DEPARTMENT OF AGRICULTURE BOTANY,
DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI

Thesis title	**:**	Genetic variability, correlation and path analysis studies in cowpea (*Vigna unguiculata* (L.) Walp.)
Name of the student	**:**	Miss. Lekshmy S.
Regd. No.	**:**	1699
Research Guide	**:**	Dr. V.W. Bendale
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THESIS ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important, early, multiseason and multipurpose pulse crop grown extensively throughout the tropics and subtropics. Being rich in protein and many other nutrients, cowpea is known as vegetable meat.

Inspite of being an excellent multipurpose crop, the productivity of this crop is low. Taking into consideration, the importance of this crop, it is necessary to pay attention to raise it's per hectare yield and bring about significant increase in it's production. Yield improvement would be achieved by developing new superior varieties, which is feasible only by altering the genetic make up of the existing varieties. Such type of work will be facilitated only when genetic variability exists in the available germplasm.

Fifty five genotypes of cowpea were grown in Randomized block design with three replications at Research Farm of Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra during *rabi* 2005-06. The genotypes were studied for fifteen characters *viz*., days to first flowering, days to fifty per cent flowering, days to first pod maturity, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per

plant, number of grains per pod, pod length, biological yield per plant, harvest index, hundred grain weight and grain yield per plant.

The experimental studies revealed substantial amount of genetic variability among the genotypes under study. In general, phenotypic coefficients of variation were higher in magnitude than genotypic coefficient of variation. The characters, number of secondary branches per plant and plant height at maturity showed comparatively higher estimates of genotypic and phenotypic coefficients of variation indicating high level of variability and ample scope for effective improvement. The higher estimates of heritability coupled with high genetic advance as percentage of mean indicated additive gene action for the above characters. Correlation studies revealed strong positive association of biological yield per plant, hundred grain weight and number of peduncles per plant with grain yield per plant. The path analysis studies indicated that the characters number of pods per plant and days to first pod maturity bearing direct positive effect on grain yield, could be the selection criteria for genetic improvement of grain yield per plant in cowpea population under study.

Thus, the genotypes COCP 711, DCP 11, KSM 5, HC 03-2 and CPD 16 are observed as desirable among the population for future use in breeding programme, as these genotypes had good performance for the important quantitative traits.

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(Miss. Lekshmy S.)
Regd. No. 1699

APPENDIX – II

ABBREVIATIONS USED

@	:	at the rate
%	:	Percentage
C.D.	:	Critical difference
^{0}C	:	degree Celsius
cm	:	centimeter (s)
d.f.	:	degrees of freedom
E.M.S.	:	Error mean sum of square
σ^2e	:	Environmental variance
et al.	:	and others
Fig.	:	Figure
g	:	gram (s)
G.A.	:	Genetic advance
G.A.M.	:	genetic advance as percentage of mean
G.C.V.	:	genotypic coefficient of variation
σ^2g	:	genotypic variance
h^2b	:	Heritability in broad sense
ha.	:	Hectare (s)
i.e.	:	that is
kg	:	kilogram
m	:	meter(s)
M.S.S.	:	mean sum of squares
mg	:	milligram
NPK	:	Nitrogen, Phosphorus, Potassium
P.C.V.	:	phenotypic coefficient of variation
σp	:	phenotypic standard variance
σ^2p	:	Phenotypic variance
q	:	Quintal
S.E.	:	Standard error
via	:	through
viz.	:	namely

CHAPTER I
INTRODUCTION

Pulses are reckoned with national priority in agricultural research by virtue of their role in nutritional security, soil enrichment, production sustainability, income generation and as source of food, fodder, feed and vegetable. Pulses are inseparable ingredients of the predominantly vegetarian Indian diet, as they are the cheapest source of dietary protein and an essential food ingredient. Even though India has successfully achieved food sufficiency, nutritional security continues to be a cause of concern. The food legumes are rich in protein, the value being 2 to 3 fold higher than that in cereals. So it is apt to say that “Look after the pulses and proteins will look after you”. As they are fair sources of nutrients, pulses can play a wide role in correcting the wide spread malnutrition in the country.

Pulse crops have the unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as by consoling and improving the physical properties of soil by virtue of their taproot system. The value of pulse crops to agriculture is thus immense, especially when we consider the exhaustion of soils, which takes place at an alarming speed in tropical countries due to both high temperature and torrential rains. Many of them can give reasonable yields even in exhausted soils and can survive the drought conditions.

India is the largest producer of pulses in the world. The production of pulses in the country is 15.24 million tonnes from an area of 24.45 million hectares, with productivity of 623 kg per hectare (Masood Ali and Shivkumar, 2005). In Maharashtra, pulses are grown on an area of 35

lakh hectares with production of 22.57 lakh tonnes and average productivity of 644 kg per hectare.

The decreasing per capita availability of pulses from 69 g in 1961 to 37g in 2004, in the country has been a serious concern. To alleviate protein – energy malnutrition, a minimum of 50 g pulses per capita per day should be available in addition to other sources of protein. In order to make the nation pulse sufficient, productivity levels of pulses has to be increased substantially to 12 q per hectare by 2020.

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important, early, multiseason and multipurpose pulse crop grown extensively throughout the tropics and subtropics. It is a popular legume grown for tender green pod, fodder and dry grains. It is mostly cultivated as a mixed crop with a cereal or in association with a root or tuber crop in rice fallows. It fits well into different cropping systems, due to its relative drought tolerance. Cowpeas are efficient plant types requiring minimum natural resources but grains of high economic value.

Cowpea belongs to the genus *Vigna* which comprises 169 species of which 120 are endemic to Africa, 28 to Asia, 14 to America and 7 to Australia. (Faris, 1965). The diploid chromosome number of cowpea is 2n = 2x = 22. It belongs to the family *Leguminoseae* and subfamily *Fabacea*. According to Verdcourt (1970), *Vigna unguiculata* has five subspecies, which are *cylindrica, sesquipedalis, dekindtiana, unguiculata* and *mensensis.* Among them *cylindrica, unguiculata* and *sesquipedalis* are cultivated species whereas *mensensis* and *dekindtiana* are wild ones.

Cowpea is believed to be originated in Africa. India and China are considered to be the two secondary centres of origin of cowpea. In India, it has been known since Vedic times and is popularly known by many

vernacular names like Lobia (Hindi), Barbati (Bengali), Chavali (Marathi) and Mambayar (Malayalam). It is mostly grown in Kerala, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Punjab and Delhi.

Being rich in protein and many other nutrients, cowpea is known as vegetable meat. On dry weight basis cowpea seeds contain 23.4 per cent protein, 1.8 per cent fat and 3 per cent carbohydrates (Singh, 1983). Cowpea supplies 76 mg per 100 g calcium, 5.7 mg per 100 g iron, 430 mg per 100 g phosphorous, 0.92 mg riboflavin, 0.18 mg thiamine and calorific value 342 calories per 100 g (Anon., 2002). Cowpea fixes atmospheric nitrogen through symbiosis with nodule bacteria (*Bradyrhizobium* sp.) to the tune of 40-50 kg nitrogen per hectare.

The annual area cropped under cowpea and its total production is difficult to estimate since it is rarely grown as a single crop. Total area under cowpea in Maharashtra and Konkan is about 11,800 hectares and 1,200 hectares respectively. The annual production of cowpea in Maharashtra and Konkan is 4600 M tonnes and 500 M tonnes, with a productivity of 390 kg per hectare and 400kg per hectare, respectively (Anon., 1998)

Inspite of being an excellent multipurpose crop, the productivity of this crop is low. Taking into consideration, the importance of this crop, it is necessary to pay attention to raise it’s per hectare yield and bring about significant increase in it’s production. Yield improvement would be achieved by developing new superior varieties, which is feasible only by altering the genetic make up of the existing varieties. Such type of work will be facilitated only when genetic variability exists in the available germplasm.

Genetic variability is a key factor, which determines the amount of progress expected from selection. It is not only true for making selections but it also helps in selecting desirable parents in breeding programmes. Since many characters of economic importance are highly influenced by environmental conditions, study of genetic variability present in the base population is essential.

The selection of plants with desirable phenotypes from genetically variable population is the essential feature of all plant breeding programmes. But the selection of phenotypically superior individuals will not lead to improvement, if most of the variability among the individuals is attributable to non-heritable agencies. The success of a breeder in changing the characteristics of a population depends upon the degree of correspondence between the phenotypic values and genotypic values. This is obtained from the estimates of heritability, which is a quantitative measure, which provides information about the correspondence between genotypic variance and phenotypic variance.

Yield is regarded as a complex character or super character, which is influenced by many contributing traits both in positive and negative directions and is also largely subjected to the environmental fluctuations. So selection based on yield components is likely to be more effective. Correlation is a biometrical technique, which provides information about the relative contribution of various component traits towards yield. It measures the mutual relationship among various plant characters and helps in determining the yield components. This gives a reasonable indication for the breeder to base his selection on traits to improve economic yield and also plan a more efficient breeding programme.

Linear correlation between yield and various growth characters can present a confusing picture because of the inter relationship of the

component characters themselves. The technique of path-efficient analysis, developed by Wright (1921), provides an effective means of partitioning the correlation coefficient to direct and indirect effects of the component characters towards yield. Rate of improvement is expected to be rapid, if differential emphasis is laid on the component characters during selection. Based on the direct effect exerted by a character on yield, breeder can consider that particular character for improvement.

Keeping all the above mentioned points in view, the present study is undertaken with the following objectives.

1) To work out the range of genetic variability in relation to yield and its component characters.
2) To estimate the phenotypic and genotypic correlations of different yield components.
3) To know the important yield components having greater direct and indirect effects over yield through path analysis.

CHAPTER II

REVIEW OF LITERATURE

The present investigation was undertaken to assess the variability, correlation and path analysis among 15 characters in fifty five genotypes of cowpea (*Vigna unguiculata* (L.) Walp). The literature pertaining to these aspects in cowpea is furnished below.

2.1 Genetic variability, heritability and genetic advance:

The assessment of genotypic variance, heritability estimates and genetic advance are very important for a successful selection programme. Johannsen (1909) suggested that variation between pure lines is due to both heritable and non heritable components. If the heritable variation in the genes controlling a character is purely additive, then that character can be fixed by selection and maximum genetic advance can be accomplished by continued selection (Panse, 1957).

Dumbre *et al.* (1983) studied different variability parameters for six quantitative characters among 24 genotypes of cowpea. Wide range of variation was observed for plant height, maturity period and grain yield. The GCV and PCV estimates were high for grain yield per plant, pods per plant and plant height. Heritability for the characters like days to flowering, plant height, grains per pod and pods per plant was high whereas that for maturity period and grain yield per plant was moderate. Genetic advance was found to be highest for grain yield per plant, followed by plant height.

Kumar and Mishra (1983) revealed wide range of genetic variation for days to first flowering, seed yield, and pods per plant in fifty genotypes of cowpea. High heritability estimates were observed for days

to first flower, seed weight, pod width and pod length, which indicated larger genetic variability and lesser effect of environment.

Apte *et al.* (1987) studied fifty genotypes of cowpea and reported considerable variation for the characters like plant height, 100 seed weight, harvest index and seed yield per plant. High heritability and high genetic advance were recorded for 100 seed weight, seeds per pod and pod length.

Patil and Baviskar (1987) observed high genotypic and phenotypic coefficients of variation for the characters like pods per plant, clusters per plant, grain yield per plant and 100 grain weight. Heritability estimates were highest for 100 grain weight, followed by days to maturity and pod length. High heritability coupled with high genetic advance was recorded for 100 grain weight, pods per plant, clusters per plant and grain yield per plant.

Sharma *et al.* (1988) noticed wide range of variation for plant height, dry matter yield, pods per plant, seed weight and green forage yield in 35 genotypes of cowpea. High heritability estimate was observed for days to 50 per cent maturity.

Siddique and Gupta (1991) evaluated 50 genotypes of cowpea for their seed yield and other eight traits. They observed high GCV and PCV for the number of pods per plant, plant height, seed yield and 100 seed weight. The heritability and genetic advance were quite high with high GCV for seed yield, number of pods per plant, 100 seed weight and plant height.

Ram *et al.* (1994) observed a wide range of variability for plant height and seed yield per plant in 27 varieties of cowpea. Heritability estimates were highest for plant height. High heritability coupled with

high genetic advance was estimated for plant height, seed yield per plant and pods per plant.

Selvi *et al.* (1994) worked out different genetic parameters for eleven characters in 54 diverse genotypes of cowpea. High variability was noticed for yield per plant, clusters per plant and plant height. High heritability and genetic advance were also estimated for the same character.

Rewale *et al.* (1995) reported high heritability estimates coupled with high genetic gain for 100 seed weight, plant height and harvest index in 70 diverse genotypes of cowpea.

Backiyarani and Nadarajan (1996) recorded high GCV and PCV for leaf area index, number of pods per plant, number of clusters per plant and 100 seed weight. Heritability and genetic advance estimates suggested the preponderance of additive gene effects for 100 seed weight, harvest index and single plant yield in 34 cowpea genotypes.

Sreekumar *et al.* (1996) observed high values for genotypic and phenotypic coefficient of variation and heritability and genetic advance for pod length and seeds per pod. The number of days to flowering and the days to harvest showed high heritability with low genetic advance.

Ram and Singh (1997) reported high heritability estimates for pod and peduncle length, green pod yield per plant, days to 50 per cent flowering, days to maturity, plant height, seeds per pod, branches per plant and 100 seed weight. High heritability estimates combined with high genetic advance were observed for pod length and green pod yield per plant.

Sobha and Vahab (1998) conducted genetic variability studies in 31 genotypes of vegetable cowpea. High genotypic coefficient of

variation was observed for pod weight and pod yield per plant. Heritability and genetic advance were high for yield per plant.

Vardhan and Savithramma (1998) evaluated 29 accessions of cowpea and observed high genotypic and phenotypic coefficients of variation, heritability and genetic advance for pods per plant, plant height and number of secondary branches.

Sharma (1999) reported high genotypic variation for plant height, harvest index and days to 50 per cent flowering in 42 diverse genotypes of cowpeas. Almost all the characters showed high heritability values and plant height showed highest genetic advance.

Girish (2000) recorded high phenotypic and genotypic coefficient of variability for plant height, branches per plant, number of pods per plant and seed yield whereas moderate values for pod length, number of seeds per pod and 100 seed weight. Genetic advance as per cent of mean was high for plant height, primary branches, secondary branches, number of seeds per pod, seed yield and 100 seed weight in cowpea genotypes.

Rameshkumar and Sangwan (2000) studied yield related traits in 72 diverse genotypes of cowpea. Significant differences in GCV and PCV were observed for all the characters. Moderate to high heritability coupled with high genetic advance were recorded for plant height, pod length, 100 seed weight, grain yield per plant, number of branches per plant and pods per plant.

Selvam *et al.* (2000) observed high GCV and PCV for plant height, number of pods, seed yield and number of branches per plant in 50 cowpea genotypes. GCV, heritability and genetic advance were high for plant height and days to 50 per cent flowering.

Tyagi *et al.* (2000) reported higher genotypic co-efficient of variation, heritability and genetic advance for days to 50 per cent flowering, plant height, seed yield per plant and days to maturity in 24 cowpea genotypes.

Borah and Khan (2001) studied the extent of different genetic parameters in 60 cowpea genotypes. High estimates of PCV and GCV were observed only for number of branches. The characters like number of branches and plant height exhibited high heritability coupled with high genetic advance.

Nehru and Manjunath (2001) reported high phenotypic coefficient of variation for pods per plant, cluster, primary branches and yield per plant. High PCV coupled with high heritability resulted in high genetic advance for pods per plant and moderate for plant height, 100-seed weight and yield per plant.

Hodawadekar (2002) studied genetic variability, correlation and path analysis for thirteen yield contributing characters in 30 genotypes of cowpea. The analysis of variances showed significant variation for all the characters. High heritability coupled with high genetic advance over mean was recorded for 100 seed weight, dry weight per plant, plant height, seed yield per plant, pod length, pods per plant and primary branches per plant.

Chauhan *et al.* (2003) studied genetic parameters of seed yield components in 18 forage cowpea genotypes. Additive gene effects were significant for plant height, pods per plant and 100 seed weight.

Kutty *et al.* (2003) noticed high GCV and PCV for yield, pods per plant and pod weight in 37 genotypes of vegetable cowpea. High

heritability coupled with high genetic advance was also observed for the above characters.

Pal *et al.* (2003) reported high genotypic and phenotypic coefficient of variation for plant height, number of branches per plant, number of peduncles per plant, and pods per plant. High heritability with moderate to high GCV and genetic advance were observed for plant height, primary branches per plant and peduncles per plant.

Patil (2003) studied 47 genotypes of cowpea and observed wide range of variation for plant height, days to complete maturity, days to first flowering and days to first pod maturity. High heritability along with high genetic advance was observed for pods per plant, seed yield per plant, biological yield and plant height.

Vineetakumari *et al.* (2003) recorded high GCV and PCV values for days to maturity and flowering, pods per plant, 100 seed weight and seed yield per plant in 50 cowpea genotypes. High heritability and genetic gain were recorded for seed yield per plant and number of pods per plant.

Venkatesan *et al.* (2003) evaluated 20 genotypes of cowpea for variability, heritability and genetic advance. Significant variation was found among the genotypes for all the traits. High GCV, PCV, heritability and genetic advance were recorded for plant height and dry matter production. High heritability coupled with genetic advance was recorded for plant height, dry matter production and seed yield.

Nigude *et al*. (2004) observed wide range of genetic variability in yield and yield components in 45 genotypes of cowpea. High magnitude of GCV and PCV were recorded for plant height, grain yield and pods per plant. The characters like plant height, grain yield, test weight, number of

pods per plant and pod length showed high heritability and high genetic advance.

Prasanthi (2004) reported very high GCV and PCV for plant height, pods per plant, 100 seed weight and seed yield in 22 cowpea genotypes. High heritability and high to moderate genetic advance were observed for 100 seed weight pods per plant, plant height and seeds per pod.

Kumawat *et al*. (2005) computed components of variation and estimates of heritability and genetic advance for seed yield and it's components in 50 genotypes of cowpea. Significant variability was found for all the traits studied. High estimates of heritability along with genetic advance were recorded for harvest index and seed yield per plant.

2.2 Correlation:

An attempt to understand the effects of environmental factors on the heredity expression forms the basis for differentiating the association among various components of yield into correlation due to phenotypic and genotypic attributes.

Dumbre *et al.* (1982) studied association of grain yield with other economic characters in 24 cultivars in cowpea. Plant height and pods per plant were significantly correlated with yield at both phenotypic and genotypic levels. Weak association was observed between days to 50 per cent flowering and days to maturity with yield. The estimates of genotypic correlation coefficients were more than the corresponding phenotypic correlations indicating the consistency of association among traits.

Singh and Dabas (1985) carried out correlation studies in 50 genotypes of cowpea. Positive significant correlation was observed

between grain yield and plant height, pods per plant, pod length and grains per pod.

Patil and Bhapkar (1987) studied inter relationship between grain yield, pods per plant and other component traits in 49 cultivars of cowpea. Significant correlation of grain yield with pods per plant and that of grains per pod with pod length and 100 grain weight were observed. Significant positive correlation at genotypic level was also observed between days to flowering and maturity and days to flowering with number of primary branches.

Sharma *et al.* (1988) reported significant positive correlation of seed yield with pods per plant, seeds per pod, days to first flowering and days to 50 per cent maturity in 35 genotypes of cowpea.

Apte *et al.* (1991) worked out genotypic, phenotypic and environmental correlation coefficients for 11 characters in cowpea. Highly significant positive correlation was observed for seed yield with number of inflorescences per plant, number of pods per plant and number of grains per pod. However, 100 grain weight and harvest index indicated significant negative genotypic correlation, thus emphasizing the importance of these traits in designing the ideal plant type in cowpea.

Oseni *et al.* (1992) elucidated the inter relationship among yield characters of 36 lines of cowpea. Pods per plant showed significant positive correlation with yield. Days to flowering showed positive correlation with 100 seed weight. But both number of days to flowering and 100 seed weight showed high negative correlation with grain yield.

Altnbas and Sepetoglu (1993) reported significant positive correlation of seed yield with pods per plant, seeds per pod and branches per plant in 75 accessions of cowpea. The 1000 seed weight was

negatively and significantly associated with pods per plant and seeds per pod.

Damarany (1994) derived information on genotypic and phenotypic correlations in 15 genotypes, including 5 parents and their F_1's in cowpea. Seed yield was found to be positively correlated with number and weight of pods, seeds per pod, plant height and number of branches per plant.

Reddy *et al.* (1994) analysed character association in 36 genotypes of green gram. The characters like pods per plant, pods per cluster, and seeds per pod had strong positive association with grain yield and also among themselves, thus indicating that yield increased whenever there was increase in these characters.

Sawant (1994) analysed 10 varieties and 45 crosses of cowpea for association between seed yield and it's component traits. Genotypic correlations were higher in magnitude than the phenotypic correlations. Seed yield was significantly and positively correlated with branches per plant, pods per plant, inflorescences per plant, pod length, seed per pod, 100 seed weight and harvest index at genotypic and phenotypic levels. A positive association was found among the characters such as branches per plant, pods per plant, inflorescences per plant, pod length, seeds per pod and 100 seed weight.

Tamilselvam and Das (1994) recorded positive correlation of seed yield with plant height, number of branches, pods per plant, pod length, number of seeds per pod and 100 seed weight in cowpea. Pod length was positively correlated with 100 seed weight. But number of clusters and pods per plant were negatively correlated with pod length and 100 seed weight.

Pariya *et al.* (1999) noticed positive significant association of yield per plant with plant height, number of pods per plant, 100 seed weight and pod length. Days to 50 per cent flowering and days to maturity exhibited significant and positive genotypic correlation with seed yield in black gram.

Kapoor *et al.* (2000) estimated correlation coefficients for yield and component characters in sixty genotypes of cowpea. The number of seeds per pod and 100 seed weight were found to be positively correlated with seed yield.

Tyagi *et al.* (2000) observed significant genotypic and phenotypic correlation coefficients between nine characters in 24 genotypes of cowpea. Seed yield per plant showed highly significant positive correlation with days to 50 per cent flowering, plant height, pod length, number of pods per plant, seed weight per pod and 100 seed weight at phenotypic and genotypic levels.

Hodawadekar (2002) reported highly significant positive correlation of seed yield per plant with 100 seed weight and harvest index at both phenotypic and genotypic levels in 30 genotypes of cowpea. The characters seeds per pod, dry weight per plant, plant height, days to first pod maturity and complete maturity showed significant positive association with seed yield at both levels. The character pods per plant had significant negative association with pod length and grains per pod.

Patil (2003) carried out correlation studies in 47 genotypes of cowpea. Highly significant positive correlation was observed between seed yield per plant and number of pods per plant, harvest index, leaf area per plant, dry weight of pods per plant and biological yield per plant at both genotypic and phenotypic levels.

Vineetakumari *et al.* (2003) reported significant positive correlation of seed yield per plant with number of clusters, pods per plant and 100 seed weight in 50 cowpea genotypes. But days to maturity was found to be negatively correlated with seed yield per plant.

Venkatesan *et al*. (2003) studied correlation for 10 traits in 20 genotypes of cowpea. The number of branches per plant, number of clusters per plant, number of pods per plant and pod yield were positively correlated with seed yield at genetic and phenotypic levels. The magnitude of genetic correlation was higher than that of phenotypic correlation.

Nigude *et al*. (2004) observed highly significant and positive association for almost all the characters studied except pod length and test weight at genotypic and phenotypic levels in 45 genotypes of cowpea.

Singh *et al.* (2004) revealed comparatively higher degree of genotypic correlation coefficients than their phenotypic counterparts in most of the characters in cowpea. Grain yield was significantly and highly correlated with pods per plant, clusters per plant and harvest index. Number of seeds per pod, pod length and 100 seed weight had positive and significant association with yield at genotypic level. Grain yield had negative association with days to 50 per cent flowering, days to maturity and plant height.

2.3 Path analysis

Yield being a multiplicative end product of many factors which jointly or singly influence it, the prime requirement of a plant breeder would be to have the exact information on the nature and extent of direct and indirect influence of component characters in building up the ultimate yield. This makes path analysis studies more and more important.

Patil and Telang (1976) reported direct positive influence of number of grains per pod on grain yield. Hundred seed weight also had a large positive direct effect on grain yield but it also showed an indirect negative influence through length of pod.

Apte *et al.* (1989) revealed that days to 50 per cent flowering, primary branches per plant, number of inflorescence per plant, number of seeds per pod, 100 seed weight and harvest index had the maximum direct effect on seed yield in cowpea. But the characters like number of pods per plant and pod length had negative direct effect on seed yield.

Bhavsar and Birari (1989) recorded positive direct effect of characters days to 50 per cent flowering, days to maturity, number of primary branches per plant, plant height, number of seeds per pod, number of pods per plant and 100 seed weight on grain yield in genetic studies of moth bean.

Patil *et al.* (1989) observed high positive direct effect of pods per plant, 100 grain weight and seeds per pod on yield in cowpea.

Patnaik and Roquib (1990) conducted path analysis studies in 25 genotypes of cowpea. Direct positive effect of days to 50 percent flowering, days to maturity and number of pods per plant on seed yield was indicated.

Oseni *et al.* (1992) reported direct positive effect of characters days to flowering, 100 seed weight, days to pod filling and pod length on grain yield, whereas seeds per plant and days to maturity had high but negative direct effect on grain yield.

Misra *et al.* (1994) indicated greatest direct effect of pod length on pod yield, followed by leaf area and pod diameter in cowpea, while direct

but negative effects were observed for number of leaves per plant and average pod weight.

Reddy *et al.* (1994) revealed that pods per plant, clusters per plant and seeds per pod had high magnitudes of positive direct effect on grain yield in green gram. Most of the characters studied showed positive indirect effect, which suggested their importance in selection to isolate superior lines with genetic potentiality for high grain yield.

Sawant (1994) observed that pods per plant had the highest positive direct effect on grain yield, followed by 100 seed weight, seeds per pod, days to 50 per cent flowering, inflorescences per plant, harvest index, plant height and pod length. This suggested the usefulness of component selection method to improve yield per plant in cowpea.

Girish (2000) revealed highest positive direct effect of secondary branches per plant, number of pods per plant pod length and number of seeds per pod in path coefficient analysis in cowpea. The indirect contribution of component characters on seed yield was high through pod length and direct effect from number of pods per plant.

Kapoor *et al.* (2000) reported that number of seeds per pod and 100 seed weight contributed directly towards the seed yield whereas pod length contributed indirectly towards seed yield *via* the number of seeds per pod and 100 seed weight.

Tyagi *et al.* (2000) studied direct and indirect effects of different characters on seed yield per plant using path coefficient levels in cowpea. Among the different characters studied, seed yield per plant registered highest positive direct effect on seed weight per pod followed by number of pods per plant, 100 seed weight and days to maturity.

Vidya and Oommen (2002) observed that number of pods per plant had greatest direct effect on yield. The number of pods per plant also had positive indirect effect through duration of harvesting period and number of pods per inflorescence.

Oliveira *et al.* (2003) noticed that average length of pods, number of seeds per pod, number of secondary branches, average length of the main branches and number of leaves per plant had slight direct effect on grain yield.

Venkatesan (2003) suggested that traits, number of pods per plant, pod length, number of clusters per plant number of seeds per pod and 100 seed weight should be given more emphasis during selection as they showed positive direct effect on seed yield.

Singh *et al.* (2004) worked out direct and indirect effect of different characters on grain yield per plant. Number of pods per plant showed highest positive direct effect followed by days to 50 per cent flowering, harvest index, clusters per plant, pod length and branches per plant. Days to maturity and plant height showed highest negative direct effect.

CHAPTER III

MATERIALS AND METHODS

The information pertaining to the experimental details and analytical methodology followed during the present investigation entitled "Genetic variability, correlation and path analysis studies in cowpea (*Vigna unguiculata* (L.) Walp.)" has been presented below.

3.1 Experimental site

The present field experiment was carried out at Research Farm, Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra State during the *rabi* season from December, 2005 to April, 2006.

Geographically, Dapoli is situated in the subtropical region on 17^0 45' North latitude and 73^0 12' East longitude at an altitude of 250 meters above mean sea level with warm and humid conditions throughout the year. The soil of the experimental plot was lateritic in nature. The mean annual rainfall of this region ranges from 3500 to 4000 mm, which is generally received from June to October. The meteorological data during the period of investigation was collected from Meteorological Observatory, Department of Agronomy, College of Agriculture, Dapoli and are presented in Appendix-I.

3.2 Experimental material

The material for the present study comprised of fifty five genotypes of cowpea, from various locations. The list of genotypes along with their source is given in Table 1.

Table 1. List of genotypes and their source

A)	Entries from Pulses and Oilseed Crops Research and Training Center, Pandharpur (Maharashtra) Genotypes: 1) PCP 9708, 2) PCP 9702-1, 3) PCP 9790 4) PCP 97102, 5) PCP 9776, 6) PCP 97111, 7) PCP 9719, 8) PCP 97223, 9) PCP 9757, 10) PCP 97124, 11) PCP 9722.
B)	Entries from AICRP on Arid Legumes, CAZRI, Jodhpur (Rajasthan) Genotypes: 1) CPD 16, 2) CPD 45, 3) CPD 20-16, 4) V 240, 5) GC 9040, 6) TCM 148-1, 7) CAZC 21, 8) V 585, 9) VCP 39, 10) VCP 16
C)	Entries received from IARI, New Delhi Genotypes: 1) Pusa phalguni, 2) DCP 2, 3) DCP 11
D)	Entries from Dharwad, Karnataka Genotypes: 1) DCS 5, 2) DCS 6
E)	Entries from Coimbatore, Tamil Nadu Genotypes: 1) COCP 711
F)	Entries from Anand, Gujarat Genotypes: 1) ACP 126, 2) ACP 109
G)	Entries from Hissar,Haryana Genotypes: 1) HC 03-1, 2) HC 03-2, 3) HC 03-3, 4) HC 03-4
H)	Released varieties from Dr.B.S.K.K.V., Dapoli Genotypes : 1) Konkan Safed, 2) Konkan Sadabahar

I)	Entries received from Botany Department, AC, Dapoli Genotypes: 1) M 10, 2) KSM 1, 3) KSM 2, 4) KSM 3,

	5) KSM 4, 6) KSM 5, 7) KSM 6, 8) KSM 7, 9) KSM 8, 10) KSM 9, 11) KSM 10, 12) KSM 11, 13) KSM 12, 14) KSM 13, 15) KSM 14, 16) PND 1
J)	Local collection from Kankavali block of Sindhudurg District, Maharashtra Genotypes: 1) KNKL 3
K)	Local collection from Kudal block of Sindhudurg, Maharashtra Genotypes: 1) KDL 2
L)	Local collection from Banda block of Sindhudurg, Maharashtra Genotypes: 1) BND 1, 2) BND 2

3.3 Methodology

3.3.1 Experimental design

The experiment was laid out in Randomized Block Design with three replications. The genotypes represented the treatments under each replication. The details of field experiment are given below.

3.3.2 Plot size

Three rows of each genotype having ten plants in each row were grown in each replication.

Plot size : 0.9 m × 2.0 m

Spacing : 30 cm × 20 cm

Date of sowing : 30th December, 2005

3.3.3 Method of sowing

The seeds were dibbled at a spacing of 30 cm × 20 cm and single healthy seedling per hill was kept to ensure healthy growth of the plant.

3.3.4 Cultural practices

The preliminary tillage practices were carried out properly in order to bring soil at proper condition. The basic fertilizer dose @ 25 kg N, 50 kg P and 50 kg K per hectare was applied at the time of sowing. The second dose of nitrogen was applied @ 25 kg N per hectare before flowering. The operations like gap filling and thinning were done within 10-15 days of sowing so as to maintain one plant per hill. Other recommended cultural practices like weeding, spraying of insecticides, fungicides, etc. were followed as and when required. The experiment was irrigated as per the requirements.

3.3.5 Sampling of plants

Five plants were selected randomly from each genotype in each replication and observations were recorded from each selected plants.

3.4 Observations recorded

The observations were recorded on five randomly selected plants per genotype from each replication for fifteen characters. The mean of observations of the five selected plants was used for statistical analysis. The observations recorded are as follows:

1. Days to first flowering

Number of days were counted from the date of sowing to appearance of first flower.

2. Days to 50 per cent flowering

Number of days were counted from the date of sowing to the day when 50 per cent of the plants in a row flowered.

3. Days to first pod maturity

Number of days were counted from the date of sowing to first pod maturity in a row.

4. Days to complete maturity

Number of days required from date of sowing to complete maturity of plant was recorded.

5. Plant height at maturity (cm)

Plant height was measured from ground level to the tip of main axis of the plant at the time of maturity and expressed in centimeters.

6. Number of primary branches per plant

The total number of primary branches on the main stem were counted at the time of maturity.

7. Number of secondary branches per plant

Te total number of secondary branches on primary branches were counted for each observational plant.

8. Number of peduncles per plant

The total number of peduncles present on the plant at the time of first pod maturity were counted.

9. Number of pods per plant

The total number of seed bearing pods on each observational plant were counted.

10. Number of grains per pod

The number of seeds from randomly selected, five pods of each selected plant was taken for analysis.

11. Pod length (cm)

The pods were selected from each of the randomly selected plant and average of their length in centimeter was taken for analysis.

12. Biological yield per plant (g)

The biological yield per plant was recorded as the sum of seed yield and dry weight of each observational plant and average was taken for analysis.

13. Hundred grain weight (g)

From the bulk of harvested seeds from randomly selected plants, hundred seeds were counted and weighed to record the hundred grain weight in grams.

14. Grain yield per plant (g)

The matured pods were collected from observational plants at each picking and the pods from all pickings of individual plants were dried, threshed and the clean seeds were weighed in grams.

15. Harvest index (%)

The proportion of economic yield per plant with biological yield per plant was recorded as harvest index and denoted in percentage.

$$\text{H.I. (\%)} = \frac{\text{Economic yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

Where economic yield refers to seed yield of each plant.

3.5 Statistical analysis

The mean values worked out from the measurements recorded on five randomly selected plants for different characters were used for statistical analysis. The following statistical parameters were used for presentation of data on different quantitative attributes.

3.5.1 Analysis of design of experiment

The data available on individual characters were subjected to the method of analysis of variance commonly applicable to the Randomised Block Design (Panse and Sukhatme, 1988). The analysis of variance was done as given below :

Sources of variation	**d.f.**	**M.S.**	**Expected M.S.**
Replication	(r-1)	RMS	$\sigma^2 e + g\sigma^2 r$
Genotypes	(g-1)	GMS	$\sigma^2 e + r\sigma^2 g$
Error	(r-1) (g-1)	EMS	$\sigma^2 e$

Where

r = number of replications

g = number of genotypes

MS = mean square

$\sigma^2 e$ = environmental variance

$\sigma^2 g$ = genotypic variance

$\sigma^2 r$ = replication variance

The genotypes mean square (GMS) was tested against error mean sum of square (EMS) by 'F' test for n_1 = (g-1) and n_2 = (r-1) (g-1) degrees of freedom.

3.5.2 Estimation of mean and range

The mean value for each character was worked out by dividing sum of all observations by number of observations

$$\bar{X} = \frac{\sum Xi}{n}$$

Where

$\bar{X}$ = Mean of the character

$\sum$ Xi = summation of all observations

n = number of observations

Range : The lowest and highest values from mean of each character were recorded as range.

$$\text{Coefficient of variation (C.V.)} = \frac{\text{S.D.}}{\bar{X}} \times 100$$

Where

$$\text{Standard deviation (S.D.)} = \sqrt{\frac{1}{n}\sum (X - \bar{X})^2}$$

3.5.3 Estimation of components of variation

The phenotypic, genotypic and environmental variances were calculated by utilizing the respective mean square values from the variance table.

a) Environmental variance

$$\sigma^2 e = EMS$$

b) Genotypic variance

$$\sigma^2 g = \frac{GMS - EMS}{r}$$

c) Phenotypic variance

$$\sigma^2 p = \sigma^2 g + \sigma^2 e$$

Where

GMS = Genotypic mean sum of squares

EMS = Error mean sum of squares

r = Number of replications

3.5.4 Estimation of coefficients of variation

The genotypic and phenotypic coefficients of variations were calculated as per the formulae given by Burton and Devane (1953).

a) Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

Where

$\sigma^2 g$ = Genotypic variance

$\bar{X}$ = Mean of the character

b) Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

Where

$\sigma^2 p$ = Phenotypic variance

$\bar{X}$ = Mean of the character

3.5.5 Estimation of heritability ($h^2 b$)

Heritability in broad sense was estimated for various characters by the formulae suggested by Lush (1945).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

3.5.6 Estimation of genetic advance (GA)

The genetic advance was calculated in per cent by the formula suggested by Johnson *et al*. (1955).

a) $$GA = \frac{\sigma^2 g}{\sigma^2 p} \times \sigma p \times K$$

b) GA as percentage of mean

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

Where

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

σp = Phenotypic standard deviation

K = Selection differential at 5 per cent selection intensity (2.06)

$\bar{x}$ = Mean of the character

3.5.7 Estimation of standard error, standard error of difference and critical difference

a) Standard error of mean

$$SE(m) = \frac{\sqrt{\sigma^2 e}}{r}$$

b) Standard error of difference between two means were calculated as S.E. of difference of mean (SEd)

$$\text{S.E. of difference of means} = SE(m) \times \sqrt{2}$$

c) Critical difference between any two means was calculated as :

C.D. = SEd table 't' value at error degrees of freedom.

3.5.8 Correlation coefficient

Analysis of covariance was carried out by taking two characters at a time, plot error was used as environmental covariance. Thus, phenotypic and genotypic covariance were derived as detailed below :

Sources of variation	d.f.	Mean product
Replication	(r-1)	--
Varieties	(v-1)	GMP
Error	(r-1) (v-1)	EMP
Total	(rv-1)	--

Where

r = Number of replications

v = Number of varieties

GMP = Genotypes sum of products

EMP = Error sum of products

The genotypic and phenotypic co-variance were worked out as per formulae given by Singh and Chaudhary (1985).

a) Environmental co-variance = (CoVe 1.2)

= EMP

b) Genotypic co-variance = (CoVg 1.2)

$$= \frac{GMP - EMP}{r}$$

c) Phenotypic co-variance = (CoVp. 1.2)

= (CoVe 1.2) + (CoVg 1.2)

The appropriate variances and co-variances were used for calculating phenotypic and genotypic correlation coefficients (Johnson *et al*. 1955).

A) Phenotypic correlation

Phenotypic correlation coefficients were derived as

$$r_{p1.2} = \frac{CoVp \quad 1.2}{\sqrt{(\sigma^2 P_1)\ (\sigma^2 P_2)}}$$

Where

$r_{p1.2}$ = Phenotypic correlation between characters l and 2.

$CoVp_{1.2}$ = Phenotypic co-variance between characters l and 2.

$\sigma^2 P_1$ and $\sigma^2 P_2$ = Phenotypic variance of characters 1 and 2, respectively.

B) Genotypic correlation

Genotypic correlation coefficients were obtained by the formulae :

$$r_{g1.2} = \frac{CoVg \quad 1.2}{\sqrt{(\sigma^2 g_1)\ (\sigma^2 g_2)}}$$

Where

$r_{g1.2}$ = Genotypic correlation between characters l and 2.

$CoVg_{1.2}$ = Genotypic co-variance between characters l and 2.

$\sigma^2 g_1$ and $\sigma^2 g_2$ = Genotypic variance of characters 1 and 2, respectively.

The significance of phenotypic and genotypic correlation co-efficient were tested against 'r' values given by Fishers table at (g-2) degrees of freedom, respectively at P = 0.05 and P = 0.01 to test their significance.

The significance of phenotypic and genotypic correlation coefficients can also be tested by using 't' test.

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

Where

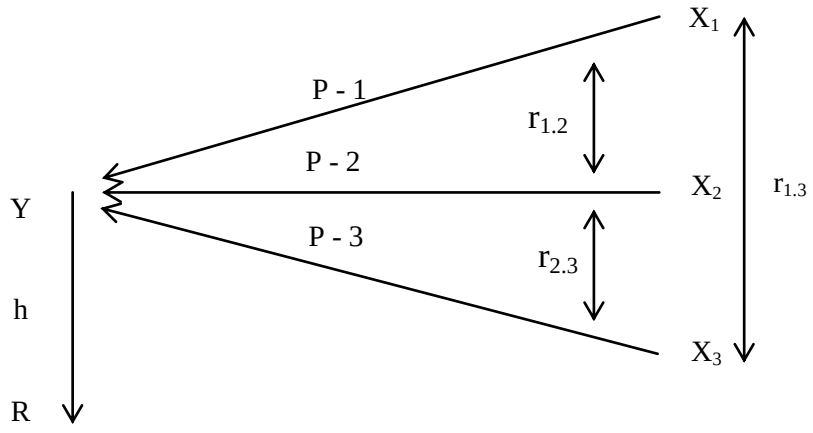
r = Correlation coefficients

n = Total number of observations.

The calculated 't' value is tested with table 't' value for respective (n-2) degrees of freedom for significance.

3.5.9 Path coefficient analysis

To establish a cause and effect relationship, the genotypic and phenotypic correlation coefficients were partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959). The first step in path analysis is to prepare a path diagram based on cause and effect relationship. The concept is that yield is the function of various components like X_1, X_2, X_3. Then these components show following type of association with one another.



From this figure, it is obvious that yield is the result of X_1, X_2 and X_3 and some other undefined factor denoted by 'R'. The double arrowed lines indicate mutual association as measured by correlation coefficients and the single arrowed line represent direct influence as measured by path coefficients P_{ij}.

Path coefficients were obtained by solving a set of simultaneous equations of the form.

$$r_{ny} = P_{ny} + r_{n2} + r_{n2}P_y + r_{n3} + \ldots..$$

Where

r_{ny} = Correlation between one component and yield

P_{ny} = Path coefficient between that character and the yield

r_{n2} = Correlation between the character and each of the other yield components in turn

Matrix A **Matrix B**

$$\begin{bmatrix} r_1 y \\ r_2 y \\ r_n y \end{bmatrix} \qquad \begin{bmatrix} 1 & r_{12} & r_{13} & \ldots.. & r_{1n} \\ r_{21} & 1 & r_{23} & \ldots.. & r_{2n} \\ r_{n1} & r_{n2} & r_{n3} & \ldots & 1 \end{bmatrix}$$

Where

r_{12} = r_{21} and so on

r_{1y} = Correlation between one component character and yield

The B matrix was inverted (B^{-1}) and path coefficients (P_{ij}) were obtained as

$$(P_{ij}) = A \times (B^{-1})$$

The indirect effect of a particular character through other characters was obtained by multiplication of direct path and particular correlation coefficients between the characters, separately.

$$\text{Indirect effects} = r_{ij} \times P_{ij}$$

Where

i = 1 to 6

j = 1 to 6

$P_{ij} = P_{iY1}, P_1y_2, \ldots\ldots, P_{ny}$

Path coefficients (P_{ij}), correlation coefficient (r_{ij}) and residual factors were diagrammatically presented.

The residual factors i.e. variation in yield unaccounted for by these association was calculated from the following formula.

$$\text{Residual effect (X)} = 1 - R^2$$

Where,

$$R^2 = P_{1Y}r_1y + P_2yr_2y + P_3yr_3y + \ldots + P_nyr_ny$$

Where,

$P_1y, P_2y, \ldots P_ny$ = path values

$r_1y, r_2y, \ldots r_ny$ = Correlation coefficients.

CHAPTER IV
EXPERIMENTAL RESULTS

The present investigation entitled, “Genetic variability, correlation and path analysis studies in cowpea (*Vigna unguiculata* (L.) Walp) was carried out for the assessment of the extent of genetic variability for fifteen quantitative characters in fifty five genotypes of cowpea. The results obtained are presented in this chapter under the following headings.

4.1 Genetic variability, heritability and genetic advance

4.2 Correlation

4.3 Path analysis

4.1 Genetic variability, heritability and genetic advance

4.1.1 Analysis of variance

The analysis of variance revealed significant differences among the genotypes. The difference between treatment means was tested by ‘t’ test at both 5 per cent and 1 per cent levels. The results of analysis of variance are presented in Table 2.

The mean sum of squares due to the genotypes was highly significant for all the characters under study. This showed substantial variation for all the characters among the population.

Table 2. Analysis of variance in cowpea

Sr. No.	Characters	Mean sum of squares		
		Replications	Genotypes	Error
1.	Days to first flowering	0.2970	39.8604**	3.7846
2.	Days to 50 per cent flowering	4.0788	113.9836**	6.6776
3.	Days to first pod maturity	2.1012	53.1054**	3.1410
4.	Days to complete maturity	0.2822	58.3569**	3.7103
5.	Plant height at maturity (cm)	0.0303	302.9549**	9.2010
6.	Number of primary branches per plant	0.0368	1.1517**	0.1741
7.	Number of secondary branches per plant	0.0084	0.4621**	0.0323
8.	Number of peduncles per plant	1.3522	14.4079**	0.8358
9.	Number of pods per plant	0.1602	31.7694**	0.7326
10.	Number of grains per pod	0.3232	5.5993**	0.3108
11.	Pod length (cm)	0.2169	12.8939**	0.4310
12.	Biological yield per plant	5.2853	67.0260**	1.9208
13.	Harvest index (%)	3.9329	120.5367**	15.7451
14.	Hundred grain weight (g)	0.0394	12.0189**	0.3734
15.	Grain yield per plant (g)	2.4893	18.4939**	0.7930

**Significant at 1 per cent level.

4.1.2 Mean performance and range of variability

The mean performance of genotypes, general mean and range of variation for fifteen characters studied are presented in Table 3.

Table 3. Mean performance for 15 quantitative characters in cowpea

Sr. No.	Genotypes	Days to first flowering	Days to 50% flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)
1.	PCP 9708	63.67	75.67	86.33	92.40	18.09
2.	PCP 9702-1	62.33	71.33	87.73	93.73	19.09
3.	PCP 97102	59.67	71.33	84.87	92.67	33.53
4.	PCP 9790	63.33	71.67	86.20	92.40	34.41
5.	PCP 9776	63.33	73.00	87.67	95.00	33.43
6.	PCP 97111	63.67	72.67	87.10	92.60	28.01
7.	PCP 9719	65.00	73.67	90.00	95.53	34.16
8.	PCP 97223	60.67	70.67	84.87	91.60	34.14
9.	PCP 9757	61.33	74.33	85.10	91.10	31.99
10.	PCP 97124	61.67	68.33	85.73	90.60	36.68
11.	PCP 9722	64.67	74.00	86.00	92.80	23.52
12.	KDL 2	64.33	82.67	93.80	97.67	43.29
13.	Pusa Phalguni	61.33	74.67	84.73	91.93	30.85
14.	BND 1	68.33	84.00	97.93	104.20	46.07
15.	BND 2	61.00	74.33	89.53	95.93	40.62
16.	M 10	61.33	71.00	85.60	91.20	29.14
17.	PND 1	59.33	72.00	85.27	92.47	27.54
18.	VCP 39	66.67	75.67	91.47	97.80	46.58
19.	VCP 16	63.00	73.00	88.47	94.20	29.34
20.	V 585	69.33	82.00	93.40	100.27	48.98
21.	V 240	65.67	79.33	92.07	97.20	48.19
22.	HC 03-1	67.00	73.33	85.13	90.93	24.27
23.	HC 03-2	64.67	72.00	86.60	97.20	38.51
24.	HC 03-3	62.00	73.33	86.87	94.80	30.06
25.	HC 03-4	63.00	71.33	89.73	98.27	56.89
26.	CPD 20-16	59.67	74.67	84.53	94.33	21.09
27.	GC 9040	64.00	73.33	85.73	92.33	49.22
28.	DCP 2	67.67	83.67	94.93	101.33	30.79

29.	DCP 11	67.00	75.33	86.53	94.20	22.99
30.	CAZC 21	58.67	70.67	85.87	93.53	28.49

Contd…

Contd…

Sr. No.	Genotypes	Days to first flowering	Days to 50 per cent flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)
31.	COCP 711	63.00	72.00	85.40	91.53	22.97
32.	TCM 148-1	69.00	84.67	94.00	100.47	27.58
33.	Konkan Safed	59.00	67.33	83.87	90.73	17.79
34.	ACP 126	63.00	71.67	84.67	90.47	19.81
35.	ACP 106	61.00	71.33	84.53	90.07	18.08
36.	Konkan Sadabahar	57.67	63.67	81.73	86.73	15.25
37.	KSM 1	56.33	63.00	81.60	88.20	22.47
38.	KSM 2	60.33	67.33	82.33	91.27	20.75
39.	KSM 3	56.33	61.67	81.73	89.33	19.46
40.	KSM 4	56.67	61.67	80.13	87.00	19.01
41.	KSM 5	60.33	68.33	83.47	91.67	31.50
42.	KSM 6	60.67	67.67	82.93	89.67	23.79
43.	KSM 7	59.67	65.33	82.80	88.87	24.41
44.	KSM 8	60.00	64.33	80.87	85.47	17.67
45.	KSM 9	59.00	65.67	80.47	85.30	19.52
46.	KSM 10	60.33	66.67	81.80	87.53	20.31
47.	KSM 11	60.00	65.33	82.27	86.47	18.27
48.	KSM 12	55.33	62.67	82.53	86.93	17.71
49.	KSM 13	55.00	62.67	80.80	86.40	16.97
50.	KSM 14	59.33	65.00	82.67	89.87	18.04
51.	DCS 5	69.33	81.00	89.70	99.07	24.48
52.	DCS 6	69.33	88.00	96.00	102.20	38.14
53.	KNKL 3	62.67	74.67	85.87	92.20	22.57
54.	CPD 16	66.33	74.67	85.73	93.27	27.51
55.	CPD 45	61.33	76.00	92.27	97.73	35.45
	Range	55.00 to 69.33	61.67 to 88.00	80.13 to 97.93	85.30 to 104.20	15.25 to 56.89
	General mean	62.26	72.09	86.37	92.89	28.72

	S.E. ±	1.12	1.50	1.02	1.11	1.75
	C.D. at 5%	3.15	4.19	2.88	3.12	4.92
	C.D. at 1%	4.17	5.54	3.80	4.13	6.51

Contd…

Contd…

Sr. No.	Genotypes	Number of primary branches per plant	Number of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod
1.	PCP 9708	2.40	0.13	10.47	14.87	10.13
2.	PCP 9702-1	3.20	0.27	10.47	11.80	11.13
3.	PCP 97102	4.07	0.00	13.60	14.60	12.80
4.	PCP 9790	3.00	0.17	9.47	13.33	12.40
5.	PCP 9776	2.60	0.00	9.20	11.33	12.27
6.	PCP 97111	2.87	0.13	12.27	18.07	12.93
7.	PCP 9719	2.87	0.20	9.33	14.53	12.00
8.	PCP 97223	3.13	0.53	10.67	14.87	12.73
9.	PCP 9757	3.00	0.13	9.53	12.93	12.73
10.	PCP 97124	3.53	0.53	12.06	17.53	13.07
11.	PCP 9722	2.53	0.20	9.93	13.53	12.07
12.	KDL 2	3.13	0.27	9.13	10.53	13.73
13.	Pusa Phalguni	3.20	0.47	10.00	14.87	13.00
14.	BND 1	4.00	0.60	6.60	8.53	12.80
15.	BND 2	2.93	0.00	9.93	10.80	12.93
16.	M 10	2.47	0.00	11.60	15.00	11.48
17.	PND 1	3.27	0.47	11.00	14.93	13.80
18.	VCP 39	2.73	0.20	10.13	18.73	12.00
19.	VCP 16	2.47	0.47	11.20	17.87	14.33
20.	V 585	3.87	0.60	7.93	12.83	13.73
21.	V 240	3.27	0.87	10.20	12.20	10.67
22.	HC 03-1	2.93	0.53	7.20	7.47	14.40
23.	HC 03-2	2.73	0.20	12.87	20.60	11.13
24.	HC 03-3	2.53	0.27	11.07	20.20	10.00
25.	HC 03-4	3.20	1.00	10.33	16.47	12.33
26.	CPD 20-16	2.87	0.47	9.93	13.00	11.47
27.	GC 9040	2.80	0.80	9.13	12.20	11.47

28.	DCP 2	3.47	0.53	8.73	9.67	13.47
29.	DCP 11	4.27	0.00	16.27	19.80	10.87
30.	CAZC 21	1.67	0.20	8.13	13.47	10.80

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Sr. No.	Genotypes	Number of primary branches per plant	No. of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod
31.	COCP 711	3.73	0.67	9.60	9.13	16.27
32.	TCM 148-1	4.53	0.47	7.33	13.73	12.60
33.	Konkan Safed	2.40	2.00	13.07	15.20	9.13
34.	ACP 126	2.57	0.00	7.07	8.07	13.80
35.	ACP 106	3.07	1.33	12.47	12.60	12.60
36.	Konkan Sadabahar	2.93	0.87	8.00	12.00	12.60
37.	KSM 1	4.53	1.00	12.00	15.07	11.93
38.	KSM 2	4.20	0.87	14.93	18.13	12.13
39.	KSM 3	3.13	0.87	12.07	15.53	11.07
40.	KSM 4	3.73	0.60	11.73	14.93	11.00
41.	KSM 5	2.53	0.40	13.23	20.67	10.93
42.	KSM 6	3.27	0.20	14.87	17.73	9.40
43.	KSM 7	2.53	0.13	12.53	13.87	11.20
44.	KSM 8	3.60	0.00	7.73	15.87	11.80
45.	KSM 9	3.53	0.27	9.60	14.40	12.47
46.	KSM 10	3.13	0.87	10.93	14.93	12.13
47.	KSM 11	2.67	0.60	7.73	13.47	12.47
48.	KSM 12	4.07	0.67	12.60	14.73	12.47
49.	KSM 13	3.07	0.40	10.07	13.60	12.47
50.	KSM 14	2.20	0.27	7.13	9.07	11.67
51.	DCS 5	3.47	0.67	10.20	10.33	9.40
52.	DCS 6	4.00	1.20	6.13	10.00	14.20
53.	KNKL 3	2.33	0.27	8.53	17.07	13.47
54.	CPD 16	2.53	0.93	10.33	17.73	11.53
55.	CPD 45	3.07	0.27	11.60	17.73	10.53
	Range	1.67 to 4.53	0.00 to 2.00	6.13 to 16.27	7.47 to 20.67	9.13 to 16.27

	General mean	3.12	0.47	10.36	14.21	12.13
	S.E. ±	0.24	0.11	0.53	0.49	0.32
	C.D. at 5%	0.68	0.29	1.48	1.39	0.90
	C.D. at 1%	0.89	0.39	1.96	1.84	1.19

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Sr. No.	Genotypes	Pod length (cm)	Biological yield per plant (g)	Harvest index (%)	Hundred grain weight (g)	Grain yield per plant (g)
1.	PCP 9708	12.08	20.87	66.33	10.99	13.83
2.	PCP 9702-1	17.52	21.70	63.59	13.96	14.16
3.	PCP 97102	14.61	25.81	57.63	10.32	14.84
4.	PCP 9790	14.08	21.89	60.68	10.48	13.28
5.	PCP 9776	13.47	20.52	62.14	10.59	12.78
6.	PCP 97111	13.28	26.31	55.81	9.37	14.67
7.	PCP 9719	14.83	24.79	57.15	11.76	14.17
8.	PCP 97223	14.70	25.82	55.70	12.61	14.39
9.	PCP 9757	15.37	27.30	53.48	12.45	14.53
10.	PCP 97124	14.01	27.09	62.11	11.18	16.79
11.	PCP 9722	12.66	19.15	51.70	8.69	9.94
12.	KDL 2	15.45	32.40	46.91	11.85	15.35
13.	Pusa Phalguni	14.02	25.71	55.73	11.87	14.29
14.	BND 1	17.41	23.60	42.31	13.70	9.98
15.	BND 2	16.71	25.79	49.47	13.39	12.76
16.	M 10	11.53	21.66	60.03	8.56	13.03
17.	PND 1	16.44	23.83	54.31	14.84	12.93
18.	VCP 39	12.36	22.83	50.09	8.31	11.45
19.	VCP 16	10.02	12.75	52.45	6.36	6.68
20.	V 585	14.16	29.79	40.88	11.71	12.16
21.	V 240	18.04	24.51	57.50	13.15	14.08
22.	HC 03-1	17.81	12.84	57.54	10.97	7.39
23.	HC 03-2	11.20	25.86	53.78	10.13	13.91
24.	HC 03-3	11.01	22.27	55.64	10.70	12.32
25.	HC 03-4	13.65	22.70	39.91	12.00	9.07

26.	CPD 20-16	12.57	14.97	50.27	14.28	7.79
27.	GC 9040	13.19	19.06	52.44	11.48	9.98
28.	DCP 2	15.40	22.73	50.07	13.10	11.37
29.	DCP 11	13.01	22.62	49.26	9.46	11.12
30.	CAZC 21	11.67	16.48	58.60	10.29	9.67

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Sr. No.	Genotypes	Pod length (cm)	Biological yield per plant(g)	Harvest index (%)	Hundred grain weight (g)	Grain yield per plant (g)
31.	COCP 711	20.10	32.25	47.25	16.91	15.14
32.	TCM 148-1	13.41	22.74	50.29	11.71	11.38
33.	Konkan Safed	13.99	20.33	70.29	15.08	14.29
34.	ACP 126	17.65	16.51	64.09	11.23	10.59
35.	ACP 106	16.08	18.58	56.76	10.04	12.27
36.	Konkan Sadabahar	12.16	16.47	68.43	9.73	11.27
37.	KSM 1	12.75	17.89	54.66	8.93	9.78
38.	KSM 2	13.45	25.35	52.81	12.13	13.40
39.	KSM 3	13.47	21.72	60.39	11.18	12.22
40.	KSM 4	11.83	19.52	62.46	9.82	12.15
41.	KSM 5	11.79	28.52	56.44	11.57	16.04
42.	KSM 6	12.33	21.94	51.48	9.63	11.30
43.	KSM 7	12.53	16.07	61.94	10.38	9.95
44.	KSM 8	11.80	13.01	47.73	7.51	6.20
45.	KSM 9	11.79	19.18	53.26	7.81	10.08
46.	KSM 10	13.94	21.47	59.94	9.88	12.85
47.	KSM 11	13.48	23.58	52.46	10.08	12.38
48.	KSM 12	13.21	23.99	46.90	8.86	11.26
49.	KSM 13	12.53	20.88	49.67	8.37	10.38
50.	KSM 14	12.21	18.75	53.53	10.00	10.05
51.	DCS 5	16.54	20.38	56.96	11.80	11.56
52.	DCS 6	14.89	16.60	51.27	11.46	8.49
53.	KNKL 3	12.97	19.33	51.72	11.81	10.00
54.	CPD 16	13.36	32.51	53.07	11.82	17.26

55.	CPD 45	13.61	29.30	52.12	12.20	15.24
	Range	10.02 to 20.10	12.75 to 32.51	39.91 to 70.29	6.36 to 16.91	6.20 to 17.26
	General mean	13.89	22.19	54.72	11.05	12.08
	S.E. ±	0.38	0.80	2.29	0.35	0.51
	C.D. at 5%	1.06	2.25	6.43	0.99	1.44
	C.D. at 1%	1.41	2.97	8.51	1.31	1.91

1. Days to first flowering

The genotypes varied significantly for the days to first flowering and it ranged from 55 days to 69.33 days. The average days to first flowering was 62.26 days. Among the fifty five genotypes, twenty six genotypes showed earlier flower initiation than general mean. KSM 13 (55 days) showed earliest flowering followed by KSM 12 (55.33 days) and late flowering was observed in V 585, DCS 5 and DCS 6 (69.33 days).

2. Days to 50 per cent flowering

The overall mean days taken for 50 per cent flowering by the genotypes was 72.09 days with a wide range of variation from 61.67 days to 88 days. Twenty six genotypes took more days to 50 per cent flowering than the overall mean. DCS 6 (88 days) took maximum days for 50 per cent flowering while KSM 3 and KSM 4 (61.67 days) took minimum days.

3. Days to first pod maturity

Days taken to first pod maturity ranged from 80.13 days to 97.93 days with an overall mean of 86.37 days. Twenty genotypes showed more number of days to first pod maturity than the overall mean and thirty five showed less number of days. BND 1 (97.93 days) showed maximum number of days to first pod maturity followed by DCS 6 (96 days) while KSM 4 (80.13 days) recorded minimum duration to first pod maturity.

4. Days to complete maturity

Days taken to complete maturity ranged from 85.30 days to 104.20 days with an average of 92.88 days. Thirty three genotypes were earlier in duration to complete maturity and twenty two were late. KSM 9 (85.30 days) and KSM 8 (85.47 days) were earlier in duration, while BND1 (104.20 days) was late, followed by DCS 6 (102.20 days) and DCP 2 (101.33 days).

5. Plant height at maturity (cm)

The variation for plant height was substantial from 15.25 cm to 56.89 cm with an overall mean of 28.72 cm (Plate II). Thirty two genotypes registered higher height than the overall mean. Among the genotypes HC 03-4 (56.89 cm) was tallest, followed by GC 9040 (49.22 cm) and V 585 (48.98 cm). Minimum height was observed in Konkan Sadabahar (15.25 cm), followed by KSM13 (16.97 cm).

6. Number of primary branches per plant

The range of variation was 1.67 to 4.53 for this character with an average of 3.12. Among the genotypes, twenty six had more number of primary branches than the overall mean and twenty nine had lesser number. TCM 148-1 and KSM 1 recorded maximum number of primary branches per plant, i.e. 4.53 followed by DCP 11 (4.27), while CAZC 21 (1.67) showed minimum number of primary branches per plant.

7. Number of secondary branches per plant

This character had a mean of 0.47 with a range of variation from 0.00 to 2.00. Twenty eight genotypes had more number of secondary branches while twenty seven genotypes had lesser number of secondary branches than the general mean. The genotypes PCP 97102, BND 2, M 10, DCP 11,

ACP 126 and KSM 8 recorded minimum, while Konkan Safed (2.00) recorded maximum number of secondary branches per plant.

8. Number of peduncles per plant

The number of peduncles per plant varied from 6.13 (DCS 6) to 16.27 (DCP 11). The average number of peduncles per plant was 10.36. Twenty four genotypes had more and thirty one had lesser number of peduncles per plant than the average. Genotypes like KSM 6 (14.87) and KSM 2 (14.93) also recorded higher number of peduncles per plant.

9. Number of pods per plant

The number of pods per plant varied from 7.47 to 20.67 (Plate III). The average number of pods per plant was 14.21. Twenty nine genotypes had more and twenty six had lesser number of pods per plant than the average. The maximum number of pods per plant was observed in KSM 5 (20.67), HC 03-2 (20.60) and HC 03-3 (20.20) while HC 03-1 (7.47) and ACP 126 (8.07) showed lesser number of pods per plant among the genotypes under study.

10. Number of grains per pod

The range of variation for this character was from 9.13 (Konkan Safed) to 16.27 (COCP-711), with a mean value of 12.13. Twenty nine genotypes had more and twenty six had lesser number of grains per pod than the mean value. Genotypes like HC 03-1 (14.40), VCP 16 (14.33) and DCS 5 (14.20) also recorded higher number of grains per pod whereas KSM 5 and KSM 14 (9.40) registered lesser number of grains per pod.

11 Pod length (cm)

The genotypes were found to be varying from 10.02 (VCP-16) to 20.10 (COCP-711) with a mean value of 13.89 (Plate V). Thirty two genotypes had shorter and twenty three genotypes had longer pods than the average.

12. Biological yield per plant

The biological yield per plant varied from 12.75 g to 32.51 g. The mean biological yield per plant was 22.19 g. Twenty seven genotypes recorded higher biological yield per plant and twenty eight genotypes recorded lower biological yield per plant than the average. CPD 16 (32.51 g) had maximum biological yield per plant, followed by KDL 2 (32.40 g) and COCP 711 (32.25 g). VCP16 (12.75 g) had lower biological yield per plant, followed by HC 03-1 (12.84 g).

13. Harvest index (%)

The genotypes varied substantially for this character from 39.91 to 70.29 per cent. The mean harvest index was 54.72 per cent. Twenty five genotypes showed higher harvest index over the mean value, whereas thirty genotypes showed lesser value than mean. Konkan Safed (70.29) recorded highest harvest index while HC 03-4 (39.91) recorded lowest harvest index among the genotype studied.

14. Hundred grain weight (g)

The weight of hundred grains varied from 6.367 g (VCP 16) to 16.91 g (COCP 711). The average hundred grain weight was 11.05 g. Twenty eight genotypes recorded higher hundred seed weight and twenty seven genotypes recorded lower hundred seed weight than the average. Genotypes KSM 9 (7.81 g) and KSM 8 (7.51 g) also showed lower hundred seed weight whereas Konkan Safed (15.08 g), PND 1 (14.84 g) and CPD 20-16 (14.28 g) recorded higher hundred seed weight.

15. Grain yield per plant (g)

The variability for seed yield ranged from 6.20 g to 17.26 g. The average seed yield per plant was 12.08 g. Thirty genotypes of cowpea showed higher grain yield per plant than average, while twenty five genotypes recorded lower yield than average. Maximum grain yield per plant was observed in CPD 16 (17.26 g) followed by PCP 97124 (16.79 g) and KSM 5 (16.04 g). KSM 8 (6.20 g) and VCP 16 (6.68 g) recorded minimum grain yield per plant.

4.1.3 Components of variation

The total variation among the population was partitioned into three components *viz*., genotypic, phenotypic and environmental variance. The estimates of variances due to these three components for fifteen characters are given in Table 4.

Table 4. Estimates of phenotypic (σ^2p), genotypic (σ^2g) and environmental (σ^2e) variance

Sr. No.	Characters	σ^2p	σ^2g	σ^2e
1.	Days to first flowering	15.810	12.025	3.785
2.	Days to 50 per cent flowering	42.446	35.769	6.678
3.	Days to first pod maturity	19.796	16.655	3.141
4.	Days to complete maturity	21.926	18.216	3.710
5.	Plant height at maturity (cm)	107.119	97.918	9.201
6.	Number of primary branches per plant	0.500	0.326	0.174
7.	Number of secondary branches per plant	0.176	0.143	0.033
8.	Number of peduncles per plant	5.360	4.524	0.836
9.	Number of pods per plant	11.078	10.345	0.733
10.	Number of grains per pod	2.074	1.763	0.311
11.	Pod length (cm)	4.585	4.154	0.431
12.	Biological yield per plant(g)	23.623	21.702	1.921
13.	Harvest index (%)	50.676	34.931	15.745
14.	Hundred grain weight (g)	4.255	3.882	0.373
15.	Grain yield per plant (g)	6.693	5.900	0.793

The phenotypic variances ranged between 0.18 (number of secondary branches per plant) to 107.12 (plant height). The genotypic variances ranged between 0.14 (number of secondary branches per plant) to 97.92 (plant height). The environmental variances ranged between 0.03 (number of secondary branches per plant) to 15.74 (harvest index).

In general phenotypic variances were greater in magnitude than the genotypic variances. Phenotypic variance was found to be maximum for

plant height (107.12). The characters harvest index (50.68), days to 50 per cent flowering (42.46) and biological yield per plant (23.62) recorded comparatively moderate phenotypic variance, while grain yield per plant (6.70), pod length (4.59), hundred grain weight (4.26), number of peduncles per plant (5.36), number of primary branches per plant (0.50) and number of secondary branches per plant (0.18) indicated lower magnitude of phenotypic variance.

The genotypic variances were higher in magnitude over the respective environmental variances for all the characters. Plant height at maturity (97.92) showed highest estimate of genotypic variance, followed by days to 50 per cent flowering (35.77) harvest index (34.93) and biological yield per plant (21.70). The characters days to complete maturity (18.22), days to first pod maturity (16.66), days to first flowering (12.03) and number of pods per plant (10.35) showed moderate genotypic variance. Grain yield per plant (5.90), peduncles per plant (4.52), pod length (4.15), hundred grain weight (3.88), number of grains per pod (1.76), number of primary branches per plant (0.33) and number of secondary branches per plant (0.14) indicated lower magnitudes of genotypic variance.

In general, the environmental variances were lower in magnitude over the respective phenotypic and genotypic variances for the different characters.

4.1.4 Coefficient of variation

The estimates of phenotypic and genotypic coefficient of variation are presented in Table 5.

In general phenotypic coefficient of variation (PCV) was greater in magnitude over the respective genotypic coefficient of variation. Least

magnitude of phenotypic coefficient of variation was recorded for characters days to complete maturity (5.04%) and days to first pod maturity (5.15%), followed by days to first flowering (6.39%) and days to 50 per cent flowering (9.04%), Number of pods per plant (23.43%), number of primary branches per plant (22.63%), number of peduncles per plant (22.35%), biological yield per plant (21.90%) and grain yield per plant (21.42%) indicated comparatively moderate estimates of phenotypic coefficient of variation. Maximum magnitude of phenotypic coefficient of variation was observed for number of secondary branches per plant (88.69%), followed by plant height at maturity (36.04%).

The amount of genetic variation present in the population was worked out in terms of genotypic coefficient of variation (GCV). The minimum genotypic coefficient of variation was exhibited by characters days to complete maturity (4.60%) and days to first pod maturity (4.73%). Number of pods per plant (22.64%), biological yield per plant (20.99%), number of peduncles per plant (20.53%) and grain yield per plant (20.11%) recorded comparatively moderate values of genotypic coefficient of variation. Highest value of genotypic coefficient of variation was registered for number of secondary branches per plant (79.95%), followed by plant height at maturity (34.46%).

4.1.5 Heritability and genetic advance

The estimates of heritability and genetic advance are presented in Table 5.

High estimates of heritability in broad sense were exhibited by all the characters studied. Heritability ranged from 65.20 per cent for number of secondary branches per plant to 93.38 per cent for number of pods per plant.

Very high estimates of heritability was exhibited by characters number of pods per plant (93.38%), biological yield per plant (91.87%), plant height at maturity (91.41%), hundred grain weight (91.23%) and pod length (90.60%).

Table 5. Estimates of genetic parameters for various characters of cowpea

Sr. No.	Characters	GCV %	PCV %	h^2b %	G.A.	GAM %
1.	Days to first flowering	5.57	6.39	76.06	6.23	10.00
2.	Days to 50 per cent flowering	8.30	9.04	84.27	11.31	15.69
3.	Days to first pod maturity	4.73	5.15	84.13	7.71	8.93
4.	Days to complete maturity	4.60	5.04	83.08	8.01	8.62
5.	Plant height at maturity (cm)	34.46	36.04	91.41	19.49	67.85
6.	Number of primary branches per plant	18.28	22.63	65.20	0.95	30.41
7.	Number of secondary branches per plant	79.95	88.69	81.25	0.70	147.99
8.	Number of peduncles per plant	20.53	22.35	84.40	4.03	38.90
9.	Number of pods per plant	22.64	23.43	93.38	6.40	45.05
10.	Number of grains per pod	10.95	11.88	85.00	2.52	20.78
11.	Pod length (cm)	14.67	15.41	90.60	4.00	28.79
12.	Biological yield per plant	20.99	21.90	91.87	9.20	41.46
13.	Harvest index (%)	10.80	13.01	68.93	10.11	18.48
14.	Hundred grain weight (g)	17.82	18.66	91.23	3.88	35.10
15.	Grain yield per plant (g)	20.11	21.42	88.15	4.70	38.92

The estimates of heritability for other characters were 88.15 per cent for grain yield per plant, 85 per cent for grains per pod, 84.40 per cent for number of peduncles per plant, 84.27 per cent for days to 50 per cent flowering, 84.13 per cent for days to first pod maturity, 83.08 per cent for days to complete maturity, 81.25 per cent for number of secondary branches per plant, 76.06 per cent for days to first flowering, 68.93 per cent for harvest index and 65.20 per cent for number of primary branches per plant.

Plant height at maturity showed comparatively higher estimate of genetic advance, i.e. 19.49. Minimum magnitude of genetic advance was recorded for number of secondary branches per plant (0.70) and number of primary branches per plant (0.95). Genetic advance as percentage of mean ranged from 8.62 per cent (days to complete maturity) to 147.99 per cent (number of secondary branches per plant). Plant height at maturity (67.85%) and number of pods per plant (45.05%) showed higher estimates of genetic advance as per cent of mean, while days to first pod maturity (8.93%) and days to first flowering (10.00%) exhibited minimum genetic advance as per cent of mean.

4.2 Correlation

In order to get knowledge of inter relationship between quantitative characters and yield, correlation coefficients were worked out for all the possible combinations among the characters under study at phenotypic and genotypic level and presented in Table 6 and 7, respectively.

4.2.1 Phenotypic correlation coefficient

Seed yield per plant showed positive and highly significant correlation with biological yield per plant (r=0.816). It also had positive significant correlation with number of peduncles per plant (r=0.360), hundred grain weight (r=0.360) and harvest index (r=0.301). Grain yield per plant exhibited positive but non significant correlation with number of pods per plant, pod length, plant height at maturity, days to complete maturity, days to first pod maturity, number of secondary branches per plant, days to 50 per cent flowering and days to first flowering. It showed negative non-significant correlation with number of grains per pod and number of primary branches per plant.

Table 6. Estimates of phenotypic correlation coefficient between characters in cowpea

Sr. No.	Characters	Days to first flowering	Days to 50 per cent flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod	Pod length (cm)	Biological yield per plant (g)	Harvest index (%)	Hundred grain weight (g)	Grain yield per plant (g)
1.	Days to first flowering	1.000	0.777**	0.690**	0.707**	0.456**	0.109	-0.033	-0.270*	-0.201	0.273*	0.288*	0.165	0.257	0.176	0.002
2.	Days to 50 per cent flowering		1.000	0.858**	0.840**	0.507**	0.102	-0.050	-0.367**	-0.273*	0.282*	0.343*	0.200	-0.305*	0.338*	0.018
3.	Days to first pod maturity			1.000	0.908**	0.628**	0.109	-0.043	-0.344*	-0.238	0.222	0.313*	0.245	-0.332*	0.289*	0.041
4.	Days to complete maturity				1.000	0.625**	0.100	-0.018	-0.240	-0.152	0.143	0.253	0.240	-0.319*	0.357**	0.046
5.	Plant height at maturity (cm)					1.000	0.084	-0.029	-0.121	0.026	0.155	0.164	0.388**	-0.378**	0.192	0.150
6.	Number of primary branches per plant						1.000	0.196	0.176	-0.036	0.294*	0.248	0.206	-0.357**	0.060	-0.005
7.	Number of secondary branches per plant							1.000	0.063	-0.078	-0.017	0.171	-0.005	0.058	0.276*	0.032
8.	Number of peduncles per plant								1.000	0.654**	-0.297*	-0.214	0.252	0.128	-0.092	0.360**
9.	Number of pods per plant									1.000	-0.416**	-0.605**	0.215	0.007	-0.314**	0.250
10.	Number of grains per pod										1.000	0.499**	0.089	-0.279*	0.106	-0.107
11.	Pod length (cm)											1.000	0.272*	-0.059	0.652**	0.232
12.	Biological yield per plant (g)												1.000	-0.275*	0.395**	0.816**
13.	Harvest index (%)													1.000	-0.033	0.301*
14.	Hundred grain weight (g)														1.000	0.360**
15.	Grain yield per plant (g)															1.000

*Significant at 5 per cent. ** Significant at 1 per cent.

Table 7. Estimates of genotypic correlation coefficient between characters in cowpea

Sr. No.	Characters	Days to first flowering	Days to 50 per cent flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)	Number of primimary branches per plant	Number of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod	Pod length (cm)	Biological yield per plant (g)	Harvest index (%)	Hundred grain weight (g)	Grain yield per plant (g)
1.	Days to first flowering	1.000	0.936**	0.863**	0.851**	0.552**	0.147	-0.069	-0.372**	-0.208	0.369**	0.363**	0.177	-0.332*	0.218	0.001
2.	Days to 50 per cent flowering		1.000	0.943**	0.933**	0.597**	0.176	-0.043	-0.374**	-0.286*	0.352**	0.399**	0.265	-0.390**	0.380**	0.064
3.	Days to first pod maturity			1.000	0.978**	0.723**	0.204	0.001	-0.369**	-0.258	0.293*	0.379**	0.302*	-0.445**	0.349**	0.059
4.	Days to complete maturity				1.000	0.731**	0.179	0.010	-0.258	-0.156	0.200	0.308*	0.297*	-0.452**	0.401**	0.051
5.	Plant height at maturity (cm)					1.000	0.044	-0.048	-0.174	-0.003	0.162	0.174	0.393**	-0.479**	0.220	0.135
6.	Number of primary branches per plant						1.000	0.183	0.133	-0.084	0.363**	0.280*	0.176	-0.390**	0.072	-0.034
7.	Number of secondary branches per plant							1.000	0.029	-0.090	-0.058	0.167	-0.049	0.091	0.305*	0.007
8.	Number of peduncles per plant								1.000	0.693**	-0.372**	-0.293*	0.224	0.187	-0.124	0.361**
9.	Number of pods per plant									1.000	-0.492**	-0.673**	0.204	-0.000	-0.341*	0.244
10.	Number of grains per pod										1.000	0.555**	0.068	-0.354**	0.123	-0.137
11.	Pod length (cm)											1.000	0.272*	-0.068	0.700**	0.228
12.	Biological yield per plant (g)												1.000	-0.283*	0.432**	0.848**
13.	Harvest index (%)													1.000	-0.011	0.256
14.	Hundred grain weight (g)														1.000	0.410**
15.	Grain yield per plant (g)															1.000

*Significant at 5 per cent. ** Significant at 1 per cent.

Days to first flowering was found to have positive and highly significant correlation with days to 50 per cent flowering (r=0.777), days to complete maturity (r=0.707), days to first pod maturity (r=0.690) and plant height at maturity (r=0.456). It exhibited positive significant correlation with number of grains per pod (r=0.273) and pod length (r=0.288) and negative significant correlation with number of peduncles per plant (r=-0.270). Positive non significant correlation was observed with harvest index, hundred grain weight, biological yield per plant, number of primary branches per plant and grain yield per plant. It had negative and non-significant correlation with number of pods per plant and number of secondary branches per plant.

Days to 50 per cent flowering showed highly significant positive correlation with days to first pod maturity (r=0.858), days to complete maturity (r=0.840) and plant height (r=0.507). Pod length (r=0.343), 100-grain weight (r=0.338) and number of grains per pod (r=0.282) were found to have significant positive association with days to 50 per cent flowering. It exhibited strong negative correlation with number of peduncles per plant (r=-0.367) and harvest index (r=-0.305). It had positive but non-significant association with biological yield per plant, number of primary branches per plant and grain yield per plant. It showed negative non-significant correlation only with number of secondary branches per plant.

Days to first pod maturity exhibited strong positive correlation with days to complete maturity (r=0.908) and plant height at maturity (r=0.628). It showed positive significant association with pod length (r=0.313) and hundred grain weight (r=0.289). Numbers of peduncles per plant (r=-0.344) and harvest index (r=-0.332) were found to have significant negative correlation with days to first pod maturity. Days to first pod maturity showed positive but non-significant association with biological yield per

plant, number of grains per pod and number of primary branches per plant, while negative non-significant correlation with number of pods per plant and number of secondary branches per plant.

Days to complete maturity had highly significant positive correlation with plant height (r=0.625) and hundred grain weight (r=0.357). It showed significant negative correlation with harvest index (r=-0.319). It had positive but non-significant association with pod length, biological yield per plant, number of grains per pod and number of primary branches per plant. Number of peduncles per plant, pods per plant and secondary branches per plant were found to have non-significant negative association with days to complete maturity.

Plant height at maturity had strong positive correlation with biological yield per plant (r=0.388), while it had strong negative correlation with harvest index (r=-0.378). It had positive but non-significant association with hundred grain weight, pod length, number of grains per pod, number of pods per plant and number of primary branches per plant. Plant height had negative but non-significant correlation with number of peduncles per plant and number of secondary branches per plant.

Number of primary branches per plant was positively and significantly correlated with number of grains per pod (r=0.294) and negatively correlated with harvest index (r=-0.357). It had positive but non-significant correlation with pod length, biological yield per plant, number of secondary branches per plant, number of peduncles per plant and hundred grain weight. Negative non-significant correlation was noticed with number of pods per plant.

Number of secondary branches per plant showed positive significant correlation with hundred grain weight (r=0.276). It had positive but non-significant association with pod length, number of peduncles per plant and

harvest index. It exhibited negative non-significant correlation with number of pods per plant, number of grains per pod and biological yield per plant.

Number of peduncles per plant was found to have strong positive association with number of pods per plant (r=0.654) and negative significant association with number of grains per pod (r=-0.297). It had positive but non-significant correlation with biological yield per plant and harvest index and negative non-significant correlation with pod length and hundred grain weight.

Number of pods per plant showed strong negative correlation with pod length (r=-0.605) and number of grains per pod (r=-0.416). It had significant negative association with hundred grain weight (r=-0.314). Biological yield per plant and harvest index showed positive but non-significant association with number of pods per plant.

Number of grains per pod exhibited strong positive correlation with pod length (r=0.499) and significant negative correlation with harvest index (r=-0.279). Association of hundred grain weight and biological yield per plant were found to be positive but non-significant.

Pod length exhibited strong positive correlation with hundred grain weight (r=0.652) and significant positive association with biological yield per plant (r=0.272). It had negative non-significant correlation with harvest index.

Biological yield per plant had highly significant positive correlation with hundred grain weight (r=0.395) and significant negative correlation with harvest index (r=-0.275).

Harvest index was found to have negative non-significant association with hundred grain weight (r=-0.033).

4.2.2 Genotypic correlation

The genotypic correlation coefficients were worked out for all the characters and presented in Table 7. In general genotypic correlation coefficients were higher in magnitude over the respective phenotypic

correlation coefficients were higher in magnitude over the respective phenotypic correlation coefficients except for the association in few pairs of characters.

Association of grain yield per plant with biological yield per plant (r=0.848), hundred grain weight (r=0.410) and number of peduncles per plant (r=0.361) were found to be positive and highly significant. Grain yield per plant showed positive but non-significant correlation with harvest index, number of pods per plant, pod length, plant height at maturity, days to 50 per cent flowering, days to first pod maturity, days to complete maturity, number of secondary branches per plant and days to first flowering. It had non-significant negative association with number of grains per pod and number of primary branches per plant.

Days to first flowering showed positive and highly significant correlation with days to 50 per cent flowering (r=0.936), days to first pod maturity (r=0.863), days to complete maturity (r=0.851), plant height at maturity (r=0.552), number of grains per pod (r=0.369) and pod length (r=0.363). It exhibited highly significant negative correlation with number of peduncles per plant (r=-0.372) and significant negative correlation with harvest index (r=-0.332). It was found to have positive but non-significant association with number of primary branches per plant, biological yield per plant and hundred grain weight. It had negative non-significant association with number of secondary branches per plant and number of pods per plant.

Days to 50 per cent flowering exhibited highly significant positive correlation with days to first pod maturity (r=0.943), days to complete maturity (r=0.933), plant height at maturity (r=0.597), pod length (r=0.399), hundred grain weight (r=0.380) and number of grains per pod (r=0.352). It

had highly significant negative correlation with number of peduncles per plant (r=-0.374) and harvest index (r=-0.390). Number of pods per plant showed significant negative correlation with days to 50 per cent flowering (r=-0.286). Days to 50 per cent flowering had negative non-significant correlation with number of secondary branches per plant and positive non-significant association with number of primary branches per plant and biological yield per plant.

Days to first pod maturity was found to have strong positive correlation with days to complete maturity (r=0.978), plant height at maturity (r=0.723), pod length (r=0.379) and hundred grain weight (r=0.349). It had positive significant correlation with biological yield (r=0.302) and number of grains per pod (r=0.293). It exhibited strong negative correlation with harvest index (r=-0.445), and number of peduncles per plant (r=-0.369). Positive but non significant correlation was found between number of primary branches per plant and number of secondary branches per plant with days to first pod maturity.

Days to complete maturity showed positive and highly significant association with plant height at maturity (r=0.731) and hundred grain weight (r = 0.401), while it had significant positive correlation with pod length (r = 0.308) and biological yield (r=0.297). It had highly significant negative correlation with harvest index (r=-0.452) It was found to have positive but non-significant relation with number of grains per pod, number of primary branches per plant and number of secondary branches per plant. Negative non-significant association was observed with number of peduncles per plant and number of pods per plant.

Plant height at maturity was strongly associated with biological yield (r=0.393) in positive direction and harvest index (r=-0.479) in negative direction. It had positive non-significant correlation with hundred grain weight, pod length, number of grains per pod and number of primary branches per plant. Association of plant height with number of peduncles per plant, number of secondary branches per plant and number of pods per plant were found to be negative and non-significant.

Number of primary branches per plant had strong positive correlation with number of grains per pod (r=0.363) and significant positive correlation with pod length (r=0.280). It had strong negative correlation only with harvest index (r=-0.390). Positive but non-significant correlation of primary branches per plant was noticed with number of secondary branches per plant, biological yield per plant, number of peduncles per plant and hundred grain weight, while negative non-significant correlation was observed for number of pods per plant.

Number of secondary branches per plant had positive significant correlation with hundred grain weight (r=0.305). It showed positive but non-significant association with pod length, harvest index and number of peduncles per plant. It was negatively but weakly correlated with number of pods per plant, number of grains per pod and biological yield per plant.

Number of peduncles per plant exhibited strong positive association with number of pods per plant (r=0.693). It showed strong negative correlation with number of grains per pod (r=-0.372) and significant negative correlation with pod length (r=-0.293). It had positive but non-significant association with number of pods per plant, biological yield per plant and harvest index, while weak negative correlation was observed with hundred grain weight.

Number of pods per plant showed strong negative association with pod length (r=-0.673) and number of grains per pod (r=-0.492). It had significant negative correlation with hundred grain weight (r=-0.341). Positive but non-significant correlation of number of pods per plant was observed with biological yield per plant.

Number of grains per pod was found to exhibit strong positive association with pod length (r=0.555) and strong negative correlation with harvest index (r=-0.354). It had positive but non-significant correlation with hundred grain weight and biological yield per plant.

Pod length exhibited highly significant positive correlation with hundred grain weight (r=0.700), while significant positive correlation with biological yield per plant (r=0.272). Negative non-significant association was noticed with harvest index.

Association of biological yield per plant with hundred grain weight (r=0.432) was positive and highly significant. Biological yield per plant exhibited significant negative correlation with harvest index (r=-0.283).

Hundred grain weight was found to be negatively and weakly correlated with harvest index (r=-0.011).

4.3 Path coefficient analysis

As it was essential to measure the contribution of the various variables to the observed association, the correlation coefficients were further partitioned to assess the direct and indirect effects of various characters on yield. Grain yield per plant was taken as the dependent variable, which was the output of direct and indirect effects of independent characters *viz*., days to first flowering, days to 50 per cent flowering, days to first pod maturity, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per

plant, number of peduncles per plant, number of pods per plant, number of grains per pod, pod length, biological yield per plant, harvest index and hundred grain weight.

4.3.1 Phenotypic correlation coefficient partitioned for path coefficient analysis

The phenotypic correlation coefficients were partitioned into direct and indirect effects and are presented in Table 8.

The character days to first flowering had low negative direct effect (-0.033) on grain yield per plant. It's indirect effect via biological yield per plant, days to 50 per cent flowering and pod length were positive, while indirect effects through days to first pod maturity, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, harvest index and hundred grain weight were negative.

Days to 50 per cent flowering had low negative direct effect (-0.025) on grain yield per plant. It had positive indirect effect through days to first flowering, pod length and biological yield per plant. It's indirect effect via days to first pod maturity, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, harvest index and hundred grain weight were negative.

Days to first pod maturity had high positive direct effect (0.051) on green yield per plant. It had positive indirect effect via pod length and biological yield per plant. It's indirect effect via days to 50 per cent flowering, harvest index, plant height at maturity, hundred grain weight, number of peduncles per plant, number of primary branches per plant, days

to complete maturity and number of secondary branches per plant were negative.

Days to complete maturity had low negative direct (-0.008) on grain yield per plant. Its indirect effect via days to first pod maturity, biological yield per plant and pod length were positive. It had negative indirect effect through days to first flowering, days to 50 per cent flowering, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, harvest index and hundred grain weight.

Plant height at maturity had negative direct effect (-0.000) on grain yield per plant. It had positive indirect effect *via* days to first pod maturity, number of pods per plant, pod length and biological yield per plant. It's indirect effect *via* days to first flowering, days to 50 per cent flowering, days to complete maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, harvest index and hundred grain weight were negative.

Number of primary branches per plant had low negative direct effect (-0.002) on grain yield per plant. The positive indirect effect of number of primary branches per plant was through days to first pod maturity, number of secondary branches per plant, number of peduncles per plant, pod length and biological yield per plant. It's indirect effect *via* days to first flowering, days to 50 per cent flowering, days to complete maturity, plant height at maturity, number of pods per plant, number of grains per pod, harvest index and hundred grain weight were negative.

Number of secondary branches per plant had low negative direct effect (-0.004) on grain yield per plant. It had positive indirect effect on grain yield through harvest index, pod length, days to first flowering,

number of peduncles per plant, number of grains per pod, number of primary branches per plant, days to 50 per cent flowering, days to complete maturity and plant height at maturity. It's indirect effect *via* days to first pod maturity, number of pods per plant, biological yield per plant and hundred grain weight were negative.

Table 8. Path analysis of different characters at phenotypic level in cowpea

Sr. No.	Characters	Days to first flowering	Days to 50 per cent flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)	No. of primary branches per plant	No. of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod	Pod length (cm)	Biologi-cal yield per plant (g)	Harvest index (%)	Hundred grain weight (g)	Total
1.	Days to first flowering	-0.033	0.046	-0.006	-0.000	-0.009	-0.002	-0.000	-0.007	-0.012	-0.014	0.029	0.156	-0.139	-0.008	0.002
2.	Days to 50 per cent flowering	0.059	-0.025	-0.008	-0.000	-0.010	-0.002	-0.000	-0.010	-0.016	-0.014	0.034	0.190	-0.165	-0.015	0.018
3.	Days to first pod maturity	-0.009	-0.022	0.051	-0.000	-0.013	-0.002	-0.000	-0.009	-0.014	-0.011	0.031	0.232	-0.180	-0.013	0.041
4.	Days to complete maturity	-0.000	-0.023	0.050	-0.008	-0.012	-0.002	-0.000	-0.006	-0.009	-0.007	0.025	0.228	-0.172	-0.016	0.046
5.	Plant height at maturity (cm)	-0.020	-0.015	0.030	-0.006	-0.000	-0.002	-0.000	-0.003	0.002	-0.008	0.016	0.368**	-0.204	-0.009	0.015
6.	Number of primary branches per plant	-0.018	-0.004	0.006	-0.001	-0.000	-0.002	0.001	0.005	-0.002	-0.015	0.025	0.195	-0.193	-0.003	-0.005
7.	Number of secondary branches per plant	0.007	0.001	-0.003	0.000	0.000	0.001	-0.004	0.002	-0.004	0.001	0.017	-0.004	0.031	-0.012	0.032
8.	Number of peduncles per plant	0.027	-0.009	-0.022	0.003	0.000	0.002	-0.003	0.000	0.038	0.015	-0.021	0.239	0.069	0.004	0.360**
9.	Number of pods per plant	0.058	0.007	-0.016	0.002	0.000	-0.001	0.001	-0.001	0.017	0.021	-0.060	0.204	0.004	0.014	0.250
10.	Number of grains per pod	-0.051	-0.009	0.017	-0.002	-0.000	-0.003	-0.005	-0.000	-0.008	-0.024	0.050	0.084	-0.151	-0.005	-0.107
11.	Pod length (cm)	0.099	-0.009	0.020	-0.003	-0.000	-0.003	-0.004	0.001	-0.006	-0.035	-0.025	0.258	-0.032	-0.029	0.232
12.	Biological yield per plant (g)	0.948**	-0.005	0.012	-0.002	-0.000	-0.008	-0.004	-0.000	0.007	0.012	-0.005	0.027	-0.149	-0.018	0.816**
13.	Harvest index (%)	0.540**	0.008	-0.018	0.003	0.000	0.008	0.006	0.000	0.003	0.000	0.014	-0.006	-0.261*	0.001	0.301*
14.	Hundred grain weight (g)	-0.044	-0.006	0.020	-0.003	-0.000	-0.004	-0.001	0.002	-0.002	-0.018	-0.005	0.065	0.375**	-0.018	0.360**

(Underlined figures indicate direct effect)

* Significant at 5% level ** Significant at 1% level. Residual effect = 2.9442.

Number of peduncles per plant had no direct effect (0.000) on grain yield per plant. However, it's indirect effect through harvest index, number of pods per plant, biological yield per plant, days to first flowering, number of grains per pod, days to 50 per cent flowering, hundred grain weight, days to complete maturity, number of primary branches per plant and plant height at maturity were positive which were nullified by it's negative indirect effect *via* days to first pod maturity, number of secondary branches per plant and pod length.

Number of pods per plant had low positive effect (0.017) on grain yield per plant. Its positive indirect effect on grain yield was observed through biological yield per plant, days to first flowering, number of grains per pod, hundred grain weight, days to 50 per cent flowering, harvest index, days to complete maturity, number of secondary branches per plant and plant height at maturity. Its indirect effect *via* days to first pod maturity, number of primary branches per plant, number of peduncles per plant and pod length were negative.

Number of grains per pod had low negative direct effect (-0.024) on grain yield per plant. It's indirect effect through days to first pod maturity, biological yield per plant and pod length were positive, while it had negative indirect effect through days to first flowering, days to 50 per cent flowering, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, harvest index and hundred grain weight.

Pod length had low negative direct (-0.025) on grain yield per plant. It's indirect effect through biological yield per plant, days to first flowering, days to first pod maturity and number of peduncles per plant were positive. It's indirect effect *via* days to 50 per cent flowering, days to complete

maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, pods per plant, number of grains per pod, harvest index and hundred grain weight were negative.

Biological yield per plant had low positive direct effect (0.027) on grain yield per plant. Its positive indirect effect on grain yield per plant was through days to first flowering, days to first pod maturity, number of grains per pod and pods per plant. It's indirect effect through days to 50 per cent flowering, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, pod length, harvest index and hundred grain weight were negative.

Harvest index had high negative direct effect (-0.261) on grain yield per plant. It's indirect effect through days to first flowering, days to 50 per cent flowering, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, pod length and hundred grain weight were positive. Its indirect effect *via* days to pod maturity and biological yield per plant were negative.

Hundred grain weight had low negative direct effect (-0.018) on grain yield per plant. It had positive indirect effect on grain yield through biological yield per plant, days to first pod maturity and number of peduncles per plant. It's indirect effect *via* days to first flowering, days to 50 per cent flowering, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of grains per pod and pod length were negative.

The residual effect of path analysis at phenotypic level was found to be about 2.9442.

4.3.2 Genotypic correlation coefficient partitioned for path coefficient analysis

The genotypic correlation coefficients were partitioned into direct and indirect effects and presented in Table 9.

The character days to first flowering had low negative direct effect (-0.029) on grain yield per plant. It's indirect effects *via* days to first pod maturity, days to 50 per cent flowering, biological yield per plant, plant height at maturity and hundred grain weight were positive, while it's indirect effects *via* days to complete maturity, number of peduncles per plant, harvest index, number of pods per plant, number of grains per pod, pod length, number of primary branches per plant and number of secondary branches per plant were negative.

Days to 50 per cent flowering had low negative direct effect (-0.027) on grain yield per plant. It had positive indirect effect on grain yield through days to first pod maturity, days to first flowering, biological yield per plant, hundred grain weight and plant height at maturity. It's indirect effects *via* days to complete maturity, number of pods per plant, harvest index, number of peduncles per plant, number of grains per pod, pod length, number of primary branches per plant and number of secondary branches per plant were negative.

Days to first pod maturity had high positive direct effect (0.316) on grain yield per plant. It had positive indirect effect on grain yield through days to first flowering, hundred grain weight, biological yield per plant, plant height at maturity and number of secondary branches per plant. It's indirect effect through days to complete maturity, harvest index, number of peduncles per plant, number of pods per plant, number of grains per pod,

pod length, days to 50 per cent first flowering and number of primary branches per plant were negative.

Table 9. Path analysis of different characters at genotypic level in cowpea

Sr. No.	Characters	Days to first flowering	Days to 50 per cent flowering	Days to first pod maturity	Days to complete maturity	Plant height at maturity (cm)	No. of primary branches per plant	No. of secondary branches per plant	Number of peduncles per plant	Number of pods per plant	Number of grains per pod	Pod length (cm)	Biological yield per plant (g)	Harvest index (%)	Hundred grain weight (g)	Total
1.	Days to first flowering	-0.029	0.314*	0.548**	-0.800**	0.037	-0.003	-0.000	-0.049	-0.017	-0.020	-0.008	0.153	-0.153	0.028	0.001
2.	Days to 50 per cent flowering	0.336*	-0.027	0.598**	-0.876**	0.040	-0.004	-0.000	-0.050	-0.024	-0.019	-0.008	0.229	-0.179	0.049	0.064
3.	Days to first pod maturity	0.635**	-0.025	0.316*	-0.918**	0.048	-0.004	0.000	-0.049	-0.022	-0.016	-0.008	0.262*	-0.205	0.045	0.059
4.	Days to complete maturity	-0.939**	-0.025	0.313*	0.621**	0.049	-0.004	0.000	-0.034	-0.013	-0.011	-0.007	0.257*	-0.208	0.051	0.051
5.	Plant height at maturity (cm)	0.067	-0.016	0.200	0.459**	-0.687**	-0.001	-0.000	-0.023	-0.000	-0.009	-0.004	0.341*	-0.220	0.028	0.135
6.	Number of primary branches per plant	-0.020	-0.004	0.059	0.129	-0.168	0.003	-0.000	0.018	-0.007	-0.020	-0.006	0.152	-0.179	0.009	-0.034
7.	Number of secondary branches per plant	0.002	0.002	-0.014	0.001	-0.010	-0.003	-0.004	0.004	-0.008	0.003	-0.004	-0.043	0.042	0.039	0.007
8.	Number of peduncles per plant	0.132	0.011	-0.126	-0.234	0.242	-0.012	-0.003	0.003	0.058	0.020	0.006	0.194	0.086	-0.016	0.361**
9.	Number of pods per plant	0.084	0.006	-0.096	-0.164	0.147	-0.000	0.002	-0.000	0.092	0.027	0.014	0.176	-0.000	-0.044	0.244
10.	Number of grains per pod	-0.055	-0.011	0.118	0.186	-0.188	0.011	-0.007	-0.000	-0.049	-0.041	-0.012	0.059	-0.163	0.016	-0.137
11.	Pod length (cm)	-0.021	-0.011	0.134	0.241	-0.290*	0.012	-0.006	0.000	-0.039	-0.057	-0.030	0.236	-0.031	0.090	0.228
12.	Biological yield per plant (g)	0.866**	-0.005	0.089	0.192	-0.279*	0.026	-0.004	-0.000	0.030	0.017	-0.004	-0.006	-0.130	0.055	0.848**
13.	Harvest index (%)	0.460**	0.010	-0.131	-0.283*	0.424**	-0.032	0.008	0.000	0.025	-0.000	0.019	0.001	-0.245	-0.001	0.256
14.	Hundred grain weight (g)	0.128	-0.006	0.128	0.221	-0.377**	0.015	-0.001	0.000	-0.016	-0.029	-0.007	-0.015	0.374**	-0.005	0.410**

(Underlined figures indicate direct effect)

* Significant at 5% level ** Significant at 1% level. Residual effect = 4.1534.

Days to complete maturity had high positive direct effect (0.621) on grain yield per plant. It's indirect effect via days to first pod maturity, biological yield per plant, hundred grain weight, plant height at maturity and number of secondary branches per plant were positive. It had negative indirect effect on grain yield through days to first flowering, harvest index, number of peduncles per plant, days to 50 per cent flowering, number of pods per plant, number of grains per pod, pod length and number of primary branches perplant.

Plant height at maturity had high negative direct effect (-0.687) on grain yield per plant. It had positive indirect effect on grain yield through days to complete maturity, biological yield per plant, hundred grain weight, days to first pod maturity and days to first flowering. It's indirect effect *via* days to 50 per cent flowering, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of grains per pod, pod length and harvest index were negative.

Number of primary branches per plant had low positive direct effect (0.003) on grain yield per plant. It's indirect effect *via* biological yield per plant, days to complete maturity, days to first pod maturity, number of peduncles per plant, hundred grain weight and number of secondary branches per plant were positive. It had negative indirect effect on grain yield per plant through days to first flowering, days to 50 per cent flowering, plant height at maturity, number of pods per plant, number of grains per pod, pod length and harvest index.

Number of secondary branches per plant had low negative direct effect (-0.004) on grain yield per plant. It had positive indirect effect on grain yield per plant through harvest index, hundred grain weight, number of peduncles per plant, number of grains per pod, days to first flowering, days to 50 per cent flowering and days to complete maturity. It's indirect

effect *via* days to first pod maturity, plant height at maturity, number of primary branches per plant, number of pods per plant, pod length and biological yield per plant were negative.

Number of peduncles per plant had low positive direct effect (0.003) on grain yield per plant. It's indirect effect on grain yield per plant was positive through plant height at maturity, biological yield per plant, days to first flowering, harvest index, number of pods per plant, number of grains per pod, days to first flowering and pod length. It's indirect effects *via* days to complete maturity, days to first pod maturity, hundred grain weight, number of primary branches per plant and number of secondary branches per plant were negative.

Number of pods per plant had low positive direct effect (0.092) on grain yield per plant. It's indirect effects on grain yield per plant *via* biological yield per plant, plant height at maturity, days to first flowering, number of grains per pod, pod length, days to 50 per cent flowering and number of secondary branches per plant were positive, while indirect effects *via* days to first pod maturity, days to complete maturity, hundred grain weight, number of primary branches per plant, number of peduncles per plant and harvest index were negative.

Number of grains per pod had low negative direct effect (-0.041) on grain yield per plant. It had positive indirect effect on grain yield per plant through biological yield per plant, days to complete maturity, days to first pod maturity, hundred grain weight and number of primary branches per plant. It's indirect effect *via* days to first flowering, days to 50 per cent flowering, plant height at maturity, number of secondary branches per plant, number of pods per plant, pod length, harvest index and number of peduncles per plant were negative.

Pod length had low negative direct effect (-0.030) on grain yield per plant. It's indirect effect *via* days to complete maturity, biological yield per

plant, days to first pod maturity, hundred grain weight, number of primary branches per plant and number of peduncles per plant were positive, while indirect effects through days to first flowering, days to 50 per cent flowering, plant height at maturity, number of secondary branches per plant, number of pods per plant, number of grains per pod and harvest index were negative.

Biological yield per plant had low negative direct effect (-0.006) on grain yield per plant. It had positive indirect effect on grain yield through days to first flowering, days to complete maturity, days to first pod maturity, hundred grain weight, number of pods per plant, number of primary branches per plant and number of grains per pod. It's indirect effect *via* days to 50 per cent flowering, plant height at maturity, number of secondary branches per plant, pod length, harvest index and number of peduncles per plant were negative.

Harvest index had high negative direct effect (-0.245) on grain yield per plant. It's indirect effect *via* days to first flowering, plant height at maturity, number of pods per plant, pod length, days to 50 per cent flowering, number of secondary branches per plant and number of peduncles per plant were positive, while indirect effects *via* days to first pod maturity, days to complete maturity, number of primary branches per plant, hundred grain weight and number of grains per pod were negative.

Hundred grain weight had low negative direct effect (-0.005) on grain yield per plant. It's indirect effects through harvest index, days to complete maturity, days to first flowering, days to first pod maturity, number of primary branches per plant and number of peduncles per plant were positive while it's indirect effects *via* days to 50 per cent flowering, plant height at maturity, number of secondary branches per plant, number of pods per plant, number of grains per pod, pod length and biological yield were negative.

Residual effect for path analysis at genotypic level was 4.1534.

CHAPTER V
DISCUSSION

Cowpea (*Vigna unguiculata* (L.) Walp.) is gaining popularity among farmers because of its manifold uses as food, vegetable, organic matter and forage. India is the leading producer of cowpea, however it's productivity is very low (Nigude *et al*., 2004). The genetic improvement of this crop has not been attended as that in other major pulses.

The present study was undertaken to assess the genetic variability, correlation and path analysis in fifty five genotypes of cowpea collected from various locations. The results obtained from the present investigation are briefly discussed in this chapter.

5.1 Genetic variability

Any breeding programme for genetic improvement requires basic information regarding the genetic variability present in the crop. Selection based only on yield will not be much effective unless adequate information is available to formulate hybridization or selection programme for further improvement.

Nature and magnitude of variability and heritability in a population due to genetic and non-genetic factors is pre-requisite in any crop improvement programme.

In present investigation, the genotypes exhibited wide range of variation for most of the characters. The analysis of variance showed that

the difference among the genotypes were highly significant for all the fifteen characters under study. This indicated scope for selection of the genotypes for individual character in the population.

The characters days to first flowering and days to 50 per cent flowering showed wide range of variation. KSM 13 was earliest in days to first flowering (55 days), while V 585, DCS 5 and DCS 6 (69.33 days) were late in duration to first flowering. Kumar and Mishra (1983) and Patil (2003) have reported wide range of variation for days to first flowering in cowpea. KSM 3 and KSM 4 were found to be earliest in duration to 50 per cent flowering (61.67 days), whereas DCS 6 took maximum days (88 days) to a attain 50 per cent flowering. Sharma (1999) reported wide range of variation for this character in cowpea.

The range of variation observed was substantial for days to first pod maturity and days to complete maturity. KSM 4 took minimum days (80.13) to first pod maturity whereas BND 1 (97.93) showed late first pod maturity. Patil (2003) reported similar range of variation for days to first pod maturity in cowpea. BND 1 (104.20 days) was late maturing genotype, while KSM 9 (85.30 days) was the early maturing genotype among the population studied. These results are in confirmation with Apte *et al*. (1987) who recorded a range between 87.33 to 111.33 days for maturity in variability studies of cowpea genotypes.

High range of variation was observed for plant height at maturity. Among the genotypes HC 03-4 (56.89 cm) was tallest, while Konkan Sadabahar (15.25 cm) was the dwarfest one. These results corroborate well with Girish (2000) who reported a range of 20.53 to 63.47 cm in cowpea.

The characters, number of primary branches per plant and number of secondary branches per plant showed considerable variation. CAZC 21 (1.67) showed minimum number of primary branches per plant, while TCM

148-1 and KSM 1 recorded maximum number of primary branches per plant i.e. 4.53. Similar results are also reported by Apte *et al*. (1987) who found the range between 1.13 and 4.47. The number of secondary branches ranged from 0.00 to 2.00 with Konkan Safed recording the maximum figure.

All yield contributing characters like peduncles per plant, pods per plant, grains per pod and pod length varied considerably among the genotypes. The minimum number of peduncles per plant was recorded in DCS 6 (6.13) and maximum in DCP 11 (16.27). Pal *et al*. (2003) observed almost similar range of variation from 3.33 to 18.14 in cowpea. Maximum number of pods per plant was observed in KSM 5 (20.67) and minimum in HC 03-1 (7.47). This was analogous with the findings of Tyagi *et al*. (2000) who recorded a range of 8.67 to 15.00 pods per plant. Apte *et al*. (1987) and Selvam *et al*. (2000) also reported similar trend in results.

The number of grains per pod varied from a minimum of 9.13 in Konkan Safed to maximum of 16.27 in COCP 711. A number of workers like Sharma (1999), Pal *et al*. (2003) and Nigude *et al*. (2004) reported results on similar line. The character pod length was observed to be maximum for COCP 711 (20.10 cm) and minimum for VCP 16 (10.02 cm). Apte *et al*. (1987) recorded almost similar results, which ranged from 10.09 to 19.17 cm, while Nigude *et al*. (2004) observed a range of 9.30 to 34.93 cm.

Biological yield per plant was lowest for VCP 16 (12.75 g) and highest for CPD 16 (32.51 g). Very high range of variation was observed for harvest index. Konkan Safed recorded a maximum of 70.29 per cent whereas

HC 03-4 reported a minimum of 39.91 per cent harvest index. Present results conform well with those of Apte *et al*. (1987) and Sharma *et al*. (1999) observed analogous results in cowpea.

Hundred grain weight is another character, which has a direct bearing on yield. Maximum hundred grain weight was observed for COCP 711 (16.91 g), which indicated boldness of seed and minimum was observed for VCP 16 (6.36 g). Nigude *et al*. (2004) reported results on similar line with K range of 5.67 to 16.23 g.

The character grain yield per plant showed a wide range of variation from 6.20 g (KSM 8) to 17.26 g (CPD 16). A number of workers like Dumbre *et al*. (1983), Selvam *et al*. (2000) and Tyagi *et al*. (2000) observed similar trend of variation for seed yield per plant.

5.2 Components of variation

The total variability in each of the fifteen characters could be partitioned into three components *viz*., phenotypic, genotypic and environmental variation. Out of these three, genotypic variation is of prime importance, which helps to determine the heritable and nonheritable portion of variation with respect to characters under study.

Maximum phenotypic variance was found for plant height (107.12) followed by harvest index (50.68), days to 50 per cent flowering (42.45) and biological yield per plant (23.62), while the characters like hundred grain weight (4.26), number of primary branches per plant (0.50) and number of secondary branches per plant (0.18) had least phenotypic variance. The genotypic variance was also highest for plant height at maturity (97.92), followed by days to 50 per cent flowering (35.77), while it was minimum for number of primary branches per plant (0.33) and number of secondary branches per plant (0.14). The character harvest index was found to be more sensitive to environment as it exhibited comparatively higher estimate of environmental variance. Least magnitude of environmental variance was noticed in number of secondary branches per plant and number of primary branches per plant. These results are in close association with those of Apte

et al. (1987), who reported maximum phenotypic and genotypic variance for plant height and minimum for branches per plant.

5.3 Coefficient of variation

Genotypic and phenotypic coefficients of variation are useful in detecting the amount of variability present in the available genotypes. From the present study, it was found that, the characters, number of secondary branches per plant (88.69%), followed by plant height at maturity (36.04%) exhibited maximum magnitude of phenotypic coefficient of variation, whereas least magnitude was recorded for days to complete maturity (5.04%) and days to first pod maturity (5.15%).

The existence of high magnitude of genetic variability was evidenced through high value of genotypic co-efficient of variation for most of the characters. High magnitude of genotypic coefficient of variation was observed for number of secondary branches per plant (79.95%) followed by plant height at maturity (34.46%) and number of pods per plant (22.64%). Minimum genotypic coefficient of variation was exhibited by days to complete maturity (4.60%) and days to first pod maturity (4.73%). These results are in agreement with that of Girish (2000), who recorded high genotypic and phenotypic coefficient of variability for plant height, primary branches, secondary branches and number of pods per plant. Patil and Baviskar (1987), Sawant (1994) and Nigude *et al*. (2004) reported low magnitude of PCV and GCV for days to complete maturity.

5.4 Heritability and genetic advance

Heritability and genetic advance help in determining the influence of environment in the expression of characters and the extent to which improvement is possible after selection.

In the present study, high estimates of heritability in broad sense were observed for all the characters except number of primary branches per plant

and harvest index. Heritability estimate was highest for number of pods per plant (93.38%), followed by biological yield per plant (91.87%), plant height at maturity (91.41%), hundred grain weight (91.23%) and pod length (90.60%). The estimates of heritability for other characters, like grain yield per plant, grains per pod, number of peduncles per plant, days to 50 per cent flowering, days to first pod maturity, days to complete maturity, number of secondary branches per plant and days to flowering ranged between 88.15 and 76.06 per cent. These results are in agreement with those of Patil and Baviskar (1987), Tyagi *et al*. (2000), Girish (2000) and Nigude *et al*. (2004).

The characters, number of primary branches per plant (65.20%) and harvest index (68.93%) showed comparatively moderate heritability. These results are analogous with the findings of Sawant (1994) and Selvam *et al*. (2000). Genotypic co-efficient of variation together with estimates of heritability would give the best result of genetic gain to be expected from selection. The characters plant height at maturity and number of secondary branches per plant showed high estimates of heritability accompanied with high genotypic co-efficient of variation.

Genetic advance is a measure of expected progress under selection scheme. The genetic advance ranged between 0.70 (number of secondary branches per plant) and 19.49 (plant height at maturity). The estimates of genetic advance as per cent of mean varied from 8.62 per cent (days to complete maturity) to 147.99 per cent (number of secondary branches per plant). The characters, plant height at maturity (67.85%), number of pods per plant (45.05%), biological yield per plant (41.46%), grain yield per plant (38.92%), number of peduncles per plant (38.90%), hundred grain weight (35.10%) and number of primary branches per plant (30.41%) recorded relatively high estimates of genetic advance over mean. Comparatively lower values of genetic advance over mean were exhibited by days to complete maturity (8.62%), days to first pod maturity (8.93%), days to first

flowering (10.00%) and days to 50 per cent flowering (15.69%). The results obtained are in confirmation with those of Siddhique and Gupta (1991) for plant height, Patil and Baviskar (1987) for 100-grain weight and days to first pod maturity. Apte *et al*. (1987) reported low genetic gain over mean for days to first pod maturity (8.90%), days to flowering (9.58%) and days to 50 per cent flowering (12.37%).

High heritability coupled with high genetic advance was observed for number of secondary branches per plant (81.25% and 147.99%), plant height at maturity (91.41% and 67.85%), number of pods per plant (93.58% and 45.05%) and biological yield per plant (91.87% and 41.46%). Therefore, it could be concluded that selection for these traits would be more effective owing to their additive gene effects. Similar results have been reported by Siddhique and Gupta (1991), for plant height and number of pods and Sharma (1999) for plant height.

The traits such as days to complete maturity (83.08% and 8.62%), days to first pod maturity (84.13% and 8.93%), and days to 50 per cent flowering (84.27% and 15.69%), exhibited high heritability but low genetic advance over mean. This indicated non-additive gene action in the expression of these traits. The results obtained are in agreement with those of Patil and Baviskar (1987) and Sawant (1994). However, this results contradicts with those of Tyagi *et al*. (2000), who reported high heritability coupled with high genetic advance for days to maturity and days to fifty per cent flowering.

5.5 Correlation

Correlation coefficient analysis was carried out to measure the degree of relationship between yield and it’s components in cowpea. Improvement in yield is the ultimate goal in any breeding programme. Since yield is the product of interaction of various components, the identification of important components and information about their inter relationship is necessary.

Therefore, correlation studies could be utilized in determining the principal components influencing final product i.e. yield.

In the present investigation, the results revealed comparatively higher degree of genotypic correlation coefficients than their phenotypic counter parts in most of the characters. However in few cases, the phenotypic correlations were slightly higher than their genotypic counter parts. These results are in confirmation with earlier findings of Apte *et al*. (1987), Sawant (1994) and Singh *et al*. (2004) in cowpea.

The present study revealed highly significant positive correlation between biological yield per plant and grain yield per plant both at phenotypic and genotypic level. These results are in agreement with those reported by Patil (2003). The characters, hundred grain weight and number of peduncles per plant were found to have high and positive significant correlation at genotypic level and appreciably significant correlation at phenotypic level. This showed that selection for these traits would be effective for improvement in grain yield. Tyagi *et al*. (2000) and Singh *et al*. (2004) observed similar trends of results for 100 seed weight, while Apte *et al*. (1991) recorded negative significant association of 100 seed weight with grain yield.

Harvest index exhibited positive significant correlation with grain yield per plant only at phenotypic level.

Days to first flowering exhibited strong positive correlation with days to 50 per cent flowering, days to complete maturity, days to first pod maturity and plant height at maturity at both phenotypic and genotypic levels. Days to first flowering showed strong negative correlation with number of peduncles per plant and harvest index.

Days to 50 per cent flowering exhibited highly significant positive correlation with days to first pod maturity, days to complete maturity and plant height at maturity at both genotypic and phenotypic levels. Nigude *et*

al. (2004) reported findings on similar line for days to complete maturity and plant height.

Days to first pod maturity exhibited high degree of positive inter relationship with characters days to 50 per cent flowering and plant height at maturity at both phenotypic and genotypic levels. Days to complete maturity exhibited strong positive correlation with plant height at maturity and hundred grain weight. It showed strong negative correlation with harvest index at both genotypic and phenotypic levels. Analogous results are reported by Nigude *et al*. (2004) and Sawant (1994) in cowpea.

Strong positive correlation was observed between plant height at maturity and biological yield per plant both at phenotypic and genotypic levels. However, harvest index was found to be negatively correlated with plant height. Sawant (1994) observed negative but non-significant correlation of harvest index with plant height. Number of primary branches per plant was positively and strongly correlated with number of grains per pod.

Number of secondary branches per plant had positive significant correlation with hundred grain weight at both phenotypic and genotypic levels. The character number of peduncles per plant exhibited strong positive association with number of pods per plant at both levels and strong negative association with grains per pod at genotypic levels. Analogous results are reported by Oseni *et al*. (1992) in cowpea.

Strong negative correlation was observed for number of pods per plant with pod length and number of grains per pod at both levels. It indicates that increase in number of pods per plant may lead to smaller length of pod and less number of seeds per pod in cowpea. Apte *et al*. (1981) and Hodawadekar (2002) observed significant negative association of pods per plant with pod length and grains per pod.

Number of grains per pod exhibited strong positive association with pod length and strong negative inter relationship with harvest index at both phenotypic and genotypic level. Patil and Bhapkar (1987) and Sreekumar *et al*. (1996) recorded significant positive association of pod length and grains per pod and harvest index. Apte *et al*. (1991) found negative association of grains per pod and harvest index. Strong positive correlation was observed between pod length and 100 grain weight. This result is in accordance with that of Nigude *et al*. (2004) in cowpea.

Biological yield per plant was found to be strongly correlated with hundred seed weight. This result is in conformity with Nigude *et al*. (2004) who observed appreciable correlation between biomass and hundred grain weight.

By and large, the plant type having more number of peduncles per plant, more biological yield with bolder grains and more harvest index will lead to give higher yield in cowpea.

5.6 Path analysis

Yield is a complex entity and is associated with a number of component characters, which are inter related among themselves. Such inter dependence of the contributory factors often affect their direct relationship with yield thereby making correlation coefficients unreliable as selection indices. Hence, the correlations are partitioned into direct and indirect effects to know the degree of association of component characters among themselves as well as with yield. The path analysis unravels whether the association of characters with yield is due to direct effect on yield or is consequence of their indirect effect *via* some other traits (Dewey and Lu, 1959).

The character biological yield per plant had maximum positive correlation with grain yield per plant both at genotypic and phenotypic

levels. It had low positive direct effect on grain yield at phenotypic levels. It showed high positive indirect effect *via* days to flowering and low positive indirect effect *via* number of grains per pod and pods per plant. Biological yield per plant had a low negative direct effect at genotypic level on grain yield per plant. But positive indirect effect of days to first flowering, days to complete maturity, days to first pod maturity, hundred grain weight, pods per plant, number of primary branches per plant and number of grains per pod resulted in strong positive correlation of biological yield per plant with grain yield per plant. These results are in confirmation with that of Patil (2003) who recorded negative direct effect of biological yield per plant on seed yield.

Hundred grain weight had low negative direct effect on grain yield per plant at both the levels. However, it's positive indirect effect *via.* harvest index, days to complete maturity, days to first flowering and days to first pod maturity resulted in high positive correlation with grain yield per plant at genotypic level. The result is in agreement with the findings of Reddy *et al*. (1994) in green gram and Singh *et al*. (2004) in cowpea. On the other hand, Apte *et al*. (1989) reported positive direct effect of hundred grain weight or seed yield.

The character, number of peduncles per plant had low positive direct effect on grain yield per plant at both phenotypic and genotypic levels. But it had highly significant positive correlation with grain yield per plant which was due to the high positive indirect effect *via* plant height, biological yield per plant, days to first flowering, harvest index and number of pods per plant. This result is in contradiction with that of Oseni *et al*. (1992) who reported negative direct effect of peduncles per plant on grain yield.

Harvest index had high negative direct effect on grain yield per pant at both genotypic and phenotypic levels. It's positive significant correlation with grain yield at phenotypic level is due to the high positive indirect effect

via days to flowering nullifying the negative effect of other characters. This result could be supported by similar findings of Hodawadekar (2002).

The character number of pods per plant exhibited positive direct effect on grain yield per plant at both genotypic and phenotypic level. The positive indirect effects expressed by biological yield per plant and days to first flowering was diminished by the negative direct effect of days to first pod maturity and days to complete maturity. This resulted in weak positive correlation of number of pods per plant with grain yield per plant. Sawant (1994) and Singh (2000) reported analogous results in cowpea.

Pod length had negative direct effect on grain yield per plant at both genotypic and phenotypic levels. It had high positive indirect effect through days to complete maturity and biological yield per plant whereas it showed negative indirect effects through plant height at maturity and grains per pod. This resulted in weak positive correlation of pod length with grain yield per plant. Apte *et al*. (1989) recorded negative direct effect of pod length on seed yield.

Plant height had negative direct effect on seed yield both at genotypic and phenotypic levels. Positive indirect effects due to biological yield per plant and days to first pod maturity are reduced by the negative indirect effect through harvest index. This resulted in weak positive correlation of plant height with seed yield. Negative direct effect of plant height on seed yield was reported earlier by Reddy *et al*. (1989) in green gram and Apte *et al*. (1989) and Singh *et al*. (2004) in cowpea.

Days to 50 per cent flowering had negative direct effect on grain yield per plant at both levels. The positive direct effects expressed by days to first pod maturity, days to first flowering and biological yield per plant were nullified by high negative indirect effect of days to complete maturity and other characters which resulted in weak positive correlation of this character

with grain yield per plant Tyagi *et al*. (2000) reported negative direct effect of days to 50 per cent flowering on grain yield per plant.

Days to first pod maturity had positive direct effect on grain yield per plant at both phenotypic and genotypic levels. At genotypic level, it showed high positive indirect effect through days to first pod maturity, biological yield per plant and plant height. This character showed high negative indirect effect through days to complete maturity and harvest index. Days to first pod maturity showed weak positive correlation with grain yield.

Days to complete maturity had negative direct effect on grain yield per plant at phenotypic level and positive direct effect at genotypic level. Weak positive correlation observed between days to complete maturity and grain yield resulted from the nullifying negative indirect effects of days to first flowering and harvest index over the positive indirect effect of days to first pod maturity, biological yield per plant and other characters. This result was in agreement with the findings of Tyagi *et al*. (2000) who reported positive direct effect of days to complete maturity on yield.

The characters, number of secondary branches per plant and days to first flowering exhibited negative direct effect on grain yield per plant at both genotypic and phenotypic level. Both the characters had weak positive correlation with grain yield per plant.

The characters number of grains per pod and number of primary branches per plant had negative direct effect on grain yield per plant. Both the characters showed weak negative correlation with yield. The character number of grains per pod had appreciable positive indirect effect through days to complete maturity at genotypic level and through biological yield per plant at both the levels. Positive indirect effect of character primary branches per plant was observed *via* biological yield per plant and days to complete maturity at genotypic level. Sawant (1994) and Singh *et al*. (2004) reported negative indirect effect of branches per plant on grain yield.

High value of residual effects suggested more detailed correlation and path analysis study on all possible major and minor yield contributing traits.

CHAPTER VI

SUMMARY AND CONCLUSION

The present investigation entitled, “Genetic variability, correlation and path analysis studies in cowpea (*Vigna unguiculata* (L.) Walp)” was undertaken with the following objectives.

1) To work out the range of genetic variability in relation to yield and its component characters.
2) To estimate the phenotypic and genotypic correlations of different yield components.
3) To know the important yield components having greater direct and indirect effects over yield through path analysis.

Fifty five genotypes of cowpea were grown in Randomized block design with three replications at Research Farm of Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra during *rabi* 2005-06. The genotypes were studied fro fifteen characters *viz*., days to first flowering, days to fifty per cent flowering, days to first pod maturity, days to complete maturity, plant height at maturity, number of primary branches per plant, number of secondary branches per plant, number of peduncles per plant, number of pods per plant, number of

grains per pod, pod length, biological yield per plant, harvest index, hundred grain weight and grain yield per plant.

The analysis of variance revealed significant variations among the genotypes for all the characters under study. The estimates of mean sum of squares showed comparatively wide range of variation for the characters plant height at maturity, harvest index, days to 50 per cent flowering, days to complete maturity and days to first pod maturity. While, the lowest variation was recorded for number of secondary branches per plant.

Among the genotypes KSM 13 was earliest in days to initiation of flowering. While, KSM 4 was found to require least duration for 50 per cent flowering, first pod maturity as well as complete maturity. HC 03-4 was found to be the tallest among the genotypes whereas Konkan Sadabahar was the shortest. Maximum number of primary branches per plant was recorded in TCM 148-1 and KSM 1. The genotype Konkan Safed reported maximum number of secondary branches per plant as well as highest harvest index.

Maximum number of peduncles per plat was observed in DCP 11. The genotypes KSM 5 and HC 03-2 recorded maximum number of pods per plant. The genotype COCP 711 was better performing in respect of maximum number of grains per pod, pod length, high biological yield per plant and maximum hundred grain weight. Biological yield per plant was found to be maximum for CPD 16 which also recorded highest grain yield per plant.

The estimates of phenotypic, genotypic and environmental variances revealed that phenotypic variances were higher than genotypic variances for all the characters. The magnitude of phenotypic and genotypic variances was closer to each other for all characters, except harvest index, thus indicating lesser role of environment in the expression of these characters. However, harvest index showed comparatively higher estimates of

environmental variance indicating the influence of environment on this character.

In general phenotypic coefficient of variations was higher in magnitude over the respective genotypic coefficient of variation for all the characters. High genotypic and phenotypic coefficients of variation were observed for the characters, number of secondary branches per plant and plant height at maturity, while these were low for the characters days to complete maturity, days to first pod maturity and days to first flowering.

The estimates of heritability were high for almost all characters. Highest heritability estimates were recorded for number of pods per plant, biological yield per plant, plant height at maturity, hundred grain weight and pod length, while lower heritability estimates were recorded in number of primary branches per plant and harvest index. Genetic advance was found to be highest for plant height at maturity and lowest for number of secondary branches per plant. The characters number of secondary branches per plant and plant height at maturity showed comparatively higher estimates of genetic advance as percentage of mean.

High estimates of heritability coupled with higher genetic advance as per cent of mean was observed for number of secondary branches per plant and plant height at maturity, thus indicating the role of additive gene action in the expression these characters.

In the present investigation, the genotypic correlation coefficients were higher in magnitude than their phenotypic counterparts for most of the characters. The character biological yield per plant exhibited highly significant positive correlation with grain yield per plant at both phenotypic and genotypic levels. The characters hundred grain weight and number of peduncles per plant had highly significant positive correlation with grain yield per plant at genotypic level and positive but significant correlation at

phenotypic level. Harvest index exhibited significant positive correlation with grain yield per plant at phenotypic level, but non-significant positive correlation at genotypic level. The other characters showed weak and either positive or negative association with grain yield per plant at both levels.

Path co-efficient analysis revealed positive direct effect of characters days to first pod maturity and number of pods per plant on grain yield at both phenotypic and genotypic levels. Days to complete maturity also showed high positive direct effect on grain yield per plant at genotypic level.

By and large, the plant type having more number of peduncles per plant, more biological yield with bolder grains and more harvest index will lead to give higher yield in cowpea.

Conclusion

The experimental studies revealed substantial amount of genetic variability among the genotypes under study. In general, phenotypic coefficients of variation were higher in magnitude than genotypic coefficient of variation. The characters, number of secondary branches per plant and plant height at maturity showed comparatively higher estimates of genotypic and phenotypic coefficients of variation indicating high level of variability and ample scope for effective improvement. The higher estimates of heritability coupled with high genetic advance as percentage of mean indicated additive gene action for the above characters. Correlation studies revealed strong positive association of biological yield per plant, hundred grain weight and number of peduncles per plant with grain yield per plant. The path analysis studies indicated that the characters number of pods per plant and days to first pod maturity bearing direct positive effect on grain yield, could be the selection criteria for genetic improvement of grain yield per plant in cowpea population under study.

Thus, the genotypes COCP 711, DCP 11, KSM 5, HC 03-2 and CPD 16 are observed as desirable among the population for future use in breeding programme, as these genotypes had good performance for the important quantitative traits.

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*Original not seen.

Plate I. Experimental plot of cowpea

Plate II. Variation in plant height

Plate III. Variation in number of pods per plant

Plate IV. Variation in number of branches per plant

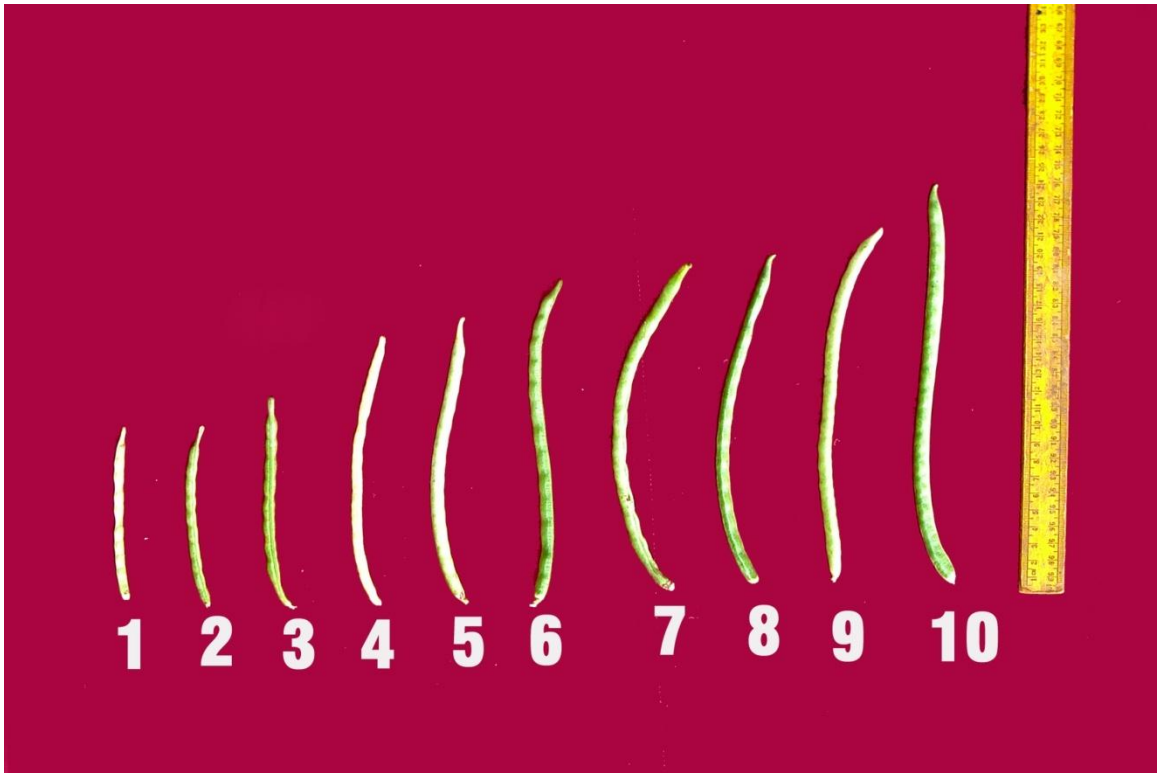

Plate V. Variation in pod length

Plate VI. Variation in seed colour