated that the characters like number of days from sowing to 50 per cent flowering (0.973) and seed yield (0.484) have exhibited high or moderately high estimates of heritability coupled with high or moderately high (38%) genetic gain estimates, thereby indicating the involvement of additive gene effects for the characters consequently they can be improved through straight selection. Characters like number of days from sowing to harvest, height of plant at harvest etc. have high or moderately high estimates of heritability together with low values of genetic gain and hence such characters may be attributed to the action of non additive genes of the type dominance or epistasis (Fig.4). As such selection has very limited scope for improving such traits.

A comparison of the selected genotypes for the different economic traits has revealed that the different genotypes carry superiority with regard to various traits thereby suggesting immense possibility of combining the desirable attributes through effective combination breeding programme between genotypes selected from the available material.

Yield in any crop is a complex character determined by a number of genetic factors and environmental conditions

x_1 = Height of plant at harvest

x_2 = Number of primary branches at harvest

x_3 = Number of secondary branches at harvest

x_4 = Number of clusters per plant

x_5 = Number of pods per plant

x_6 = Length of pod bearing branches

x_7 = Number of days from sowing to 50% flowering

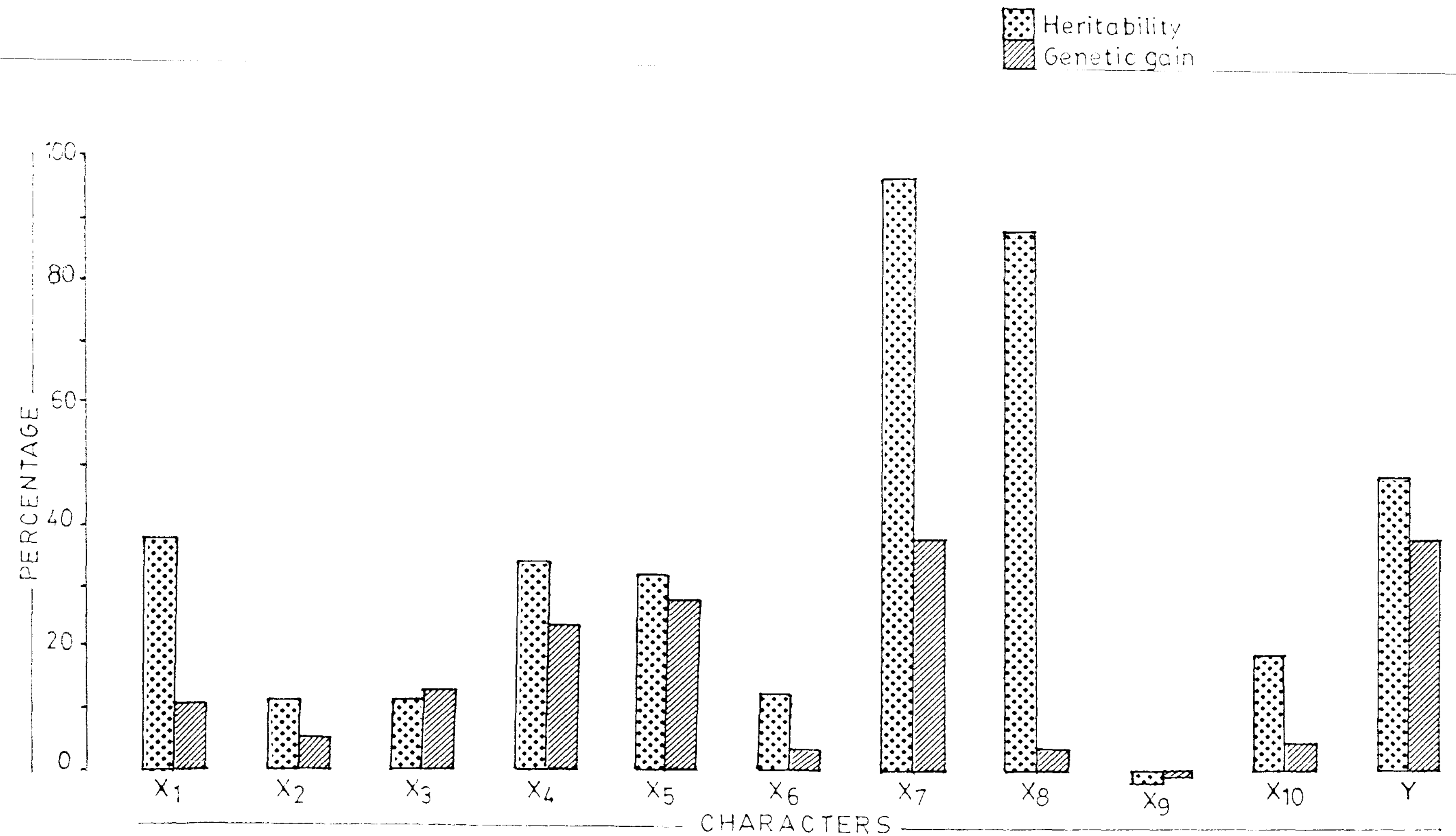
x_8 = Number of days from sowing to harvest

x_9 = Number of seeds per pod

x_{10} = 100 - Seed weight

y = Seed yield

FIG. 4. HERITABILITY AND GENETIC GAIN OF THE ELEVEN CHARACTERS IN RED GRAM



occurring at the 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. A more rational approach to the improvement of yield would therefore be to have some knowledge on the association between different yield components and their relative contribution to the final yield. A knowledge of such relationship is essential if selection for the simultaneous improvement of yield components and in turn yield is to be effective. For this purpose a simple correlation study seems to be inadequate to measure the association, since different genotypes are susceptible to environment in varying degrees. Robinson et al. (1951) have pointed out the usefulness of phenotypic and genotypic correlation 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 for consideration. With this object in mind, the phenotypic and genotypic correlation coefficients between yield and ten of its selected components and the inter correlations among them were worked out.

The results have shown that in nine out of ten cases, there has been significant positive correlation between the component character and seed yield both in the phenotypic and genotypic levels. However, in the case of 100 seed weight, the correlation with yield was not significant both in the phenotypic and genotypic levels. In all the nine out of ten cases were significant positive correlation has been obtained, the genotypic correlation coefficients have been observed to be much higher than the corresponding phenotypic correlations, thereby indicating the preponderance of inherent relationship.

The association of yield with its components through simple correlation alone is not adequate in any selection programme. A knowledge about their inter relationship is also needed. Doku (1970) based on his work in cow pea has suggested that inter correlations among the yield components should be estimated, since in actual breeding programme, rate of improvement in one component might or might not result in the improvement of other component. The estimates of inter correlations for the yield components in the present study have revealed that out of 45 intercorrelations estimated 32 in the phenotypic level 42 in the genotypic level have produced significant values. The results have shown that height of plant at harvest with six other components, number of primary branches at harvest with two other components, number of secondary branches at harvest with three other components, number of cluster per plant with two other components, number of pods per plant with one, length of pod bearing branches with one, number of days from sowing to 50 per cent flowering with two and number of days from sowing to harvest with one other component are seen to be strongly and positively associated as evidenced by high genotypic correlation coefficients (over 90%) thereby indicating that improvement through selection in one trait will take care of a simultaneous improvement in the other traits as well. One hundred seed weight is seen to be negatively correlated with number of primary branches at harvest, number of secondary branches at harvest, number of clusters per plant, number of pods per plant, number of days from sowing to 50 per cent flowering and number of days from sowing to harvest (Fig.5). This suggests that improvement through selection of 100 seed weight is possible only at the expense of the other six components.

A comparison of the magnitude of genotypic and phenotypic correlation coefficients in the present investigation has shown that within the limits of acceptable error, genotypic correlation coefficients are seen to be more than the corresponding phenotypic correlation coefficients This indicates the inherent genetic correlation of that component character with yield.

x_1 = Height of plant at harvest

x_2 = Number of primary branches at harvest

x_3 = Number of secondary branches at harvest

x_4 = Number of clusters per plant

x_5 = Number of pods per plant

x_6 = Length of pod bearing branches

x_7 = Number of days from sowing to 50% flowering

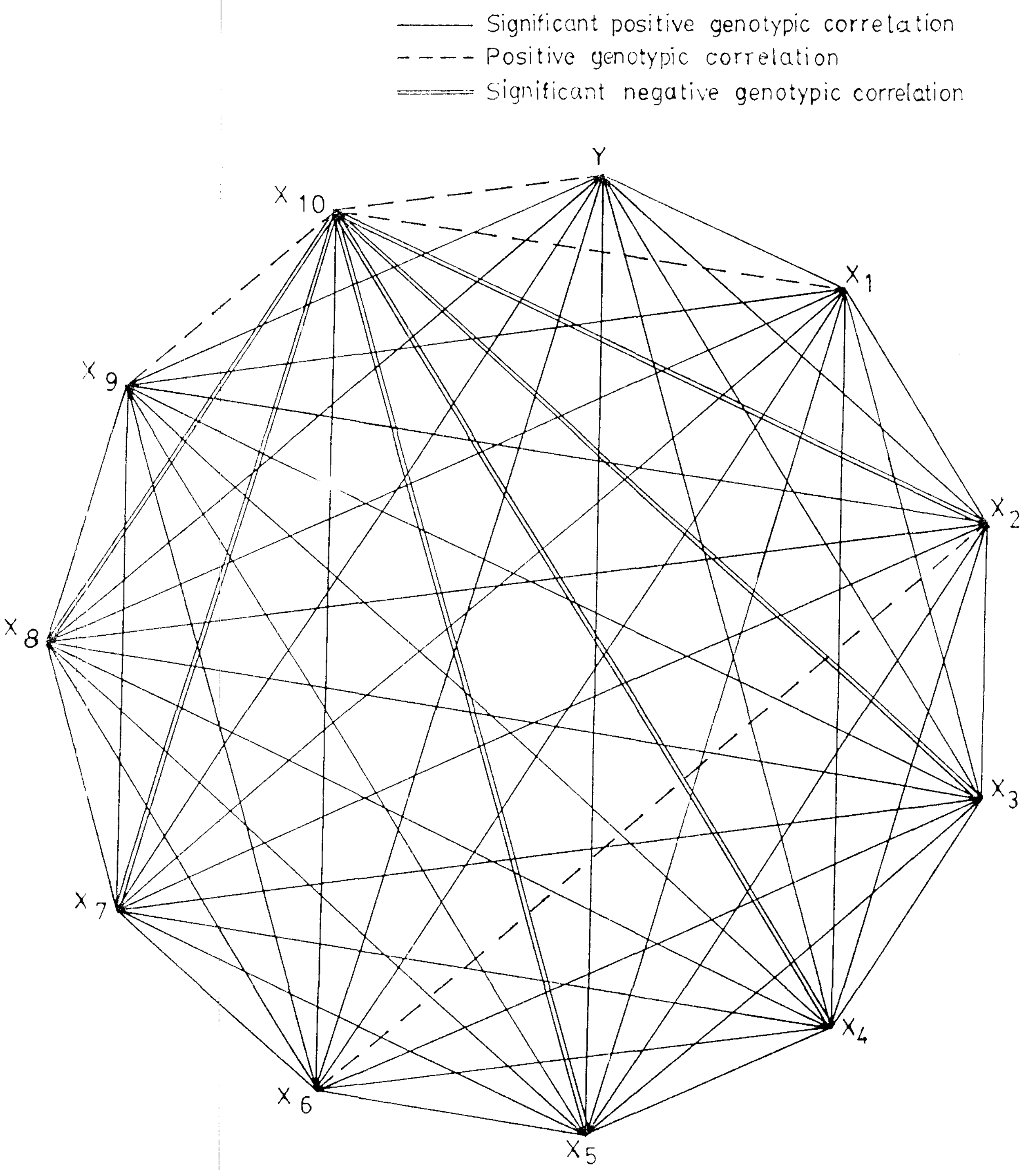
x_8 = Number of days from sowing to harvest

x_9 = Number of seeds per pod

x_{10} = 100 - Seed weight

y = Seed yield

FIG. 5. GENOTYPIC CORRELATIONS AMONG DIFFERENT CHARACTERS IN RED GRAM



The association analysis through correlation studies alone 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 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 first time in plant by Dewey and Lu (1959) furnished a means for finding out the direct and indirect effects of individual components to final yield. Results of path coefficient analysis in the present study have revealed that number of pods per plant has the maximum direct effect (4.8914) towards seed yield, followed by 100 seed weight (1.6868), number of primary branches at harvest (0.8732), number of secondary branches at harvest (0.8112) and length of pod bearing branches (0.4081). The direct effects of five of the other components such as height of plant at harvest (-1.4718), number of clusters per plant (-2.7588), number of days from sowing to 50 per cent flowering (-0.0570), number of days from sowing to harvest (-0.2357) and number of seeds per pod (-0.6395) are seen to be negative, though these components have registered significant positive correlations (Fig.6). This is explainable because of the fact

1 = Height of plant at harvest

2 = Number of primary branches at harvest

3 = Number of secondary branches at harvest

4 = Number of clusters per plant

5 = Number of pods per plant

6 = Length of pod bearing branches

7 = Number of days from sowing to 50% flowering

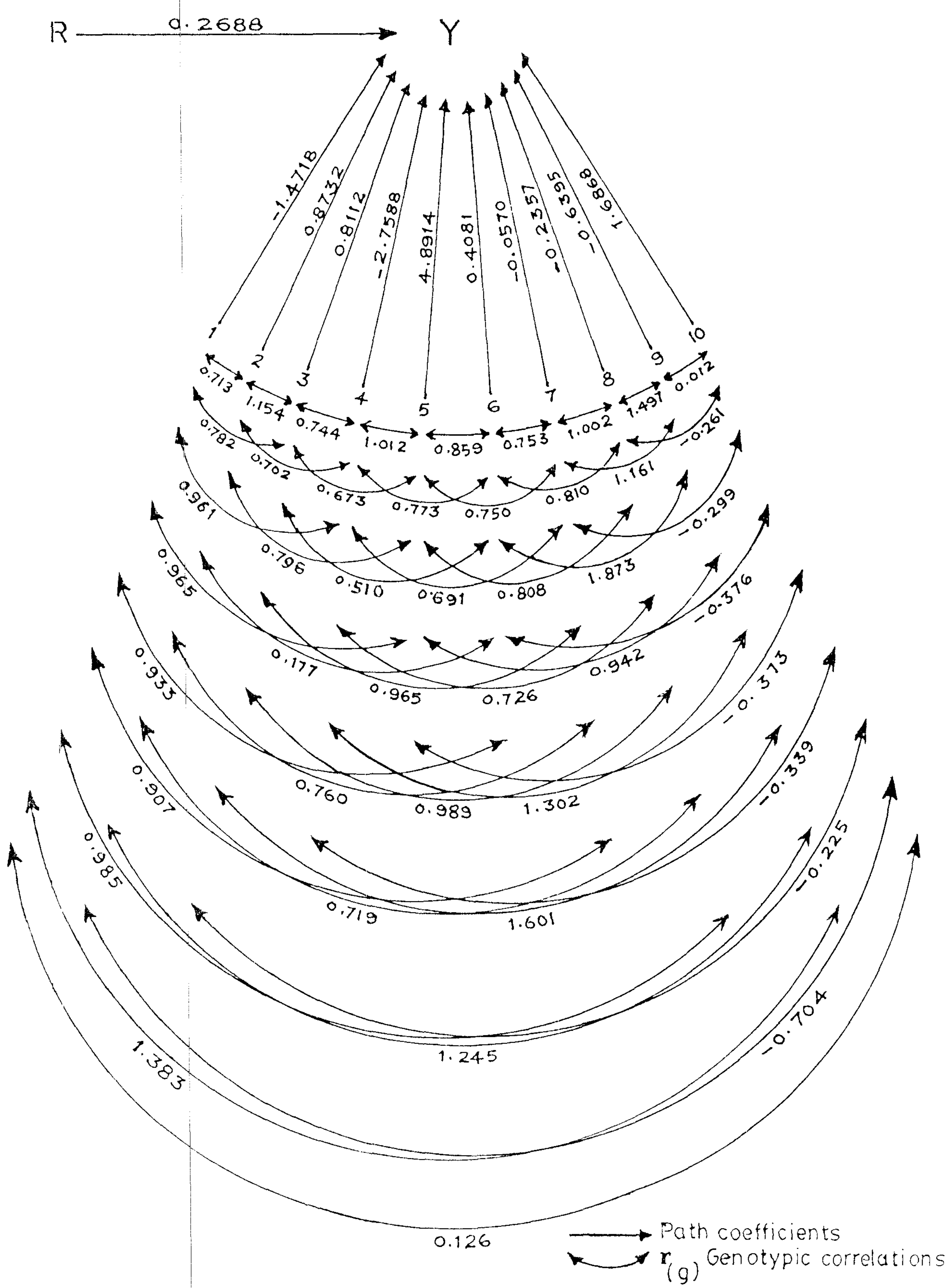
8 = Number of days from sowing to harvest

9 = Number of seeds per pod

10 = 100 - Seed weight

Y = Seed yield

FIG. 6. PATH DIAGRAM INDICATING DIRECT AND INDIRECT EFFECTS OF THE COMPONENT CHARACTERS ON YIELD



that these components might influence yield by their indirect effects through other components. Thus for example height of plant at harvest has been observed to have positive indirect effects on seed yield through number of pods per plant (3.5512), 100 seed weight (1.3630), number of primary branches at harvest (0.8601), and number of secondary branches at harvest (0.5832). Similarly number of clusters per plant is seen to have positive indirect effect through number of pods per plant (4.9501), number of secondary branches at harvest (0.6035), length of pod bearing branches (0.3154) and number of days from sowing to harvest (0.001). The same holds good in case of number of days from sowing to 50 per cent flowering which has shown positive indirect effects through number of pods per plant (3.6686), number of secondary branches at harvest (0.7828),number of primary branches at harvest (0.6637) and length of pod bearing branches (0.3703). Same is the case with reference to number of days from sowing to harvest, which has exhibited positive indirect effect through number of pods per plant (3.9523), number of secondary branches at harvest (0.8023), number of primary branches at harvest (0.6279), length of pod bearing branches (0.3305) and number of days to 50 per cent flowering (0.0001). In the case of number of seeds per pod also high positive indirect effect on seed yield is seen through number of pods per plant (4.6077), number of secondary branches at harvest (1.2987), number of primary branches at harvest (1.0872) and 100 seed weight (0.0911).

The residual effect calculated in the path coefficient analysis amounts to only $\sqrt{0.07227}$. This indicates that about 93 per cent of the variation in seed yield in red gram is contributed by the ten component traits considered for the path analysis. This comparatively low value obtained in the present case fully supports the right choice of components in red gram for path coefficient analysis. As such, from the results of present study it can be concluded that greater emphasis has to be laid for improving number of pods per plant, 100 seed weight, number of primary branches at harvest, number of secondary branches at harvest and length of pod bearing branches which have shown high positive direct effect to seed yield.

Discriminant function analysis

Hazel (1943) suggested that selection based on a suitable index was highly efficient. Goulden (1959) believed that the discriminant function would ensure a maximum concentration of the desired genes in the plants or in the lines selected. Hence the descriminant function analyses (Fisher, 1936 and Smith, 1936) were carried out with a view to evolving a selection index for isolating superior genotypes from among those tested. Seven models using various combinations of yield and its components were tried. These traits were selected based on their direct effects and genotypic correlations with yield.

Maximum efficiency of selection index over direct selection (9.8%) was observed when all the seven characters viz., seed yield, height of the plant at harvest, number of primary branches at harvest, number of clusters per plant, number of pods per plant, number of seeds per pod and hundred seed weight, were included. But for the ease of selection, the selection index should be formulated with minimum number of easily measurable characters. Here the selection index formulated by using seed yield, number of pods per plant and 100 seed weight, which has an efficiency of 8.4 per cent, is more useful. This is seen to include 57 per cent of the factors determining the yield. The selection index formulated with seven traits is seen to include only 59 per cent of the factors determining the yield.

Hence from the results of discriminant function analysis carried out in the present study, it can be concluded that greater emphasis has to be laid for improving number of pods per plant and 100 seed weight. The selection index formulated by using seed yield, number of pods per plant and 100 seed weight is suggested for selecting superior genotypes. By using the above selection index the genotype T_9 (NBPGR, Acc.No.11 (EC-10046-1) followed by T_1 (NBPGR, Acc.No.124 PLA-345-1) is suggested for selection for increasing the yield in red gram. By using the selection index formulated with seven traits, the genotype T_1 ((PLA-345-1) followed by T_9 (EC-10046-1) is to be the sequence for the improvement in yield.

Summary

SUMMARY

Genetic studies in Red gram (Cajanus cajan L. Millsp.) were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara, during 1983-86. One hundred and twelve genotypes of Red gram exhibiting wide diversity in the expression of various economic characters, obtained from the Regional Centre of the National Bureau of Plant Genetic Resources, Vellanikkara and Tamil Nadu Agricultural University, Coimbatore were raised during the khariff season of 1983-84 in a randomized block design with two replications. Observations on eleven economic characters were recorded from ten plants per treatment. The data were subjected to suitable statistical analyses for estimating the general variability available in the material, for finding out the genetic distances among the genotypes and for grouping them into clusters according to their genetic distances following the Mahalanobis' D^2 statistic.

Based on both the inter and intracluster distances, 20 genotypes representing the broad spectrum of variability present in the material, and having diversified geographical

origin were selected and utilised in the second field experiment which was laid out in a 20 x 4 R.B.D. having a plot size of 5 m x 3.5 m containing 5 rows of six plants in each row. Observations were recorded from the middle twelve plants of each plot leaving one row all around for avoiding border effect. The data were subjected to suitable statistical analyses for estimating the variability available in the selected genotypes, for working out the heritable portion of the variability, for finding out the degree of association of the different components of yield with yield either directly or indirectly and for evolving a selection index for isolating superior genotypes from among those tested.

The important findings are summarised below.

1. The 112 genotypes studied showed significant differences for eight out of eleven characters studied, viz., height of plant at harvest, number of primary branches at harvest, number of clusters per plant, number of pods per plant, length of pod bearing branches, number of days from sowing to 50 per cent flowering, 100 seed weight and seed yield.

2. The genetic component of variation was found to exceed the environmental component in the case of height of the plant at harvest, number of days to 50 per cent flowering, number of clusters per plant, seed yield and number of pods per plant. Number of primary branches at harvest, length of pod bearing branches and 100 seed weight were moderately influenced by genetic causes and number of secondary branches at harvest, number of days from sowing to harvest and number of seeds per pod were highly influenced by environment.

3. Heritability in the broad sense was high (over 50%) for five characters, moderately high (30% to 50%) for three characters and low (below 30%) for rest three characters.

4. The 112 genotypes fell into five distinct clusters based on the genetic distances among them.

5. The intracluster distance was maximum in cluster II and the clusters IV and V, constitute each one genotype viz. T_{19} and T_{13} respectively.

6. The intercluster distance was maximum between clusters IV and V and minimum between clusters III and IV.

7. Genotypes of the same place of origin fell into

different clusters while those of diversified origin fell into the same duster.

8. Cluster III showed high mean values for many of the desirable characters while cluster II showed low mean values for the desirable attributes.

9. The twenty selected genotypes showed significant differences with reference to the seven characters out of eleven studied and the rest four did not satisfy the test of significance.

10. The range of variation for all the parameters except number of days from sowing to harvest was fairly large.

11. Variance estimates showed that the total variance in two out of eleven characters studied were due to genetic causes and in the rest nine, the genotypic variance was highly influenced by fluctuating environment.

12. The values estimated for phenotypic and genotypic coefficient of variation showed that number of clusters per plant, number of pods per plant and seed yield possessed high estimates of over 20 per cent, number of secondary branches at harvest and number of days from sowing to 50 per cent flowering showed moderate of 10 per cent to 20 per cent while the rest showed below 10 per cent.

13. High heritability estimates of over 85% were shown by number of days from sowing to 50 per cent flowering and number of days from sowing to harvest while height of plant at harvest, number of clusters per plant, number of pods per plant and seed yield showed moderate (30% to 50%) and the rest showed below 30 per cent.

14. Number of days to 50 per cent flowering showed moderate genotypic coefficient of variation coupled with high heritability while seed yield possessed high genotypic coefficient of variation together with moderate heritability.

15. Genetic advance estimated in absolute values was promising for all the characters except number of seeds per pod.

16. The genetic gain estimate was maximum for seed yield (28.26%) and minimum for number of seeds per pod (-0.59%). The other characters exhibited estimates of genetic gain in between the two extremes.

17. Characters like number of days from sowing to 50 per cent flowering (0.973) and seed yield(0.484) exhibited high or moderately high estimates of heritability coupled with high or moderately high (38%) genetic gain estimates,

thereby indicating the involvement of additive gene effect. Hence these characters can be improved by straight selection. Characters like number of days from sowing to harvest, height of plant at harvest etc. possessed high or moderately high estimates of heritability together with low values of genetic gain thereby suggesting the action of non-additive genes including dominance and epistasis. Hence, straight selection has limited scope for improving these traits.

18. The ranking of the selected genotypes for the different economic traits revealed that the different genotypes carried superiority with regard to various traits suggesting the possibility of combining the desirable attribute through effective combination breeding programme by selecting genotypes from the available material.

19. Results of correlation studies have revealed that phenotypic and genotypic correlation coefficients for a number of traits were of comparable magnitudes. However, genotypic correlation coefficients were higher than phenotypic correlation coefficients in almost all the cases.

20. In nine out of ten cases, there has been significant positive correlation between the component

character and seed yield both in the phenotypic and genotypic levels. However, the correlation of 100 seed weight with seed yield was not significant both at phenotypic and genotypic levels.

21. Inter correlations studied have shown that characters exhibiting significant association with seed yield per plant were also highly intercorrelated, thereby suggesting the possibility of their simultaneous improvement. The 100 seed weight was negatively correlated with six other yield component characters, thereby, suggesting that the improvement of 100 seed weight through selection was possible only at the expense of those six components.

22. Results of path coefficient analysis have brought out that number of pods per plant, 100 seed weight, number of primary branches at harvest, number of secondary branches at harvest, and length of pod bearing branches had high positive direct effects on seed yield, in that order. Height of plant at harvest, number of clusters per plant, number of days from sowing to 50 per cent flowering, numb r of days from sowing to harvest and number of seeds per 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.

23. The residual effect was $\sqrt{0.07227}$ indicating that about 93 per cent of the variation in yield was contributed by the ten components considered in path coefficient analysis.

24. Maximum efficiency of selection index over direct selection (9.8%) was observed when seven characters were included. The selection index formulated with characters like seed yield, number of pods per plant and 100 seed weight showed an efficiency of 8.4 per cent over direct selection and it included 57 per cent of the factors determining the yield. Hence it is suggested for isolating superior genotypes.

25. A comparison of different genotypes based on the index value has revealed the superiority of the genotypes NBPGR 11 - EC-10046-1 and NBPGR 124-PLA-345-1 over others.

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* Originals not seen

Appendices

APPENDIX - I

Mean values for the different characters in the 112 genotypes of red gram

Varieties	Height of plant at harvest (cm) (x_1)	Number of primary branches at harvest (x_2)	Number of secondary branches at harvest (x_3)	Number of clusters per plant (x_4)	Number of pods per plant (x_5)	Length of pod bearing branches (cm) (x_6)	Number of days from sowing to 50% flowering. (x_7)	Number of days from sowing to harvest (x_8)	Number of seeds per pod (x_9)	Hundred seed weight (g) (x_{10})	Seed yield (g) Y
V_1	319.90	16.50	39.95	82.00	349.80	165.50	103.00	181.50	4.50	5.25	41.00
V_2	226.25	12.75	34.65	47.00	191.70	183.15	73.00	182.00	4.00	6.95	17.80
V_3	325.25	18.30	93.30	210.95	411.60	208.00	103.00	182.00	4.00	6.45	66.00
V_4	299.50	14.10	66.00	146.20	711.57	177.00	102.00	181.00	4.00	6.05	69.40
V_5	327.50	13.50	71.25	134.00	629.20	201.00	103.00	180.00	4.10	7.30	60.10
V_6	321.00	11.70	45.10	121.10	536.90	157.50	103.00	181.00	4.00	6.15	56.25
V_7	296.50	8.90	54.60	162.70	780.97	181.50	102.00	182.00	4.00	6.80	78.40
V_8	306.50	12.60	52.85	109.20	483.00	172.00	103.00	181.00	4.00	7.20	51.30
V_9	319.00	12.00	73.30	181.00	925.15	178.00	102.00	180.00	4.00	6.25	100.10
V_{10}	198.60	20.80	60.75	72.22	215.80	125.50	72.00	182.00	4.00	8.30	22.60
V_{11}	129.00	13.20	27.80	29.50	101.30	73.00	72.00	182.00	4.20	6.95	6.80
V_{12}	306.75	13.75	51.55	165.85	779.15	195.65	102.00	180.00	4.00	6.30	38.60
V_{13}	317.50	12.00	64.80	141.10	705.50	209.50	102.00	180.00	3.90	7.45	55.10
V_{14}	325.00	9.70	27.10	71.10	359.50	184.50	102.50	180.00	3.90	6.80	48.20
V_{15}	311.50	12.10	36.80	147.90	709.90	182.00	103.00	181.00	4.00	6.22	84.40

(Contd.)

Varieties	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	Y
V_{16}	164.00	10.40	35.70	36.90	147.60	90.00	72.00	181.00	3.20	6.75	17.80
V_{17}	324.00	8.10	31.90	75.80	365.00	218.50	102.00	182.00	4.30	9.70	90.65
V_{18}	279.00	8.60	46.36	92.90	437.50	194.00	102.00	182.00	4.00	6.97	81.70
V_{19}	212.50	12.70	37.00	83.80	335.20	139.00	73.00	182.00	4.00	7.25	60.40
V_{20}	310.50	10.70	52.30	129.90	570.00	184.50	103.00	180.00	4.00	5.85	103.50
V_{21}	313.50	9.70	36.15	81.10	422.00	197.00	103.00	180.00	4.00	6.65	66.10
V_{22}	264.50	12.80	42.10	88.60	424.60	140.60	72.50	181.00	4.00	8.25	24.90
V_{23}	253.00	9.40	30.30	71.20	356.00	171.00	72.00	182.00	4.00	9.55	93.20
V_{24}	323.00	9.00	37.70	192.70	807.60	179.50	101.50	182.50	3.90	5.70	108.70
V_{25}	318.00	10.80	52.70	322.40	1481.55	183.00	102.00	181.50	3.80	5.70	92.53
V_{26}	233.00	10.60	40.30	68.80	255.55	120.00	73.00	181.00	4.00	7.10	23.60
V_{27}	324.50	7.30	31.82	82.30	370.33	162.90	103.00	181.00	4.40	8.25	55.50
V_{28}	304.00	14.20	55.00	126.70	557.50	182.00	102.00	182.00	4.00	6.75	56.35
V_{29}	308.00	7.70	29.55	157.60	534.75	158.00	102.00	182.00	3.40	7.85	100.25
V_{30}	300.50	10.30	39.30	149.10	613.90	180.00	103.00	182.00	3.70	5.45	81.50
V_{31}	242.50	10.00	34.05	71.00	256.40	142.00	72.00	186.00	3.60	7.48	64.90
V_{32}	317.00	10.50	44.60	179.20	736.70	184.00	102.00	181.00	3.80	5.75	82.70
V_{33}	162.50	6.80	18.70	9.85	34.80	105.00	73.00	186.00	3.35	7.70	8.50
V_{34}	313.00	9.10	34.00	133.50	626.05	186.00	103.00	182.00	4.10	7.40	131.10
V_{35}	305.00	9.70	32.50	120.00	453.25	145.00	102.00	181.00	3.80	8.05	67.40
V_{36}	185.50	9.80	26.50	28.20	106.30	111.50	72.00	181.00	3.90	8.35	10.60
V_{37}	307.50	9.10	34.20	111.10	516.95	185.50	102.00	180.00	4.00	6.20	64.90
V_{38}	217.00	12.20	43.80	64.00	286.00	129.00	71.00	182.00	4.00	7.35	37.20

(Contd.)

Varieties	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	Y
V_{39}	323.00	9.70	32.26	134.90	653.00	209.00	103.00	180.00	4.00	6.03	109.75
V_{40}	291.50	9.90	57.85	100.90	443.70	174.00	103.00	181.00	4.00	6.12	56.70
V_{41}	203.00	10.40	36.70	66.70	315.90	103.50	73.00	182.00	4.00	9.15	29.30
V_{42}	317.00	12.70	51.65	168.60	777.40	176.50	103.00	183.00	4.30	7.40	113.80
V_{43}	320.00	10.30	34.55	145.20	652.85	183.00	101.00	181.00	4.00	7.05	77.60
V_{44}	309.00	9.60	47.00	117.10	519.85	183.00	103.00	182.00	4.00	6.75	63.70
V_{45}	310.00	10.30	42.10	117.10	547.30	189.00	103.00	182.50	3.80	5.85	72.70
V_{46}	294.50	10.60	52.98	230.50	980.60	197.00	103.00	181.50	4.00	4.78	93.60
V_{47}	316.50	10.30	34.53	110.50	521.35	177.50	102.00	182.50	4.00	6.90	50.10
V_{48}	308.00	13.40	45.90	117.30	470.00	175.50	101.00	181.50	3.90	7.50	27.80
V_{49}	331.50	12.10	30.23	219.40	1031.06	190.00	103.00	181.50	4.00	6.30	91.30
V_{50}	316.00	15.20	60.75	183.75	772.50	202.00	100.00	182.00	4.00	7.15	86.10
V_{51}	354.00	14.10	53.55	160.25	634.50	171.00	101.00	182.00	4.00	6.10	83.00
V_{52}	297.50	10.90	31.35	80.75	315.85	144.00	102.00	181.50	3.90	7.90	35.70
V_{53}	339.00	10.70	37.90	86.80	369.55	201.50	103.00	180.50	4.00	10.25	72.40
V_{54}	295.50	12.00	39.55	209.80	868.85	157.50	102.00	182.00	3.90	8.55	132.00
V_{55}	343.50	8.10	22.35	250.35	1003.00	177.50	103.00	181.00	4.00	6.65	126.85
V_{56}	294.50	10.60	52.98	230.50	980.60	197.00	103.00	181.50	4.00	4.78	93.60
V_{57}	298.00	10.00	36.80	145.90	639.85	133.00	103.00	180.00	3.90	7.57	64.00
V_{58}	252.50	13.60	53.59	73.20	274.00	150.00	73.50	178.00	4.00	6.50	297.40
V_{59}	304.00	8.20	35.14	136.20	612.85	217.50	102.00	180.00	4.10	7.10	102.90
V_{60}	313.00	13.30	53.20	117.40	474.90	184.50	101.00	182.00	4.00	7.25	74.00

(Contd.)

Varieties	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	Y
V_{61}	304.00	6.90	24.20	99.20	435.90	185.50	102.00	181.00	4.00	5.60	63.20
V_{62}	311.00	5.70	27.50	118.60	502.05	210.00	102.00	182.00	4.00	7.25	92.80
V_{63}	321.00	11.30	45.85	124.20	595.65	168.00	102.00	181.00	4.00	7.45	47.60
V_{64}	330.00	9.30	43.60	215.80	1017.70	181.50	102.00	182.00	4.00	6.35	118.60
V_{65}	314.00	10.00	39.45	157.40	787.00	165.00	103.00	181.00	4.00	6.85	70.30
V_{66}	310.00	12.20	52.30	166.50	822.40	194.00	101.00	181.00	4.00	7.25	116.80
V_{67}	321.00	9.00	35.60	126.40	562.60	158.00	103.00	181.00	4.00	6.50	103.00
V_{68}	292.50	10.60	55.85	109.10	446.70	167.50	102.00	181.00	4.00	5.97	51.10
V_{69}	324.00	13.00	50.65	173.00	842.35	147.00	103.50	181.00	4.10	7.60	118.50
V_{70}	177.00	8.10	27.20	36.20	147.60	993000	73.00	180.00	4.00	6.87	32.95
V_{71}	204.00	11.95	37.10	61.65	209.25	90.05	72.50	183.00	4.00	6.60	31.95
V_{72}	315.00	11.90	46.30	168.80	767.85	180.00	102.50	180.00	4.00	5.45	99.10
V_{73}	312.00	11.30	46.40	130.40	653.45	171.00	101.00	181.00	4.00	5.95	78.40
V_{74}	321.00	11.20	48.60	178.60	750.25	165.00	101.00	182.00	4.00	6.25	87.30
V_{75}	210.00	12.60	38.85	80.20	300.15	114.00	73.50	180.00	4.00	6.25	31.80
V_{76}	316.50	13.80	53.45	211.50	960.60	161.00	102.00	181.00	3.90	8.32	92.30
V_{77}	317.00	9.30	34.25	105.00	504.00	174.00	100.50	181.00	4.00	7.05	86.40
V_{78}	325.50	10.30	40.00	167.30	769.55	186.00	102.50	182.00	4.00	7.10	76.60
V_{79}	246.00	10.00	31.40	44.00	171.50	161.40	72.50	180.00	3.90	6.75	9.10
V_{80}	327.00	13.40	50.90	172.10	722.80	183.00	103.00	181.00	4.00	7.25	107.30
V_{81}	321.00	12.30	57.75	106.10	448.55	165.00	101.50	183.00	4.00	6.87	71.10

(Contd.)

Varieties	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	Y
V_{82}	278.50	9.20	43.55	95.60	387.48	150.00	101.50	183.00	4.10	9.20	56.20
V_{83}	213.00	10.10	29.34	69.90	300.70	114.00	72.50	180.00	4.00	7.55	35.00
V_{84}	312.00	12.60	286.40	137.20	582.30	187.50	105.00	180.00	4.10	7.20	97.00
V_{85}	330.00	10.60	39.25	152.40	689.25	183.00	102.00	180.50	4.00	6.10	75.00
V_{86}	322.00	11.20	44.80	97.70	399.10	190.50	101.00	180.00	4.00	7.55	89.90
V_{87}	345.00	8.80	34.45	108.60	510.15	159.00	101.00	181.00	4.00	7.80	61.15
V_{88}	345.00	15.00	71.90	151.60	651.40	176.00	100.50	182.00	4.00	6.20	104.80
V_{89}	325.25	7.90	34.85	111.20	520.35	188.75	100.50	183.00	3.90	5.95	46.90
V_{90}	318.00	12.30	51.65	172.10	777.35	168.00	102.00	180.00	4.00	6.80	89.25
V_{91}	304.50	11.30	41.75	109.20	439.45	147.00	104.50	180.00	4.00	8.87	116.70
V_{92}	258.00	15.90	57.30	121.50	544.20	137.50	73.50	181.00	3.80	7.40	56.20
V_{93}	199.10	9.40	24.95	25.90	102.55	118.30	72.00	182.00	4.10	9.10	13.50
V_{94}	307.50	13.30	57.20	152.20	597.00	165.00	100.50	183.00	4.00	6.50	76.40
V_{95}	281.40	15.20	74.25	64.80	273.05	194.20	72.50	180.00	4.00	6.75	29.60
V_{96}	336.00	15.90	77.80	166.40	698.90	174.00	101.50	181.00	4.00	8.75	72.10
V_{97}	231.00	15.90	64.65	109.10	449.60	151.50	73.00	183.00	3.80	7.10	22.10
V_{98}	312.00	14.70	68.40	94.00	413.50	162.00	102.00	181.00	4.00	6.75	34.10
V_{99}	334.00	13.20	55.50	160.80	794.30	210.50	102.00	181.00	4.00	7.93	73.00
V_{100}	181.50	13.50	79.30	58.60	265.10	126.60	72.00	180.00	4.00	6.60	9.80
V_{101}	321.00	10.40	48.30	111.40	547.05	174.00	105.00	181.00	4.00	6.95	70.40
V_{102}	324.00	13.10	60.30	164.90	692.60	183.00	103.00	181.00	4.00	5.55	72.40
V_{103}	274.60	13.70	104.95	83.70	304.75	163.30	101.00	180.00	4.00	6.55	27.60

(Contd.)

Varie-ties	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	Y
V_{104}	330.00	14.80	77.95	154.30	709.80	183.00	100.00	181.50	4.00	7.60	89.90
V_{105}	325.00	11.40	45.65	153.50	670.20	211.00	101.00	180.00	4.00	6.75	99.90
V_{106}	321.75	10.15	49.05	76.25	335.00	177.25	100.00	181.00	4.00	7.20	65.40
V_{107}	318.00	12.50	52.20	120.80	539.65	200.50	103.00	183.00	4.00	7.18	71.70
V_{108}	319.00	10.40	50.75	119.70	536.10	171.00	103.00	181.50	4.00	6.88	78.70
V_{109}	309.00	12.40	53.60	100.80	475.05	178.50	102.00	181.50	4.90	8.25	84.00
V_{110}	301.00	6.70	31.85	82.90	314.80	165.00	101.00	180.50	4.00	5.85	50.80
V_{111}	133.15	8.75	19.45	18.00	64.08	84.40	71.00	181.50	3.62	6.55	8.30
V_{112}	159.90	13.05	26.20	59.55	310.48	131.80	72.00	183.00	4.00	5.95	30.45
C.D.=											
0.05	46.56	4.92	46.32	72.95	362.52	54.29	13.12	35.78	0.607	1.72	46.69
0.01	61.23	6.46	60.89	95.87	476.46	70.91	17.27	47.03	0.798	2.257	61.36

APPENDIX-II

D^2 values for 112 genotypes of Red Gram

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}
V_1	0	3722.85	5972.72	5814.43	5798.37	5820.45	5938.67	5867.14	5750.17	3648.87	3667.33	5733.83	5711.27	5773.83	5898.77
V_2		0	3506.72	3288.14	3309.70	3385.98	3544.98	3421.65	3282.37	21.96	34.46	3081.13	3066.86	3268.85	3529.70
V_3			0	213.39	204.25	215.59	204.02	185.12	292.07	3704.44	3909.55	196.53	233.95	244.67	214.98
V_4				0	3.52	6.73	13.32	4.66	11.41	3509.36	3694.34	6.01	7.52	10.96	5.76
V_5					0	5.48	17.98	4.74	12.56	3533.61	3729.58	7.43	7.64	8.46	7.23
V_6						0	17.04	4.26	12.02	3608.72	3802.23	15.39	14.95	6.20	5.77
V_7							0	10.21	28.58	3792.08	3959.07	25.34	27.49	24.15	6.54
V_8								0	21.94	3649.11	3836.27	13.55	15.80	9.14	3.74
V_9									0	3505.29	3697.44	18.69	12.69	15.73	16.03
V_{10}										0	32.62	3297.73	3291.35	3501.39	3763.61
V_{11}											0	3481.02	3474.45	3687.34	3952.19
V_{12}												0	3.89	16.57	18.43
V_{13}													0	9.54	19.75
V_{14}														0	12.95
V_{15}															0
V_{16}	3641.28	49.75	3839.67	3543.35	3577.36	3633.43	3806.20	3682.44	3579.81	61.10	57.07	3338.94	3312.55	3509.63	3791.98
V_{17}	5836.94	3251.96	185.14	20.71	18.41	27.11	20.01	16.62	44.21	3497.51	3659.74	22.93	23.36	21.77	22.51
V_{18}	5839.26	3167.55	176.82	24.16	30.22	37.44	20.48	22.61	54.84	3410.20	3555.98	24.63	26.47	31.28	31.19
V_{19}	3726.85	7.16	3432.36	3197.72	3221.65	3289.34	3452.05	3331.79	3182.34	22.12	37.07	2996.74	2983.00	3180.78	3435.13
V_{20}	5888.82	3417.66	173.43	8.30	10.01	10.04	5.53	3.64	27.27	3653.20	3830.29	17.51	19.61	14.94	5.64
V_{21}	5810.28	3288.93	224.56	7.29	6.53	9.08	14.48	5.86	19.07	3527.13	3703.28	13.23	8.72	3.34	9.13
V_{22}	3615.75	49.90	3597.52	3258.84	3274.73	3336.83	3532.75	3399.37	3211.06	55.79	103.81	3058.53	3034.24	3226.66	3496.67
V_{23}	3618.69	25.26	3715.80	3403.08	3421.76	3489.90	3668.08	3544.08	3364.94	46.23	66.13	3198.57	3172.29	3370.27	3643.96

(Contd.)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}
V_{24}	5895.65	3472.10	166.25	17.87	19.07	13.65	8.20	12.28	30.47	3708.47	3889.52	24.86	29.17	25.01	10.72
V_{25}	5925.43	3467.68	143.77	633.31	621.31	626.77	600.15	590.08	739.04	3685.41	3829.22	584.03	641.74	667.18	639.18
V_{26}	3671.57	21.86	3499.44	3232.10	3251.37	3312.47	3491.42	3365.28	3202.24	34.22	58.42	3030.67	3011.92	3203.44	3468.66
V_{27}	5830.46	3388.13	213.60	16.82	11.85	9.43	17.60	10.40	25.27	3625.22	3799.22	24.37	24.32	12.73	13.07
V_{28}	5858.68	3339.74	165.53	4.23	6.24	9.74	12.49	2.27	27.37	3562.07	3747.51	9.41	14.92	15.13	7.41
V_{29}	5872.06	3416.79	152.78	45.62	47.57	33.85	34.42	32.54	63.58	3650.40	3830.54	50.07	51.26	40.20	39.13
V_{30}	5988.98	3643.54	159.07	25.16	29.08	23.57	8.87	13.53	50.80	3887.02	4066.14	38.48	43.01	32.46	14.16
V_{31}	3875.64	45.20	2984.17	2743.09	2767.35	2821.03	2973.72	2864.11	2725.88	84.88	112.22	2560.47	2540.94	2716.63	2960.12
V_{32}	5835.07	3325.02	157.10	12.75	13.32	10.85	12.51	9.10	27.14	3553.38	3737.82	14.36	18.05	18.06	12.09
V_{33}	3935.71	67.04	3084.19	2844.45	2881.47	2933.86	3060.06	2964.11	2845.83	122.39	101.07	2662.29	2642.55	2819.47	3065.60
V_{34}	5937.64	3587.74	206.19	15.16	16.15	13.90	4.78	8.97	28.45	3833.46	4009.56	30.80	31.10	20.20	4.84
V_{35}	5781.08	3238.85	181.96	15.80	16.09	7.80	22.83	10.73	26.46	3460.40	3641.51	18.13	18.37	11.25	17.80
V_{36}	3588.89	24.46	3791.27	3704.71	3731.59	3799.38	3974.07	3846.23	3685.13	31.65	20.80	3489.99	3470.32	3676.29	3959.08
V_{37}	5738.80	3086.06	204.83	9.72	10.16	12.92	20.58	11.73	21.17	3315.77	3484.38	6.98	5.28	8.12	18.07
V_{38}	3595.35	20.28	3869.44	3584.41	3608.41	3677.24	3858.32	3728.41	3556.85	22.77	33.30	3373.70	3354.05	3560.06	3835.84
V_{39}	5836.85	3367.46	213.31	7.01	5.97	8.27	8.95	6.10	15.72	3607.37	3788.66	13.86	11.32	7.77	4.67
V_{40}	5884.10	3377.67	171.27	10.87	13.48	14.43	6.90	4.90	34.93	3615.42	3782.15	18.13	20.51	16.24	10.67
V_{41}	3683.75	22.57	3544.99	3243.63	3268.89	3329.92	3500.98	3381.09	3213.58	38.22	46.78	3045.06	3025.34	3219.11	3481.92
V_{42}	6000.87	3768.21	201.64	22.39	22.90	21.71	12.77	16.16	37.82	4004.99	4195.55	42.06	49.30	39.24	8.99
V_{43}	5711.18	3055.76	206.08	9.82	9.53	11.06	25.71	14.43	15.76	3277.01	3455.59	5.35	4.90	10.27	19.19
V_{44}	5939.96	3550.11	177.78	13.44	14.45	12.90	3.59	4.76	34.50	3793.78	3969.39	25.32	27.78	18.37	6.01
V_{45}	6004.90	3722.79	204.43	21.55	24.58	20.09	7.32	11.26	42.04	3972.56	4154.52	40.46	40.53	25.66	8.67

(Contd.)

	v_1	v_2	v_3	v_4	v_5	v_6	v_7
v_{46}	5957.18	3506.62	127.53	31.89	36.54	40.49	13.80
v_{47}	5887.82	3461.86	204.79	6.65	7.59	4.98	6.15
v_{48}	5737.09	3066.96	168.69	10.50	11.24	13.55	29.90
v_{49}	5983.71	3605.18	109.39	588.32	571.46	577.62	557.89
v_{50}	5691.75	2921.26	155.46	20.00	21.05	31.53	44.41
v_{51}	5822.57	3441.54	190.23	18.25	12.48	6.62	32.74
v_{52}	5803.04	3257.14	188.12	10.27	11.58	6.03	19.80
v_{53}	5767.64	3257.47	203.69	12.20	5.55	6.85	26.23
v_{54}	5842.65	3342.21	158.46	14.54	18.52	14.46	14.67
v_{55}	5972.69	3701.35	209.17	775.23	753.92	574.78	734.73
v_{56}	6066.83	3850.93	147.65	37.93	37.33	35.77	16.44
v_{57}	5809.06	3377.02	225.32	11.89	13.34	3.37	17.35
v_{58}	3609.68	84.36	3630.79	3320.97	3336.15	3398.89	3595.16
v_{59}	5711.10	2932.40	178.64	28.35	28.99	40.47	36.08
v_{60}	5768.94	3120.71	157.44	9.11	9.16	13.58	24.82
v_{61}	5813.21	3199.50	180.04	16.97	18.41	19.44	14.36
v_{62}	5839.76	3220.09	160.61	29.05	29.90	33.95	18.56
v_{63}	5783.68	3303.85	237.86	5.36	4.47	1.55	18.91
v_{64}	5935.98	3477.77	120.87	586.58	570.73	575.09	554.92
v_{65}	5885.49	3571.77	262.49	12.17	13.68	7.18	11.19
v_{66}	5711.56	3058.17	239.56	7.33	10.21	15.04	26.72
v_{67}	5904.07	3607.13	227.17	17.15	15.93	6.20	12.34
v_{68}	5806.52	3181.45	158.08	11.02	13.36	15.30	16.03
v_{69}	5932.87	3814.76	300.98	33.21	32.43	21.39	35.52
v_{70}	3628.58	24.68	3816.48	3541.83	3569.20	3632.83	3801.41

v_8	v_9	v_{10}	v_{11}	v_{12}	v_{13}	v_{14}	v_{15}
26.86	61.37	3746.11	3914.06	34.99	48.23	55.41	26.62
1.96	20.75	3699.29	3880.04	17.05	17.39	8.51	2.50
11.48	28.51	3279.42	3463.70	7.34	9.82	13.54	21.68
537.12	700.68	3797.38	3981.99	548.67	603.97	613.75	587.89
28.09	39.46	3126.27	3311.61	7.65	15.33	34.50	38.06
13.91	22.24	3653.63	3870.79	25.68	28.67	20.11	15.25
5.15	26.69	3479.47	3657.68	14.73	15.50	7.15	13.59
8.14	20.61	3485.72	3680.21	14.74	10.89	3.55	14.06
13.52	28.22	3562.23	3743.58	18.50	25.90	27.85	13.85
716.23	890.04	3892.47	4071.84	727.94	787.33	796.02	772.11
21.49	69.69	4098.71	4286.68	54.50	64.10	50.30	20.67
10.00	13.08	3600.45	3784.39	20.01	19.47	11.08	10.09
3459.15	3273.55	85.82	135.05	3130.30	3100.20	3296.32	3555.97
32.57	48.57	3165.69	3319.92	17.01	18.72	32.89	41.64
8.88	30.37	3337.15	3520.32	7.00	10.96	14.87	18.64
12.90	37.08	3440.99	3598.54	16.82	17.06	15.50	19.75
23.27	54.03	3469.54	3621.95	27.26	28.73	29.90	29.99
6.86	6.87	3528.29	3718.31	11.35	8.73	4.07	7.63
537.60	693.28	3673.15	3845.17	545.37	596.58	607.94	589.09
11.79	10.54	3809.22	3996.18	27.15	24.76	15.12	4.30
18.41	9.64	3278.66	3457.32	5.95	3.59	14.15	18.93
9.54	20.70	3844.83	4033.35	32.99	31.74	14.60	5.85
8.18	34.63	3407.77	3574.87	10.83	14.75	16.45	17.84
31.31	23.65	4042.73	4252.84	58.41	56.42	38.56	18.46
3680.57	3519.01	38.59	23.06	3333.83	3314.19	3514.29	3789.26

(Contd.)

	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	v_{13}	v_{14}	v_{15}
v_{71}	3757.58	21.40	3322.02	3076.71	3102.10	3160.04	3327.13	3206.43	3058.66	34.17	49.17	2892.78	2869.11	3056.77	3309.32
v_{72}	5816.02	3340.59	201.42	3.80	4.03	3.54	11.33	5.03	10.18	3565.17	3754.35	9.38	10.79	10.32	4.06
v_{73}	5739.60	3157.45	250.25	5.14	7.22	6.92	22.67	11.97	5.91	3379.85	3560.63	8.35	4.54	6.11	12.91
v_{74}	5804.91	3286.09	176.19	9.11	9.34	5.89	15.38	8.67	17.58	3506.58	3693.39	11.44	15.59	15.95	10.54
v_{75}	3671.93	15.45	3534.05	3284.84	3307.03	3371.19	3546.75	3420.02	3261.85	20.87	40.77	3081.11	3066.33	3263.29	3525.12
v_{76}	5784.26	3346.91	232.87	10.80	11.90	7.33	25.43	16.25	6.86	3560.12	3761.79	16.38	17.90	19.34	12.29
v_{77}	5671.89	2981.23	245.84	15.41	15.65	15.80	36.06	21.72	16.76	3203.17	3376.39	12.36	6.65	9.25	27.47
v_{78}	5901.19	3539.89	204.06	9.50	9.35	6.27	5.25	5.88	17.74	3777.68	3965.67	20.20	21.93	15.34	1.84
v_{79}	3593.25	19.08	3791.27	3518.04	3535.32	3604.14	3788.06	3655.86	3488.92	32.31	52.70	3305.59	3282.59	3482.52	3764.37
v_{80}	5886.98	3529.97	173.19	11.25	8.78	6.65	14.17	6.04	22.81	3754.06	3956.74	21.38	25.99	19.43	4.95
v_{81}	5826.97	3352.26	194.15	5.82	4.75	1.62	16.10	2.25	17.32	3574.57	3766.24	14.23	14.23	6.46	6.59
v_{82}	5812.80	3154.51	162.05	17.93	22.67	23.32	19.03	14.78	44.46	3383.37	3536.10	17.98	23.03	24.19	25.08
v_{83}	3583.09	28.47	3842.96	3549.73	3572.08	3636.48	3819.86	3691.65	3515.65	33.67	43.08	3339.56	3318.72	3520.40	3797.42
v_{84}	5973.42	3747.18	220.15	58.24	54.34	59.90	48.87	50.48	72.43	3985.07	4178.67	80.97	76.64	73.31	55.15
v_{85}	5788.50	3298.93	210.60	6.34	4.22	2.44	15.17	6.74	9.45	3525.47	3715.90	9.78	9.13	6.70	7.01
v_{86}	5636.23	2872.47	202.25	23.51	20.43	25.77	50.41	27.88	33.61	3085.51	3265.73	13.96	11.41	18.23	40.22
v_{87}	5705.99	3219.26	284.64	23.62	18.85	10.48	43.10	25.64	11.34	3441.64	3636.55	27.94	19.36	9.92	26.43
v_{88}	5779.04	3321.91	215.76	11.36	7.91	5.62	32.91	13.02	12.51	3531.59	3744.15	18.55	18.07	14.50	14.31
v_{89}	5818.16	3259.47	207.56	10.27	11.50	9.67	11.51	8.38	22.05	3499.44	3670.46	13.37	10.67	7.22	11.79
v_{90}	5745.75	3219.60	220.46	7.01	6.34	4.71	23.54	11.63	6.53	3435.30	3628.14	8.96	8.99	10.94	12.03
v_{91}	5110.01	3625.43	203.47	19.09	17.25	8.37	17.66	8.71	29.08	3854.79	4048.37	37.01	37.13	18.18	8.44
v_{92}	3708.19	61.00	3280.48	2960.01	2977.87	3036.30	3225.77	3095.77	2916.41	66.68	131.03	2770.35	2748.78	2935.01	3188.52
v_{93}	3618.87	16.65	3851.05	3587.46	3612.05	3680.71	3852.56	3726.80	3588.29	28.59	20.01	3375.80	3357.59	3560.56	3837.44

	v_1	v_2	v_3	v_4	v_5	v_6	v_7
v_{94}	5815.51	3216.61	138.62	10.89	12.98	13.55	19.69
v_{95}	3598.08	15.64	3933.04	3712.03	3733.46	3818.73	3989.68
v_{96}	5727.30	3207.44	203.38	13.16	8.81	9.29	40.22
v_{97}	3780.07	18.90	3216.73	2978.56	3001.49	3067.59	3232.46
v_{98}	5862.97	3429.95	196.85	6.03	6.05	4.67	18.63
v_{99}	5772.97	3266.15	235.44	4.31	2.59	7.54	21.33
v_{100}	3568.89	27.04	4054.76	3792.31	3819.60	3896.06	4070.82
v_{101}	6050.58	3990.87	259.17	38.09	36.49	27.75	22.50
v_{102}	5917.37	3568.47	163.82	11.60	9.82	8.35	10.64
v_{103}	5670.16	2805.09	163.41	35.86	39.30	39.67	61.07
v_{104}	5660.08	2999.09	237.34	13.48	12.35	16.38	46.01
v_{105}	5683.87	2890.43	190.76	20.27	18.35	27.07	42.76
v_{106}	5622.92	2846.43	233.40	25.15	23.40	26.29	53.46
v_{107}	5998.47	3688.36	173.05	18.77	19.23	20.33	9.36
v_{108}	5921.98	3598.59	205.88	11.91	11.10	5.69	7.66
v_{109}	5763.14	3125.82	198.23	34.30	30.84	45.09	50.76
v_{110}	5694.12	2927.94	185.57	29.68	30.15	30.63	39.57
v_{111}	3599.99	54.90	4171.61	3919.02	3956.47	4022.97	4183.86
v_{112}	3737.42	14.71	3667.04	3426.97	3461.54	3536.55	3681.57

v_8	v_9	v_{10}	v_{11}	v_{12}	v_{13}	v_{14}	v_{15}
9.01	33.53	3431.58	3613.91	10.93	18.99	22.45	16.93
3856.52	3703.06	18.25	30.41	3491.71	3476.39	3695.89	3971.07
16.80	15.26	3409.42	3622.65	13.46	15.49	18.23	21.24
3110.53	2962.26	32.33	71.74	2783.46	2770.28	2964.88	3210.76
2.12	22.64	3649.38	3845.85	16.91	18.90	10.86	7.06
30.19	6.28	3490.82	3657.94	7.09	5.10	9.00	9.01
3940.28	3774.92	23.40	18.79	3574.29	3557.29	3775.21	4054.45
24.82	47.20	4242.06	4439.51	66.49	64.66	39.14	16.33
4.77	27.88	3796.29	3995.09	21.91	27.84	21.45	4.87
40.22	66.23	3010.53	3172.69	23.58	28.19	44.49	61.44
24.24	12.70	3203.08	3401.61	9.93	7.76	17.41	29.22
27.61	30.38	3106.74	3286.23	8.36	8.68	22.61	36.27
30.98	31.26	3061.17	3236.33	16.91	11.37	16.46	43.29
8.66	45.02	3930.83	4119.18	34.71	39.36	28.65	8.40
4.15	22.93	3836.29	4024.87	27.48	27.19	13.36	2.76
38.00	55.70	3343.52	3510.03	31.96	41.75	50.30	45.27
28.69	46.97	3155.23	3309.71	20.74	20.09	23.37	42.45
4063.19	3910.99	63.37	21.65	3700.82	3681.96	3894.45	4180.72
3568.20	3427.07	3 32.43	11.84	3220.68	3209.87	3420.11	3675.46

	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}	V_{21}	V_{22}	V_{23}
V_{16}	0	3536.88	3428.72	41.61	3681.19	5544.05	62.85	43,13
V_{17}		0	8.68	3174.14	10.75	9.89	3262.17	3380.13
V_{18}			0	3090.35	14.15	16.84	3196.11	3306.21
V_{19}				0	3327.52	3204.35	32.82	17.34
V_{20}					0	7.58	3407.93	3541.13
V_{21}						0	3267.13	3401.68
V_{22}							0	14.97
V_{23}								0
V_{24}								
V_{25}								
V_{26}								
V_{27}								
V_{28}								
V_{29}								
V_{30}								
V_{31}								
V_{32}	3574.55	23.22	23.28	3232.02	6.34	15.25	3304.94	3442.87
V_{33}	62.56	2812.40	2704.49	60.94	2952.25	2837.88	139.34	102.55
V_{34}	3856.78	16.25	25.48	3492.90	4.12	12.16	3568.43	3703.84
V_{35}	3469.27	28.12	28.68	3143.34	12.08	14.11	3205.47	3346.85
V_{36}	21.69	3677.32	3582.70	23.95	3843.82	3704.56	50.64	23.14
V_{37}	3333.23	11.78	13.72	3000.97	11.42	5.24	3067.09	3196.91
V_{38}	30.22	3567.28	3482.61	15.03	3728.25	[illegible]90.51	24.92	9.53

V_{24}	V_{25}	V_{26}	V_{27}	V_{28}	V_{29}	V_{30}	V_{31}
3727.87	3795.24	38.66	3657.60	3606.72	3636.92	3899.82	65.72
25.88	565.38	3217.03	13.87	14.78	52.60	30.88	2723.74
28.83	533.36	3139.83	30.22	17.35	43.58	27.33	2640.81
3374.46	3393.92	8.47	3295.45	3253.07	3319.36	3551.37	29.88
6.43	557.11	3366.48	11.71	4.26	26.20	8.66	2857.53
20.42	641.03	3236.28	10.07	8.87	41.10	24.59	2743.76
3449.62	3626.60	12.82	3354.40	3330.42	3402.01	3643.41	60.15
3587.95	3708.16	19.67	3495.49	3470.22	3535.53	3979.39	54.56
0	518.55	4408.26	18.52	14.21	15.98	8.63	2896.28
	0	3470.20	610.75	558.42	456.60	525.19	2968.59
		0	3321.01	3292.93	3349.19	3593.31	34.24
			0	16.72	46.55	30.92	2834.89
				0	36.10	15.43	2794.16
					0	17.34	2829.21
						0	3057.41
							0
3.09	505.19	3264.99	19.35	9.27	13.47	11.61	2764.71
2999.06	3049.35	79.73	2942.39	2890.80	2917.58	3142.07	29.50
9.23	612.09	3530.56	11.72	13.34	36.46	11.46	3012.36
11.77	536.52	3167.88	16.48	14.34	14.26	21.73	2679.01
3895.64	3908.81	24.88	3803.87	3765.76	3826.27	4080.83	84.06
19.67	580.71	3032.06	13.65	11.53	35.83	31.89	2555.90
3777.95	3837.58	12.54	3686.33	3649.09	3720.65	3968.10	70.22

(Contd.)

	v_{16}	v_{17}	v_{18}	v_{19}	v_{20}	v_{21}	v_{22}	v_{23}	v_{24}	v_{25}	v_{26}	v_{27}	v_{28}	v_{29}	v_{30}	v_{31}
v_{63}	3548.11	26.76	36.64	3209.46	13.25	7.17	3251.63	3403.20	18.29	659.19	3231.45	10.86	11.92	41.40	30.82	2747.90
v_{64}	3813.03	503.78	481.43	3407.72	505.41	582.34	3636.89	3711.88	478.32	12.13	3481.54	549.86	510.26	417.43	480.32	2976.27
v_{65}	3819.27	36.78	47.42	3470.59	15.39	15.52	3515.15	3669.98	15.95	702.10	3494.72	15.65	19.99	46.03	24.45	2989.44
v_{66}	3304.01	23.84	27.68	2968.08	18.63	11.95	3021.62	3186.93	26.37	644.35	2999.24	23.66	16.72	53.61	45.27	2529.48
v_{67}	3856.74	31.21	43.45	3505.11	10.40	15.16	3558.59	3708.48	19.60	639.86	3529.66	10.93	18.83	31.06	16.95	3017.64
v_{68}	3436.06	11.15	8.09	3096.59	6.60	9.90	3181.42	3310.34	15.04	513.10	3134.55	15.92	5.83	27.32	19.68	2645.63
v_{69}	4068.21	71.58	92.83	3702.18	38.67	42.76	3729.68	3901.25	37.39	775.98	3720.99	35.19	43.89	75.57	47.79	3209.05
v_{70}	23.11	3514.02	3421.61	17.77	3676.20	3541.40	44.62	29.24	3725.03	3759.76	17.07	3633.40	3603.58	3659.43	3909.70	66.32
v_{71}	42.17	3060.86	2977.33	5.83	3204.96	3084.49	31.67	26.86	3248.69	3291.45	7.35	3168.37	3132.34	3189.72	3423.59	20.80
v_{72}	3595.63	21.13	28.67	3245.14	6.21	8.57	3302.42	3447.35	8.29	598.52	3275.13	11.43	7.12	32.72	20.45	2784.27
v_{73}	3396.61	24.59	30.76	3064.70	15.67	7.46	3110.55	3253.81	23.26	669.22	3089.91	15.57	14.29	47.66	39.05	2614.55
v_{74}	3537.44	24.81	30.11	3188.98	8.31	15.24	3250.22	3394.56	5.60	540.13	3217.41	13.56	9.63	24.29	20.96	2729.22
v_{75}	35.93	3270.12	3187.93	4.05	3420.58	3292.82	20.38	14.05	3464.78	3494.58	2.54	3380.45	3343.89	3406.18	3647.82	29.67
v_{76}	3587.08	47.28	55.56	3243.40	21.74	23.53	3281.13	3440.23	17.74	641.10	3265.19	25.25	20.21	42.96	36.23	2781.62
v_{77}	3214.42	24.37	29.47	2892.05	23.38	11.62	2940.49	3074.46	31.65	636.30	2915.45	20.04	23.17	47.97	51.63	2452.44
v_{78}	3801.85	23.84	33.00	3443.86	5.88	12.15	3540.76	3652.02	5.35	607.58	3474.67	11.99	10.20	31.61	12.01	2965.20
v_{79}	32.55	3494.35	3414.90	17.91	3657.20	3515.85	20.87	7.39	3704.61	3753.65	10.00	3611.83	3579.89	3640.48	3892.56	62.72
v_{80}	3798.13	28.38	39.92	3432.53	7.57	17.31	3494.29	3644.86	7.63	565.47	3464.29	15.82	9.03	30.89	14.86	2958.59
v_{81}	3604.84	19.88	28.41	3259.23	6.00	6.88	3316.98	3463.60	12.97	596.32	3287.18	9.43	5.59	30.78	20.01	2793.00
v_{82}	3408.70	11.30	5.83	3069.33	10.42	15.19	3163.45	3285.80	19.83	506.54	3110.04	18.42	11.72	32.65	24.63	2621.68
v_{83}	30.10	3534.23	3451.46	17.87	3692.19	3553.69	19.78	8.40	3736.93	3804.74	8.84	3644.18	3616.19	3676.90	3930.21	68.80
v_{84}	4016.29	71.44	75.85	3562.22	48.95	63.30	3726.52	3871.36	59.50	637.60	3886.12	62.64	56.76	83.17	55.03	3164.01
v_{85}	3550.16	22.26	32.31	3204.56	9.43	7.95	3253.64	3400.48	10.54	606.36	3229.19	9.70	10.32	32.51	25.25	2743.61

(Contd.)

	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}	V_{21}	V_{22}	V_{23}	V_{24}	V_{25}	V_{26}	V_{27}	V_{28}	V_{29}	V_{30}	V_{31}
V_{86}	3116.78	25.61	30.26	2789.54	29.56	19.29	2847.81	2976.77	40.23	562.36	2816.97	20.33	25.49	50.66	59.76	2362.04
V_{87}	3446.50	46.71	62.86	3119.71	33.57	20.80	3139.01	3294.98	34.68	705.38	3328.17	20.10	35.26	52.89	57.59	2658.99
V_{88}	3574.58	38.81	53.86	3223.74	19.50	19.48	3261.43	3418.61	22.92	631.66	3245.79	21.17	16.41	46.48	39.26	2762.49
V_{89}	3505.06	13.41	15.48	3172.63	6.90	4.89	3238.90	3372.50	11.64	591.45	3202.95	12.53	10.33	26.40	18.73	2706.12
V_{90}	3463.69	31.29	39.92	3121.88	15.82	13.67	3165.40	3315.38	16.57	617.64	3144.85	15.75	14.36	39.62	35.70	2670.03
V_{91}	3879.33	32.78	44.49	3523.77	11.04	17.91	3584.37	3734.45	14.72	610.71	3551.51	13.84	17.23	31.45	16.83	3030.33
V_{92}	77.12	2974.48	2907.16	37.54	3104.34	2974.40	19.64	34.71	3142.88	3323.65	22.35	3062.85	3028.23	3093.84	3326.18	39.82
V_{93}	31.17	3555.39	3467.38	15.55	3723.81	3586.91	42.61	16.98	3775.90	3797.98	17.41	3679.93	3647.23	3715.15	3961.40	72.01
V_{94}	3476.72	19.57	19.40	3126.75	7.77	17.51	3207.59	3344.04	11.30	386.32	3164.53	20.12	5.08	26.20	20.00	2674.66
V_{95}	56.63	3679.67	3590.68	28.44	3854.04	3717.12	65.35	34.26	3912.83	3877.07	42.20	3824.04	3768.27	3856.07	4095.49	102.58
V_{96}	3459.26	43.52	56.20	3111.45	25.70	23.87	3148.23	3306.90	28.10	602.44	3132.34	25.96	18.29	49.92	47.47	2663.14
V_{97}	54.99	2971.80	2889.97	9.64	3111.57	2991.59	31.44	33.12	3155.52	3207.78	15.57	3085.78	3033.70	3101.30	3325.53	18.70
V_{98}	3668.68	25.57	33.38	3339.38	9.63	10.30	3398.84	3551.11	20.68	620.45	3370.18	15.53	4.72	41.92	21.34	2870.91
V_{99}	3524.78	25.64	37.00	3176.49	15.47	9.01	3220.16	3368.52	22.09	664.10	3204.06	18.30	11.83	52.82	36.10	2722.56
V_{100}	36.62	3771.14	3675.56	30.05	3939.45	3800.38	58.07	31.69	3995.51	4001.99	35.76	3903.39	3855.24	3935.38	4182.81	106.21
V_{101}	4258.82	55.06	70.94	3890.38	28.46	36.19	3947.65	4106.17	32.62	719.69	3919.97	33.29	37.03	61.66	24.22	3378.47
V_{102}	3839.90	26.95	35.98	3473.74	6.43	17.57	3541.94	3692.04	7.19	553.77	3507.72	16.46	7.13	30.14	10.27	2996.52
V_{103}	3052.29	35.45	24.14	2729.85	41.05	37.66	2820.29	2940.62	58.42	496.34	2770.38	52.34	30.89	64.20	67.04	2312.99
V_{104}	3241.39	39.68	48.29	2907.47	30.66	21.75	2944.54	3092.91	38.03	643.72	2930.15	31.00	23.32	61.58	61.30	2473.11
V_{105}	3143.45	23.64	26.75	2807.70	26.48	20.36	2870.99	2998.18	33.06	542.18	2839.60	30.98	22.67	49.59	54.54	2381.80
V_{106}	3080.07	29.96	33.98	2762.82	34.19	19.72	2813.58	2944.60	46.09	608.70	2785.99	30.30	30.28	56.55	66.38	2333.68
V_{107}	3970.83	22.38	29.39	3600.71	7.47	18.91	3686.02	3826.50	16.01	582.26	3644.36	23.38	10.17	41.03	7.30	3113.58
V_{108}	3857.58	23.69	33.59	3502.37	5.44	10.15	3564.82	3712.40	9.35	619.22	3532.38	10.42	10.68	31.00	10.77	3017.45
V_{109}	3435.68	21.98	39.67	3043.09	37.55	37.12	3122.55	3251.15	55.96	586.80	3085.05	26.64	32.51	105.41	75.45	2628.48
V_{110}	3165.75	20.28	16.47	2845.24	25.37	20.57	2923.28	3043.03	32.47	513.86	2875.82	26.19	26.88	35.91	46.72	2408.16
V_{111}	26.11	3886.89	3771.53	58.71	4055.04	3717.96	13.46	67.50	4109.47	4074.43	70.07	4028.81	3977.58	4025.48	4287.15	124.58
V_{112}	46.97	3394.12	3293.76	19.51	3459.98	3434.08	83.12	47.00	3617.90	3623.92	44.62	3538.00	3481.06	3564.97	3787.10	70.05

	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}
V_{32}	0	2865.83	14.86	5.71	3741.77	11.41	3627.06
V_{33}		0	3111.66	2778.32	94.74	2648.33	104.39
V_{34}			0	22.03	4020.46	21.81	3900.73
V_{35}				0	3639.10	9.35	3527.96
V_{36}					0	3487.41	6.54
V_{37}						0	3377.78
V_{38}							0
V_{39}							
V_{40}							
V_{41}							
V_{42}							
V_{43}							
V_{44}							
V_{45}							
V_{46}							
V_{47}							
V_{48}	10.69	2637.48	28.88	8.15	3471.62	5.59	3359.58
V_{49}	471.00	3187.57	558.30	497.64	4063.98	540.70	3988.90
V_{50}	20.26	2520.71	47.84	25.25	3326.84	15.02	3212.76
V_{51}	15.64	3005.92	25.38	15.51	3863.37	28.39	3732.97
V_{52}	9.56	2797.40	19.02	3.21	3663.02	7.38	3552.43
V_{53}	13.86	2825.28	19.29	10.08	3671.88	7.89	3553.76
V_{54}	3.72	2883.84	15.71	10.31	3756.72	17.81	3639.78
V_{55}	630.64	3284.21	733.66	656.92	4151.35	711.65	4083.25

V_{39}	V_{40}	V_{41}	V_{42}	V_{43}	V_{44}	V_{45}	V_{46}	V_{47}
9.70	9.76	3284.14	27.62	10.54	10.21	19.66	16.20	9.78
2915.93	2906.98	67.76	3299.42	2629.36	3070.51	3220.94	3034.74	2993.69
5.89	9.24	3543.32	7.94	26.14	3.94	7.28	22.35	5.59
14.24	13.49	3186.89	40.21	8.69	17.03	28.20	36.56	12.34
3789.50	3800.19	20.43	4216.62	3454.13	3983.29	4164.68	3945.67	3886.57
7.97	10.55	3045.87	43.29	2.36	18.34	33.42	36.66	12.15
3670.90	3691.05	10.99	4087.19	3339.47	3868.50	4047.13	3833.21	3768.81
0	8.03	3325.94	19.74	10.38	7.85	14.87	28.24	4.33
	0	3344.51	22.71	17.76	3.00	11.51	18.12	5.26
		0	3723.09	3009.82	3513.52	3683.78	3482.49	3417.75
			0	44.47	12.46	14.34	25.87	14.68
				0	24.41	40.62	40.07	15.50
					0	4.13	16.44	3.00
						0	25.88	7.62
							0	26.41
								0
14.84	14.25	3032.59	45.79	5.10	22.89	37.94	38.36	16.70
571.03	501.19	3680.47	567.32	543.25	516.04	563.45	423.25	562.86
28.65	29.77	2896.65	61.37	11.00	41.28	62.50	39.76	35.01
20.03	30.37	3387.66	26.24	20.75	25.24	33.05	47.77	17.22
11.96	7.97	3211.17	34.86	9.76	12.42	22.51	37.59	7.23
7.08	15.42	3216.81	35.60	8.57	17.40	28.43	47.71	10.29
14.52	14.99	3294.94	23.78	14.78	15.23	25.73	15.05	15.16
748.77	673.53	3778.05	748.67	711.69	689.64	745.41	581.00	742.94

(Contd.)

	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}	V_{39}
V_{56}	26.98	3357.70	16.33	43.13	4310.75	52.07	4191.78	30.20
V_{57}	10.33	2911.32	17.26	5.84	3779.70	15.08	3661.38	12.52
V_{58}	3360.90	169.50	3610.37	3258.98	84.56	3123.45	58.30	3390.66
V_{59}	24.19	2511.78	39.33	28.65	3334.94	9.39	3231.63	23.16
V_{60}	9.78	2691.28	23.93	10.37	3533.20	5.86	3420.27	12.59
V_{61}	10.50	2739.86	16.58	11.77	3609.48	4.61	3504.86	9.92
V_{62}	15.16	2758.21	21.29	22.11	3637.09	12.96	3534.84	16.38
V_{63}	13.75	2859.13	17.67	10.37	3712.14	9.80	3590.46	7.63
V_{64}	466.21	3057.69	555.75	489.40	3921.93	530.82	3850.80	566.56
V_{65}	19.58	3099.24	10.77	22.06	3992.03	24.94	3866.29	10.42
V_{66}	18.45	2634.99	27.41	19.41	3458.29	6.70	3339.61	10.95
V_{67}	15.09	3128.61	6.21	14.92	4029.45	24.62	3906.44	9.89
V_{68}	8.13	2730.11	19.26	8.99	3592.10	5.19	3485.07	12.31
V_{69}	45.78	3343.25	26.95	47.39	4244.55	59.74	4105.57	33.09
V_{70}	3577.14	77.83	3846.27	3475.34	3.86	3327.83	8.44	3623.12
V_{71}	3109.77	51.94	3367.42	3015.60	34.33	2884.00	24.39	3159.15
V_{72}	6.03	2895.26	10.08	9.50	3756.92	9.41	3635.16	3.87
V_{73}	16.85	2720.20	22.25	13.14	3557.23	6.24	3438.05	8.74
V_{74}	3.20	2840.51	15.61	5.87	3697.26	10.61	3577.75	9.89
V_{75}	3319.53	78.43	3587.69	3224.32	18.74	3086.07	9.14	3368.55
V_{76}	14.89	2805.75	25.63	16.49	3755.47	22.56	3627.32	16.68
V_{77}	21.63	2554.67	34.13	13.47	3369.10	4.37	3256.18	15.53
V_{78}	8.26	3073.41	5.06	15.49	3958.57	18.49	3845.54	5.53

V_{40}	V_{41}	V_{42}	V_{43}	V_{44}	V_{45}	V_{46}	V_{47}
20.34	3825.70	13.49	58.83	10.21	9.34	17.23	20.35
17.84	3310.49	28.32	12.66	16.86	24.46	40.06	9.62
3434.65	56.61	3794.17	3079.60	3600.46	3769.94	3583.77	3501.28
22.12	2910.96	65.69	13.77	35.17	57.43	36.76	33.97
10.27	3091.37	37.57	6.57	17.77	32.78	30.93	13.72
4.96	3166.60	39.02	11.04	11.12	24.54	24.58	11.22
9.79	3197.38	45.58	20.99	15.78	30.18	20.01	20.79
16.88	3246.78	28.22	7.93	17.13	25.44	45.92	6.78
497.40	3546.04	572.85	533.46	515.44	566.03	423.25	561.63
21.38	3506.47	15.55	24.15	14.46	15.80	41.01	7.62
23.09	3010.38	43.92	4.13	29.88	43.65	45.95	19.31
16.90	3546.06	13.77	25.02	9.76	11.95	37.86	6.66
3.70	3149.26	35.60	9.86	11.27	25.60	22.37	10.82
51.69	3735.64	20.01	54.25	37.57	34.03	71.87	28.69
3633.93	11.02	4039.06	3295.40	3812.93	3991.93	3775.77	3718.80
3169.07	7.09	3540.16	2848.81	3334.78	8502.43	3298.64	3244.79
11.79	3290.92	18.23	7.27	11.16	19.96	26.75	5.70
19.16	3101.69	37.45	4.43	23.47	34.34	49.51	11.78
13.63	3236.04	24.29	6.71	14.10	26.13	23.81	9.66
3384.56	4.56	3764.67	3048.23	3554.85	3728.59	3516.01	3461.03
30.59	3281.91	29.43	14.48	28.07	35.63	44.39	17.54
25.18	2929.23	58.48	3.12	34.31	50.73	60.73	22.06
11.40	3490.45	9.80	18.44	5.44	9.39	21.67	3.23

(Contd.)

	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}
V_{79}	3552.94	102.43	3828.65	3453.62	11.87	3306.03	5.66
V_{80}	8.27	3078.06	9.45	14.80	3961.93	22.72	3835.97
V_{81}	9.12	2901.44	12.23	6.86	3768.64	10.42	3648.77
V_{82}	14.45	2697.03	22.65	14.20	3560.75	8.60	3457.97
V_{83}	3587.67	106.46	3861.57	3485.89	8.99	3340.45	2.74
V_{84}	62.09	3267.62	51.88	71.95	4188.11	76.93	4063.77
V_{85}	7.11	2857.68	14.04	7.61	3710.75	7.85	3589.37
V_{86}	25.16	2466.83	46.92	17.60	3262.93	7.88	3152.76
V_{87}	29.09	2783.74	37.18	17.39	3611.03	20.44	3487.37
V_{88}	17.99	2894.45	25.76	16.20	3736.71	21.67	3606.56
V_{89}	8.04	2796.80	13.99	8.62	3670.25	4.63	3558.44
V_{90}	11.15	2788.35	22.28	9.89	3823.35	10.41	3500.42
V_{91}	17.27	3150.38	8.61	15.63	4050.98	28.34	3929.08
V_{92}	3003.23	115.00	3260.26	2909.94	81.91	2783.01	49.76
V_{93}	3625.94	89.35	3896.31	3225.92	2.45	3373.34	4.84
V_{94}	5.62	2774.36	20.97	9.29	3632.17	11.37	3518.08
V_{95}	3755.00	127.24	4035.23	3665.33	16.60	3502.16	17.47
V_{96}	18.99	2795.24	36.58	16.75	3616.25	20.80	3488.42
V_{97}	3014.56	60.26	3275.34	2930.30	52.44	2796.00	34.55
V_{98}	16.12	2976.52	16.33	15.08	3854.56	18.07	3733.17

v_{39}	v_{40}	v_{41}	v_{42}	v_{43}	v_{44}	v_{45}	v_{46}	v_{47}
3596.58	3619.52	14.52	4018.69	3268.88	3794.07	3971.06	3764.49	3695.29
9.64	15.36	3484.95	10.53	20.17	9.91	15.45	24.32	8.16
7.16	9.52	3305.05	21.58	10.30	9.94	17.99	35.98	4.26
18.36	5.90	3121.88	41.03	14.80	15.24	31.66	24.28	16.23
3632.67	3655.38	8.38	4049.27	3301.16	3830.99	4009.85	3797.62	3730.91
60.19	49.55	3703.49	51.86	63.19	46.79	50.24	67.17	55.39
4.88	14.57	3247.01	24.94	5.11	14.15	24.10	34.45	6.55
24.45	30.20	2836.13	72.37	6.57	43.23	64.55	63.87	33.04
22.02	39.87	3146.97	54.10	14.76	40.24	51.05	79.63	24.17
16.19	29.10	3267.29	30.13	14.59	27.63	36.17	53.92	16.78
5.96	6.99	3217.00	33.13	7.87	9.46	18.28	30.23	5.13
10.43	21.95	3161.85	32.09	4.94	23.62	35.61	42.26	13.51
13.73	16.87	3569.62	14.27	29.61	11.08	13.81	39.34	9.88
3043.73	3079.07	28.49	3424.32	2738.03	3235.14	3394.08	3214.48	3134.51
3669.87	3681.70	13.94	4087.03	3340.28	3861.39	4042.49	3824.21	3766.09
15.46	9.70	3182.95	29.93	10.54	14.51	28.56	19.59	13.23
3799.61	3812.48	43.12	4222.80	3468.40	3995.96	4179.18	3947.04	3902.27
21.79	33.14	3155.32	41.13	12.42	35.01	48.06	55.88	23.18
3063.33	3076.19	18.63	3441.58	2759.28	3240.18	3402.33	3199.61	3150.50
12.56	11.52	3386.79	20.14	19.30	11.22	16.50	39.53	5.59

(Contd.)

	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}	V_{39}	V_{40}	V_{41}	V_{42}	V_{43}	V_{44}	V_{45}	V_{46}	V_{37}
V_{99}	16.25	2839.49	20.69	19.66	3683.07	11.60	3557.52	7.02	21.15	3219.57	29.25	8.69	21.48	30.07	43.71	5.59
V_{100}	3838.31	121.45	4120.27	3740.04	6.04	3581.25	8.84	3885.46	3895.70	30.59	4310.78	3546.40	4081.94	4266.51	4027.49	3984.54
V_{101}	42.76	3486.93	16.61	49.12	4440.90	60.28	4312.22	29.94	34.53	3934.56	13.73	65.20	19.32	10.99	53.73	20.38
V_{102}	8.19	3108.82	9.19	16.45	4004.71	23.89	3880.86	11.06	11.75	3527.70	9.09	23.37	6.25	11.07	18.99	6.48
V_{103}	39.45	2389.39	68.08	34.81	3196.66	21.96	3097.30	48.16	32.85	2785.07	91.54	26.15	53.50	78.21	61.45	49.80
V_{104}	25.87	2595.35	44.11	21.45	3394.57	14.74	3270.98	22.94	36.58	2947.68	57.33	7.63	44.14	60.18	66.64	29.13
V_{105}	19.83	2487.54	43.07	19.86	3287.19	7.18	3175.03	21.06	28.50	2857.90	65.27	4.63	40.01	61.36	48.96	31.65
V_{106}	30.88	2434.84	51.30	19.50	3229.48	8.82	3120.02	27.66	33.61	2802.72	79.03	7.94	47.36	68.04	74.98	34.40
V_{107}	19.42	3209.37	7.56	30.81	4138.19	32.61	4017.98	14.73	10.10	2659.97	8.88	38.88	3.73	3.67	20.34	8.14
V_{108}	12.20	3122.67	4.00	15.03	4028.11	21.27	3906.50	7.32	9.72	3548.48	9.82	23.68	3.91	6.07	29.14	2.62
V_{109}	51.99	2737.75	44.79	55.23	3545.17	32.92	3426.83	38.28	38.28	3098.98	47.57	34.68	46.91	73.17	56.97	42.96
V_{110}	21.26	2489.97	42.10	14.36	3315.60	6.97	3215.94	26.48	20.64	2891.62	71.91	10.72	34.19	55.88	48.51	30.05
V_{111}	3952.07	98.32	4238.98	3848.19	44.85	3693.54	37.47	4007.22	4004.62	57.11	4446.92	3665.63	4196.12	4378.33	4149.12	4102.95
V_{112}	3471.28	62.58	3732.04	3384.74	23.84	3225.81	28.92	3514.61	31515.77	32.20	3915.25	3198.48	3694.67	3868.80	3641.50	3607.28

	v_{48}	v_{49}	v_{50}	v_{51}	v_{52}	v_{53}	v_{54}	v_{55}	v_{56}	v_{57}	v_{58}	v_{59}	v_{60}	v_{61}	v_{62}	v_{63}
v_{48}	0	490.60	7.56	21.03	6.41	9.23	15.03	658.64	52.00	18.33	3099.77	15.80	1.04	11.97	21.28	13.59
v_{49}		0	467.08	536.26	520.00	548.38	472.32	18.49	468.83	579.00	3769.40	478.81	478.00	492.69	451.12	612.89
v_{50}			0	35.11	25.22	25.59	22.15	631.87	70.79	37.26	2967.88	14.09	7.53	24.29	30.13	29.24
v_{51}				0	17.94	13.96	17.72	704.78	40.77	12.39	3438.17	57.24	20.96	37.10	50.85	11.37
v_{52}					0	7.90	15.22	690.56	37.98	8.19	3291.91	27.83	7.10	9.44	21.56	8.03
v_{53}						0	22.76	721.36	44.50	13.85	3271.89	26.80	9.23	14.52	25.45	6.72
v_{54}							0	630.73	30.86	11.73	3365.00	29.61	14.11	17.65	22.57	19.63
v_{55}								0	638.78	749.40	3858.43	639.10	646.78	656.78	607.26	794178
v_{56}									0	42.16	3918.43	69.45	42.78	37.06	37.26	45.28
v_{57}										0	3385.13	42.91	20.16	20.74	35.14	4.78
v_{58}											0	2989.03	3162.07	3255.07	3284.79	3118.79
v_{59}												0	14.06	10.00	9.74	36.17
v_{60}													0	9.77	17.18	14.31
v_{61}														0	3.18	19.22
v_{62}															0	34.69
v_{63}																0
v_{64}	484.58	4.11	461.08	537.19	515.04	543.95	467.48	15.80	477.58	572.91	3630.22	465.53	473.54	483.06	440.37	608.60
v_{65}	33.89	655.10	53.87	18.48	20.31	20.65	21.39	843.08	34.10	7.62	3583.49	56.28	32.46	29.41	43.35	7.43
v_{66}	10.78	608.77	14.25	27.98	18.42	14.80	19.89	789.64	67.23	18.42	3073.05	18.08	12.05	18.89	29.80	10.11
v_{67}	29.81	587.08	54.58	13.72	15.17	15.76	17.10	760.36	25.63	7.01	3608.34	54.05	28.16	24.44	35.43	10.54
v_{68}	5.52	471.79	15.20	28.91	5.58	13.56	12.92	637.70	34.99	18.01	3237.52	12.54	3.54	3.55	9.16	16.46
v_{69}	63.82	718.84	89.17	23.64	46.39	42.42	41.96	910.14	50.43	23.73	3786.18	103.63	62.29	68.36	86.99	25.25

	v_{48}	v_{49}	v_{50}	v_{51}	v_{52}	v_{53}	v_{54}	v_{55}	v_{56}	v_{57}	v_{58}	v_{59}	v_{60}	v_{61}	v_{62}	v_{63}
v_{70}	3315.61	3913.12	3175.49	3697.54	3500.43	3510.75	3588.83	3998.64	4135.95	3610.36	73.61	3178.97	3375.94	3446.46	3473.52	3567.65
v_{71}	2863.51	3413.12	2730.24	3211.77	39.20	3050.30	3118.69	3521.60	3632.84	3142.55	65.08	2749.55	2919.83	2997.61	3026.49	3083.15
v_{72}	11.21	3431.07	21.76	10.13	9.60	8.63	7.04	731.10	32.91	5.72	3357.30	28.04	10.30	15.05	24.96	3.98
v_{73}	11.00	556.55	22.46	20.09	10.78	9.70	20.10	810.75	59.57	9.56	3170.04	26.73	12.63	17.57	32.15	2.87
v_{74}	9.74	627.50	18.06	9.17	9.03	12.15	3.79	667.75	35.15	6.22	3307.55	26.91	9.22	14.41	22.94	7.95
v_{75}	3065.41	504. 65	2924.31	3421.50	3249.97	3254.18	3330.06	3729.38	3861.60	3353.92	54.61	2946.00	3123.81	3206.86	3235.42	3290.33
v_{76}	21.80	3640.64	31.33	9.11	20.04	19.59	13.49	783.24	52.28	6.76	3345.45	49.80	23.64	35.11	50.36	7.04
v_{77}	9.50	606.39	19.77	30.09	13.22	10.90	27.09	770.43	78.11	17.54	2941.64	18.33	12.74	15.86	28.69	10.64
v_{78}	23.53	597.28	38.54	13.46	14.71	15.10	11.04	737.82	18.53	8.63	3568.24	40.83	20.26	18.25	26.44	8.70
v_{79}	3289.95	562.12	3147.48	3657.53	3479.78	3474.55	3572.80	3990.26	4114.14	3589.42	59.28	3162.36	3350.63	3431.44	3460.16	3517.80
v_{80}	19.41	3900.73	32.89	6.14	15.15	13.61	8.68	687.15	19.45	11.18	3544.48	44.47	16.59	24.68	33.05	11.80
v_{81}	8.66	516.47	25.81	8.25	3.86	5.06	13.21	720.00	31.85	7.07	3370.50	33.35	7.82	14.77	26.81	4.05
v_{82}	11.10	544.71	21.15	40.87	10.01	22.12	17.24	628.92	40.67	24.48	3216.13	12.32	8.54	3.89	8.11	24.68
v_{83}	3325.38	465.92	3182.08	3692.05	3513.74	3514.84	3599.96	4047.11	4155.12	3616.45	54.35	3198.28	3387.29	3467.69	3498.80	3550.07
v_{84}	78.54	3958.51	97.73	67.49	68.73	67.60	67.92	762.64	55.56	66.41	3769.41	98.45	70.50	72.86	77.07	65.76
v_{85}	10.99	586.88	22.90	8.80	8.43	5.60	11.12	737.07	39.27	4.81	3314.31	28.45	11.00	14.82	26.09	1.99
v_{86}	6.27	564.29	11.44	35.15	17.61	13.10	31.98	687.10	85.17	30.57	2890.68	13.79	9.25	19.37	29.32	21.87
v_{87}	26.25	660.78	45.64	17.84	19.88	13.50	35.57	836.26	79.58	11.49	3201.19	52.39	30.55	35.44	54.67	7.43
v_{88}	15.60	583.09	27.92	3.42	16.53	10.80	19.62	760.40	51.85	12.49	3311.79	48.79	16.50	34.55	49.85	7.10
v_{89}	11.62	549.66	26.23	24.56	6.64	9.68	16.72	722.21	36.23	12.03	3303.90	20.00	10.58	4.42	12.03	8.57
v_{90}	11.16	580.07	20.03	9.76	11.92	9.77	12.07	753.60	53.08	5.71	3223.61	31.52	12.79	22.07	35.70	3.30
v_{91}	28.01	552.06	54.23	13.70	14.57	16.15	17.61	723.63	23.53	10.55	3623.25	57.05	26.26	27.82	38.89	15.13

(Contd.)

	V_{48}	V_{49}	V_{50}	V_{51}	V_{52}	V_{53}	V_{54}	V_{55}	V_{56}	V_{57}	V_{58}	V_{59}	V_{60}	V_{61}	V_{62}	V_{63}
V_{92}	2760.69	3459.35	2629.08	3075.46	2937.37	2929.81	3014.56	3567.76	3534.16	3022.39	51.07	2668.52	2820.32	2912.67	2949.80	2956.47
V_{93}	3359.05	3947.09	3214.67	3742.87	3548.34	3554.32	3639.85	4035.63	4183.51	3663.52	86.12	3221.46	3418.10	3493.42	3520.03	3594.78
V_{94}	5.02	447.44	10.68	17.87	8.51	16.03	6.56	609.94	32.79	17.26	3260.97	20.48	3.12	11.92	17.90	17.00
V_{95}	3479.31	4026.74	3320.60	3874.22	3685.23	3681.61	3772.12	4121.14	4313.73	3810.19	94.94	3337.93	3536.44	3626.33	3648.26	3730.92
V_{96}	13.22	560.33	20.16	6.33	17.96	12.79	21.13	734.28	61.64	15.06	3209.69	44.70	15.40	36.52	52.46	50.41
V_{97}	2771.65	3346.89	2632.58	3113.21	2952.68	2956.16	3027.47	3448.11	3529.45	3055.62	75.30	2662.24	2826.43	2912.22	2938.86	2989.93
V_{98}	14.10	563.28	32.25	12.22	7.47	10.75	20.78	748.58	28.71	13.05	3462.43	44.67	12.05	22.58	35.80	7.56
V_{99}	14.76	619.56	22.59	15.15	16.75	9.07	21.18	806.51	48.90	14.04	3285.21	2232.03	14.29	23.36	36.26	3.98
V_{100}	3561.93	4160.35	3407.60	3958.19	3761.62	3768.05	3851.54	4264.65	4410.28	3879.90	94.70	3423.97	3622.28	3708.06	3735.77	3806.89
V_{101}	67.40	652.15	100.04	36.95	42.82	42.83	46.81	841.88	19.87	33.01	4008.30	98.82	61.46	54.70	66.00	34.45
V_{102}	21.32	504.79	35.01	9.85	14.94	16.39	10.34	676.64	12.61	13.38	3601.63	45.15	17.17	28.88	30.32	13.93
V_{103}	15.77	461.64	15.34	65.43	29.22	38.89	45.87	626.26	91.64	54.88	2874.37	18.46	15.96	27.31	34.12	47.01
V_{104}	11.35	606.08	14.71	20.78	21.38	15.43	28.71	785.29	53.72	21.96	2999.93	32.57	14.55	33.46	49.36	11.73
V_{105}	7.07	510.17	5.23	35.11	21.52	16.26	25.03	674.07	77.80	30.87	2919.29	8.21	8.64	17.62	24.26	22.41
V_{106}	10.03	568.83	18.20	39.56	18.30	15.57	39.14	738.32	94.96	30.48	2863.81	19.03	13.96	21.82	34.77	20.77
V_{107}	33.07	522.33	51.57	28.87	23.04	25.97	24.00	703.46	5.16	29.10	3742.21	51.48	25.86	24.57	28.87	26.51
V_{108}	24.75	564.63	46.97	14.16	12.07	13.60	15.91	741.68	16.61	9.46	3620.05	47.45	21.48	19.52	29.09	10.02
V_{109}	35.87	531.44	33.71	55.98	44.68	39.71	48.28	706.63	73.43	57.20	3168.14	31.61	28.76	37.94	44.52	43.88
V_{110}	11.29	477.86	19.93	47.57	14.87	21.00	29.11	632.56	72.87	30.04	2975.44	8.87	12.69	8.02	13.64	28.38
V_{111}	3678.28	4241.70	3532.23	4098.64	3871.43	3895.16	3966.56	4325.44	4530.03	3997.49	145.59	3531.09	3741.50	3809.68	3833.71	3934.47
V_{112}	3209.31	3771.85	3060.07	3604.48	3400.08	3415.50	3480.90	3873.96	4002.50	3521.77	117.48	3065.70	3263.62	3336.90	3357.52	3452.33

	v_{64}	v_{65}	v_{66}	v_{67}	v_{68}	v_{69}	v_{70}	v_{71}	v_{72}	v_{73}	v_{74}	v_{75}	v_{76}	v_{77}	v_{78}	v_{79}
64	0	653.21	599.16	583.91	465.31	721.98	3770.75	3302.01	553.12	619.15	499.12	3509.46	603.57	584.40	561.52	3764.05
65		0	23.44	4.98	29.78	10.67	3818.58	3339.40	8.09	13.86	14.97	3555.78	10.39	30.05	4.32	3794.02
66			0	29.70	16.80	50.60	3299.10	2853.79	8.64	3.16	12.90	3052.36	14.46	5.59	21.46	3274.21
67				0	25.22	14.05	3854.52	3371.83	8.91	18.82	12.67	3591.36	15.71	30.95	4.65	3831.04
68					0	64.53	3430.98	2976.76	11.96	15.62	10.18	3185.32	28.49	16.18	17.93	3415.33
69						0	4064.62	3563.60	25.84	36.83	35.43	3785.00	20.59	61.07	20.13	4034.54
70							0	22.14	3590.66	3395.40	3531.74	12.98	3589.08	3211.12	3797.61	14.43
71								0	3122.48	2942.96	3064.39	6.22	3116.54	2773.75	3317.11	27.74
72									0	6.03	2.83	3330.72	5.57	14.65	4.10	3564.62
73										0	10.29	3146.43	10.27	4.43	15.30	3370.03
74											0	3272.83	7.57	15.88	7.47	3507.56
75												0	3322.47	2971.79	3533.05	11.08
76													0	22.23	11.60	3558.52
77														0	28.66	3186.29
78															0	3771.54
79																0
80	518.59	11.80	24.35	7.50	19.15	21.43	3792.69	3306.57	4.66	19.47	6.69	3520.45	10.81	32.13	4.24	3762.36
81	541.83	12.40	15.08	8.39	9.85	29.37	3603.83	3132.40	4.19	8.07	5.92	3344.03	12.28	14.98	7.88	3576.41
82	456.83	37.56	22.68	31.73	1.99	75.96	3398.07	2948.79	19.19	21.86	16.14	3159.53	39.12	20.46	25.08	3391.46
83	3818.74	3823.03	3303.90	3862.27	3450.01	4059.72	7.27	23.40	3595.81	3399.89	3537.72	8.18	3585.16	3217.62	3805.02	5.50
84	582.49	60.40	82.32	53.95	62.68	70.88	4012.30	3572.91	59.41	75.28	63.96	3745.05	73.47	92.76	53.67	3990.70
85	559.40	8.92	9.01	9.48	13.21	28.25	3545.92	3081.08	1.39	4.68	3.20	3287.34	6.03	10.83	5.80	3515.50
86	509.93	50.42	12.39	46.50	16.16	85.52	3110.58	2677.06	23.01	14.97	21.61	2869.65	34.25	5.50	41.62	3081.06

(Contd.)

	v_{64}	v_{65}	v_{66}	v_{67}	v_{68}	v_{69}	v_{70}
v_{87}	650.26	19.35	19.68	20.47	35.53	34.14	3446.80
v_{88}	581.09	17.49	16.19	16.27	26.17	24.86	3573.56
v_{89}	541.54	16.28	13.64	15.38	7.10	48.60	3507.15
v_{90}	574.05	12.91	9.65	15.50	17.29	30.02	3459.73
v_{91}	551.64	12.12	35.16	3.02	24.72	18.15	3876.61
v_{92}	3336.51	3208.40	2735.51	3249.58	2889.47	3410.28	70.05
v_{93}	3807.39	3870.45	3344.35	3907.12	3476.90	4118.13	2.83
v_{94}	443.95	29.79	17.26	24.50	4.23	56.58	3471.02
v_{95}	3893.12	4016.00	3467.54	4055.40	3603.60	4268.68	29.91
v_{96}	558.53	25.34	15.70	26.16	25.50	37.18	3456.82
v_{97}	3225.86	3244.37	2760.03	3282.05	2888.41	3466.01	44.58
v_{98}	565.76	14.68	22.42	13.31	14.27	29.53	3690.41
v_{99}	617.39	12.22	6.22	19.04	20.18	31.18	3521.81
v_{100}	4020.29	4090.89	3545.35	4133.26	3684.81	4343.54	13.87
v_{101}	658.98	15.90	66.81	13.10	55.30	16.12	4259.86
v_{102}	508.34	12.69	28.73	9.05	17.06	25.58	3835.41
v_{103}	450.48	80.12	32.85	76.55	16.88	127.94	3048.02

V_{71}	V_{72}	V_{73}	V_{74}	V_{75}	V_{76}	V_{77}	V_{78}	V_{79}
2990.29	17.03	9.76	19.13	3192.80	14.73	11.95	25.31	3411.05
3097.98	7.73	10.82	9.74	3304.07	6.86	19.50	15.56	3535.29
3050.24	8.74	9.01	9.44	3260.62	21.66	11.68	10.14	3480.83
2998.68	2.89	3.88	4.34	3201.38	3.12	9.78	11.80	3430.62
3390.48	11.70	24.44	15.67	3610.28	20.28	36.34	9.49	3854.33
30.65	3002.26	2821.68	2952.03	29.77	2978.44	2662.00	3197.38	45.32
24.88	3638.41	3442.23	3579.71	12.57	3638.77	3256.97	3846.50	9.61
3005.71	9.46	17.58	5.23	3214.65	20.57	20.93	16.10	3450.62
53.66	3769.04	3575.32	3512.84	30.85	3772.61	3389.81	3982.99	21.36
2988.45	10.30	12.39	10.52	3188.34	7.57	18.73	21.92	3417.12
10.41	3027.02	2852.18	2972.85	13.85	3018.68	2689.50	3219.42	33.49
3211.33	9.02	13.68	13.07	3425.48	17.04	25.35	10.88	3661.83
3058,37	4.67	4.47	11.19	3260.80	8.38	13.48	11.09	3485.45
46.44	3849.92	3649.22	3791.55	25.47	3847.15	3463.09	4066.05	19.34
3756.63	32.98	50.62	43.45	3983.43	42.53	75.04	17.50	4233.26
3347.02	6.86	22.89	8.42	3563.41	15.14	36.92	3.69	3806.68
2618.85	44.97	37.98	40.09	2814.47	63.12	28.61	64.47	3033.23

(Contd.)

	v_{64}	v_{65}	v_{66}	v_{67}	v_{68}	v_{69}	v_{70}	v_{71}	v_{72}	v_{73}	v_{74}	v_{75}	v_{76}	v_{77}	v_{78}	v_{79}
104	597.92	33.07	6.43	37.72	25.36	54.08	3239.37	2790.31	14.72	7.07	16.33	2984.84	14.19	8.23	31.69	3203.92
105	498.85	47.02	8.32	46.84	15.00	83.92	3134.30	2699.06	18.96	14.76	17.47	2890.71	29.49	7.92	36.02	3104.70
106	553.91	49.70	13.18	48.06	19.67	85.94	3077.11	2647.37	26.50	13.13	25.48	28.40.77	36.20	3.42	44.97	3049.10
107	528.25	20.69	41.97	15.98	22.08	37.57	3967.60	3475.48	18.49	35.42	24.08	3699.03	36.24	51.73	9.98	3943.45
108	564.24	6.09	27.83	2.05	18.39	18.91	3855.78	3371.96	17.50	18.26	11.80	2591.64	17.53	31.35	2.69	3831.44
109	527.45	60.42	35.20	59.62	32.41	85.77	3382.33	2930.83	37.75	39.24	40.21	3132.81	58.09	40.55	49.30	3366.11
110	461.93	51.82	22.12	45.20	9.26	97.19	3158.88	2728.37	27.76	22.47	22.30	2928.46	45.23	11.41	40.20	3143.91
111	4093.60	4217.94	3669.65	4255.32	3793.34	4488.59	22.47	71.52	3976.76	3772.31	3914.06	57.44	3981.30	3578.65	4191.30	49.78
112	3639.96	3718.27	3194.96	3759.13	3318.15	3970.44	23.16	33.66	3486.85	3297.86	3431.70	30.87	3494.61	3121.94	3688.85	42.52

	v_{80}	v_{81}	v_{82}	v_{83}	v_{84}	v_{85}	v_{86}	v_{87}	v_{88}	v_{89}	v_{90}	v_{91}	v_{92}	v_{93}	v_{93}
v_{80}	0	6.39	28.32	3796.53	52.51	7.45	38.31	28.40	9.43	17.88	11.19	6.59	3183.15	3839.95	12.10
v_{81}		0	16.90	3610.97	53.64	4.03	21.00	15.76	6.34	8.02	7.09	8.35	3016.61	3650.21	8.64
v_{82}			0	3422.96	72.24	21.09	21.31	44.79	37.71	11.17	25.68	31.51	2874.82	3445.14	8.35
v_{83}				0	4027.86	3548.62	3117.17	3441.93	3568.34	3520.68	3459.55	3885.95	44.80	7.17	3483.67
v_{84}					0	65.26	100.03	90.62	65.23	66.73	71.12	51.21	3408.14	4064.08	65.43
v_{85}						0	19.26	10.18	6.87	6.90	2.02	13.99	2957.87	3592.79	11.78
v_{86}							0	25.21	25.27	20.46	17.66	46.75	2572.03	3152.24	19.30
v_{87}								0	12.77	20.80	9.53	28.00	2851.89	3495.33	35.84
v_{88}									0	21.58	5.40	16.92	2960.04	3618.26	17.59
v_{89}										0	13.33	22.04	2946.81	3554.13	12.53
v_{90}											0	19.18	2871.31	3507.28	13.60
v_{91}												0	3271.72	3928.85	22.87
v_{92}													0	71.35	2909.80
v_{93}														0	3515.77
v_{94}															0
v_{95}	3968.98	3782.88	3577.48	29.38	4186.37	3726.00	3271.67	3641.38	3745.45	3689.22	3639.03	4072.67	93.21	17.81	3639.04
v_{96}	14.27	10.42	37.80	3449.98	73.39	8.70	20.31	15.12	2.86	25.31	4.96	25.94	2851.79	3500.16	16.77
v_{97}	3206.72	3039.77	2867.64	37.99	3419.56	2986.98	2590.13	2904.00	2999.53	2959.42	2905.51	3300.76	21.19	42.54	2913.41
v_{98}	8.94	2.83	22.66	3697.92	51.51	10.19	31.57	25.26	10.25	14.21	13.67	11.40	3093.58	3735.21	12.93
v_{99}	13.17	9.02	30.55	3520.77	68.64	4.17	22.03	15.30	8.23	12.65	4.85	24.17	2925.01	3561.18	18.96
v_{100}	4050.39	3863.74	3655.23	16.20	4271.11	3805.94	3352.69	3711.09	3827.19	3768.98	3714.93	4153.20	90.62	8.62	3722.50

(Contd.)

	V_{80}	V_{81}	V_{82}	V_{83}	V_{84}	V_{85}	V_{86}	V_{87}	V_{88}	V_{89}	V_{90}	V_{91}	V_{92}	V_{93}	V_{94}
V_{101}	22.83	30.68	64.67	4269.37	53.31	36.52	96.55	55.74	43.02	41.60	48.05	14.97	3622.05	4312.50	55.74
V_{102}	1.35	7.48	25.71	3842.51	46.88	9.94	43.20	34.62	14.42	16.68	15.50	8.46	3229.49	3882.25	11.59
V_{103}	60.81	39.21	18.09	3068.72	96.63	45.22	16.30	65.81	54.35	36.20	43.42	72.11	2544.11	3088.80	23.28
V_{104}	28.25	16.28	35.13	3235.27	87.34	12.37	10.58	14.92	99.59	23.69	6.87	40.73	2659.55	3281.84	21.37
V_{105}	34.30	23.02	20.48	3140.19	98.42	16.99	3.15	30.22	26.07	19.02	15.39	49.45	2593.18	3175.55	16.03
V_{106}	45.22	22.75	24.17	3083.89	103.54	21.10	1.92	20.82	27.63	20.08	19.26	50.94	2541.23	3119.70	25.24
V_{107}	11.44	16.18	28.38	3983.79	47.22	23.72	59.56	55.84	32.33	21.12	34.52	14.74	3369.56	4013.41	21.99
V_{108}	5.20	5.73	25.15	3866.03	45.23	9.16	43.80	29.14	16.23	11.98	16.28	3.68	3254.89	3905.64	18.51
V_{109}	46.68	39.18	30.94	3395.21	96.98	40.66	37.87	63.82	48.17	46.40	41.40	57.48	2843.09	3418.79	33.51
V_{110}	43.70	25.20	8.72	3178.15	97.42	24.24	8.96	35.86	42.04	14.52	27.02	47.80	2648.29	3204.86	17.99
V_{111}	4189.31	3988.27	3755.91	43.18	4412.04	3932.93	3471.07	3840.09	3968.05	3877.85	3845.29	4276.76	149.43	25.10	3839.90
V_{112}	3684.45	3501.75	3283.69	40.07	3901.43	3449.36	3017.85	3375.56	3478.81	3402.31	3366.67	3778.83	97.93	19.83	3357.01

	V_{95}	V_{96}	V_{97}	V_{98}	V_{99}	V_{100}	V_{101}
V_{95}	0	3621.85	51.00	3863.67	3687.28	9.27	4460.26
V_{96}		0	2888.99	14.22	9.39	3702.90	58.77
V_{97}			0	3113.47	2955.63	57.06	3651.98
V_{98}				0	11.73	3946.43	26.88
V_{99}					0	3771.27	42.40
V_{100}						0	4545.35
V_{101}							0
V_{102}							
V_{103}							
V_{104}							
V_{105}							
V_{106}							
V_{107}							
V_{108}							
V_{109}							
V_{110}	3336.98	38.12	2650.64	37.24	34.76	3412.39	93.79
V_{111}	42.16	3845.89	97.14	4075.25	3907.76	22.00	4675.16
V_{112}	25.24	3363.86	41.35	3578.66	3416.15	23.72	4148.08

	V_{110}	V_{111}	V_{112}
V_{110}	0	3510.63	3063.91
V_{111}		0	31.50
V_{112}			0

V_{102}	V_{103}	V_{104}	V_{105}	V_{106}	V_{107}	V_{108}	V_{109}
4010.63	3198.05	3401.34	3289.79	3245.33	4140.25	4045.57	3538.63
19.02	44.71	6.07	20.09	23.49	41.98	24.99	44.67
3245.78	2532.21	2694.57	2606.75	2563.66	3372.45	3277.45	2847.06
7.85	43.67	22.66	33.76	33.19	12.95	7.41	42.73
15.82	47.59	9.24	18.01	23.46	27.54	16.04	40.10
4098.75	3277.60	3478.69	3373.85	3320.64	4234.00	4127.97	3625.52
20.98	124.82	79.65	95.53	98.82	15.33	11.34	91.85
0	59.11	34.18	38.44	49.81	6.92	4.40	47.93
	0	33.47	18.28	19.09	68.94	65.20	43.76
		0	10.61	10.68	55.69	36.46	42.47
			0	7.19	55.19	43.08	34.89
				0	66.05	46.35	43.51
					0	7.33	54.14
						0	52.12
							0
44.21	14.87	29.00	11.11	9.67	55.06	41.92	43.19
4229.25	3385.12	3614.68	3494.91	3436.11	4356.70	4251.04	3766.87
3721.47	2933.99	3145.87	3033.47	2989.28	3837.04	3749.36	3262.65

GENETIC STUDIES IN RED GRAM (*Cajanus cajan* L.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The research project "Genetic studies in red gram (Cajanus cajan L. Mill sp.)" was carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur during the period 1983-86. The genetic diversity studies among the 112 genotypes of red gram obtained from NBPGR, Vellanikkara and TNAU, Coimbatore during 1983-84 showed that the genotypes of the same place of origin fell into different clusters while those of diversified origin fell into same cluster. All the genotypes studied were grouped into five clusters.

Based on both the inter and intracluster distances 20 genotypes representing the broad spectrum of variability were selected and raised during 1985-86. The values estimated for phenotypic coefficient of variation and genotypic coefficient of variation showed that number of clusters per plant, number of pods per plant and seed yield possessed high estimates. Number of days from sowing to 50 per cent flowering and seed yield have exhibited high heritability

coupled with moderately high genetic gain estimates indicating the involvement of additive gene effect. Number of days from sowing to harvest and height of plant at harvest, have high or moderately high estimates of heritability together with low values of genetic gain indicating the action of non-additive genes.

In nine out of ten cases there has been significant positive correlation between component characters and seed yield both in the phenotypic and genotypic levels, however the correlation of hundred seed weight with seed yield was not significant both at phenotypic and genotypic levels. Intercorrelations studies have shown that characters exhibiting significant association with seed yield per plant were also highly intercorrelated indicating that these characters can be simultaneously improved.

Path coefficient analysis showed that number of pods per plant, hundred seed weight, number of primary branches at harvest, number of secondary branches at harvest and length of pod bearing branches had high positive direct effects on seed yield in that order. The residual effect was 0.07227 indicating that about 93 per cent of the variation in yield were contributed by the ten components considered in path coefficient analysis.

The selection index formulated with characters like seed yield, number of pods per plant and hundred seed weight showed an efficiency of 8.4 per cent over direct selection and it includes 57 per cent of the factors determining the yield. Hence it is suggested for isolating superior genotypes.

A comparison of different genotypes based on the index value has revealed the superiority of the genotypes NBPGR-II-EC-10046-1 and NBPGR-124-PLA-345-1 over others.

The study paved the way for understanding the source of variability for various factors contributing to yield, the degree of diversity among the genotypes, on the association between yield and its components and between themselves, and helped to formulate selection index for selecting superior genotypes.