

Genetic Variability, Correlation and Path Coefficient Analysis for Yield and Its attributing Traits in Cowpea

THESIS

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the Degree of**

MASTER OF SCIENCE

In

AGRICULTURE

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By

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CERTIFICATE - I

*This is to certify that the thesis entitled “**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**” submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE in Agriculture, Horticulture (Vegetable Science)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Shivraj Singh Rajput** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.*

All the assistance and help received during the course of the investigation have been acknowledged by him.

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*This is to certify that the thesis entitled “**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**” submitted by Mr. Shivraj Singh Rajput to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment of the requirements for the degree of Master of Science in Agriculture, Horticulture (Vegetable Science) in the Department of Horticulture has been, after evaluation, approved by the External Examiner and by the Student’s Advisory Committee after an oral examination on the same.*

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I, Shivraj Singh Rajput S/o Shri Prem Singh Rajput Certify the work embodied in thesis entitled “Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea” is my own first hand bonafide work carried out by me under the guidance of Dr. P. K. Jain at Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2015-2016.

The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

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List of Symbols

Abbreviation	Stand for
@	At the rate
&	And
ANOVA	Analysis of Variance
Cm	Centimeter
C.D.	Critical difference
d.f.	Degrees of freedom
DAH	Days after harvesting
et al.	And others or co-workers
M	Meter
Fig.	Figure
GA	Genetic Advance
GCV	Genotypic coefficient of variation
PCV	Phenotypic coefficient of variation
G	Gram
ha	Hectare
Kg	Kilogram
Max.	Maximum
Min.	Minimum
M.S.S.	Mean Sum of Squares
No.	Number
SEm $\pm$	Standard error of mean
%	Percentage

INTRODUCTION

Cowpea ($2n=22$) belongs to the family Leguminosae also known as southern pea and black eye pea, is one of the most important vegetables. It is cultivated for its long, green or purplish pods to be cooked as vegetable or for dry seeds used as pulse. Its foliage is also used as fodder or green manure, producing 20-30 cm long pod and elongated kidney shaped, 8-12 mm long seeds. Cowpea is commonly cultivated as a nutritious and highly palatable food source in Asia and throughout the tropics and sub-tropics. Green pod of cowpea contains 85 g moisture, 3.0 g protein, 1.0 g minerals, 2.0 g fiber, 8.0 g carbohydrates, 72 mg calcium, 59 mg phosphorus, 2.0 mg iron, 0.09 mg riboflavin and 0.07 mg thiamin per 100 g of edible portion. (Anonymous , 2011).

Among the different pulses grown in the world, cowpea is grown in 14.13 million hectare with production of 4.51 ('000 MT) and the productivity of 387.45 kg ha⁻¹. In India, the cowpea is grown in an area of about 3.91 million hectare with a production of 2.22 ('000 MT) having a productivity of 564.15 kg seed ha⁻¹ and in Madhya Pradesh its covering area and production is very minor (Shivnanda, 2005).

The development of cultivars with early maturity, acceptable grain quality, resistance to some important diseases and pests has significantly increased the yield and cultivars area (Ehlers and Hall 1997) yield being a complex trait, is influenced by many other important yield contributing characters controlled by polygene and also environment factors. So, in these characters, observed variability is the sum total of hereditary effects of concerned genes plus the influence of the environment.

The magnitude of genetic variance denotes how much of the variability of the characters is heritable advance can be achieved. Hence, collection, maintenance and evolution of germplasm for studying genetic variability of economically important traits is one of the basic steps for initiating breeding programme for genetic improvement of cowpea.

To give a better insight of ancillary characters under selection, correlation coefficient analysis are the tools, which are being effectively used for determining the rate of various yield components in different crops, leading to the selection of superior genotypes. The phenotypic correlations of yield with growth attributes and path coefficient analysis become useful technique for crop improvement programmes to select the desirable traits (Ahmed and Kamaluddin, 2013).

Direct selection for the yield is not much effective as quantitative characters are controlled by polygenes. Hence, knowledge about association of character which will directly or indirectly contribute to yield is crucial. Correlation coefficients explain the degree of association among the characters. However, it is difficult to explain a system of correlation when the indirect association between the characters increases. The method of path coefficient analysis development by Wright (1921) is helpful in partitioning correlation into direct and indirect effects and in the assessment of relative contributions of each component to the yield.

There is great scope for genetic improvement in cowpea with regards to yield and quality. The success of most crop improvement programme largely depends upon the genetic variability and heritability of desirable traits. The magnitude and type of genetic variability help the breeder to determine the selection criteria and breeding scheme to be used for improvement purpose. The phenotypic variability and heritability of character determine to a large extent the rate of genetic advance. Hence, it is essential to partitioned the overall variability into the heritable and non heritable component in order to determine the most effective breeding procedure. Keeping in view of the above point the present investigation was taken up with the following objectives:-

1. To estimate the genetic variability, heritability and genetic advance of yield and its attributing characters.
2. To study correlation between yield and its attributing parameters.
3. To estimate direct and indirect effect of yield contributing characters on pod yield.
4. To identify suitable and better performing genotype for Central Zone of India.

REVIEW OF LITERATURE

An attempt has been made to study the “**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**”. The Literature relevant to the present investigation, have been reviewed under the following heads.

- 2.1 Genetic variability
- 2.2 Heritability and genetic advance
- 2.3 Correlation coefficient analysis
- 2.4 Path coefficient analysis
- 2.5 Seasonal incidence of insect pest and disease

2.1 Genetic variability

The knowledge of genetic variability in the plant material is one of the essential pre requisite for effective crop improvement programme. Plant breeding efforts should therefore aim at the manipulation of available genetic diversity in the desired direction through appropriate selection criteria. The existence of very high to low genetic variability aim to respect various vegetable reproduce and qualitative characteristics has been reported in cowpea by many workers.

Kalaiyarasi and palanisamy (2000) observed genotypic and phenotypic variability, heritability (BS) and genetic advance on yield and yield attributes in cowpea were studied. Seed yield plant⁻¹ and number of pods plant⁻¹ had high estimates of GCV followed by number of seeds pod⁻¹ and plant height.

Bezerra et al. (2001) studied in experiment was that the following variables were studied days to first flowering, number of pods plant⁻¹, pod length, number of seeds pod⁻¹ and revealed significance for all variables studied.

Pathak and Jamwal (2002) reported that the high genotypic coefficient of variation (GCV) was recorded for pod yield plant⁻¹, moderate to high GCV were recorded for number of days to 50 per cent flowering and plant height.

Whereas, it was low GCV for number of days to first picking, pod length and average pod weight.

Narayanankutty and Jaikumaran (2003) in an experiment revealed that, high phenotypic coefficient of variation and genotypic coefficient of variation were noticed for pod yield, pods plant⁻¹ and pod weight.

Pal et al. (2003) studied that the phenotypic coefficient of variation was greater than the genotypic coefficient of variation for most of the traits. Relatively high genotypic and phenotypic coefficients of variation were recorded for plant height, number of primary branches plant⁻¹, number of pods plant⁻¹ and green pod yield plant⁻¹.

Venkatesan et al. (2003) reported that the maximum variation was recorded for plant height. The magnitude of the phenotypic coefficient of variation (PCV) was higher than that of the genotypic coefficient of variation (GCV). High GCV as well as PCV were recorded for plant height.

Nigude et al. (2004) reported that the magnitude of PCV was higher than GCV for all the characters studied the genotypic (GCV) and phenotypic coefficients of variation (PCV) were higher for plant height and number of pods plant⁻¹.

Prasanthi (2004) revealed that in all the 22 genotypes of cowpea, high genotypic and phenotypic coefficient of variation were reported for plant height and pods plant⁻¹ while, moderately high values were recorded in pod length and seeds pod⁻¹.

Malarvizhi (2005) studied variability, heritability and genetic advance in 60 genotypes of cowpea. For days to 50 per cent flowering along with twelve economic traits plant height, number of branches plant⁻¹ and dry matter yield etc.

Girish et al. (2006) studied wide range of variability for most quantitative characters. The magnitude of Phenotypic Coefficient of Variation and Genotypic Coefficient of Variation was high for seed yield plant⁻¹, number of pods plant⁻¹ and plant height.

Suganthi and Murugan (2008) reported that genotypic coefficient of variation was higher than the phenotypic coefficient of the variation for all the characters. The phenotypic and genotypic coefficients of variation were highest for seed yield plant⁻¹, followed by number of pods plant⁻¹ and number of clusters plant⁻¹.

Bertini et al. (2009) found that the time to flowering, pod length, number of pods plant⁻¹, number of seeds pod⁻¹, 100 seeds weight, yield plant⁻¹ were evaluated. The cultivars showed high levels of genetic variability for most characters.

Pandey and Singh (2011) reported that significant differences among varieties for days to first flowering, days to maturity, days from flowering to physiological maturity (pod filling duration), pods plant⁻¹, pod length, number of seeds pod⁻¹ as well as seed size and grain yield. The results indicated that pod filling stage in cowpea can be reduced to protect the crop from insects at reproductive stage without affecting seed yield and seed size.

Manggoel et al. (2012) observed significant variability for days to 50 per cent flowering, number of peduncles plant⁻¹, number of flowers plant⁻¹, number of pods plant⁻¹, seeds pod⁻¹ and pod length. Phenotypic and genotypic coefficient of variation was high for the traits studied, except pod length and seeds pod⁻¹.

Kharde et al. (2014) studied the genetic variability was in 20 genotypes of cowpea. The results showed significant differences among the genotypes evaluated for all the characters. A wide range of variation was observed among the genotypes for all the character. The phenotypic and genotypic coefficients of variation were higher for plant height, pod length, average pod weight, pod yield per plot, number of seeds per pod and number of pods per plant along with high heritability estimates and high expected genetic advance, indicating the additive gene effects. Selection for such traits might be useful for development of varieties.

Om Vir and Singh (2014) revealed high degree of genetic variability for seed yield plant⁻¹, 100-seed weight, pod length, number of seeds pod⁻¹, number of pods plant⁻¹, number of pods cluster⁻¹, number of branches plant⁻¹,

number of cluster plant⁻¹, plant height, days to 50 per cent flowering and days to maturity in both the season.

Ramesh et al. (2014) In their study reported high phenotypic coefficient of variation for grain yield plot⁻¹, followed by yield ha⁻¹, number of clusters plant⁻¹, number of primary branches and pod length while, it was low for traits days to flower initiation, days to 50 per cent flowering and days to pod maturity.

Pandey, et al. (2014) conducted experiment on 43 diverse genotypes of cowpea to study the genetic variability, heritability, genetic advance, correlations and path coefficient for different traits to identify diverse genotypes of cowpea belonging to different culti-groups through multivariate analysis.

Animasaun, et al. (2015) reported the results showed considerable variations in growth and yield characters evaluated. Cultivars NGB/06/047, IFE BROWN 2012 and IT98K-133-1-1 had optimal growth performance with respect to fruiting and seed yield parameters. Genetic Variability as expressed in the studied cultivars could be useful for understanding genetic diversity of selection of cultivars with novelty in vegetative growth, yield and nutrition composition in the process of breeding programme and crop production.

2.2 Heritability and genetic advance

Heritability is an index of the transmission of characters from parents to their offspring. It is generally expressed in percentage. The estimation of heritability helps the plant breeder in selection of elite genotypes. It also measures the degree of resemblance between relative and correspondence between phenotypic and breeding value. The genetic advance is the deviation in the characters of selected population over the base population. Gain under selection or genetic advance is a measure to predict the expected progress under selection. The genetic advance helps to evaluate the selection procedures. If the value of genetic advance is more than in the succeeding generation there will be good progress over population mean. The estimation of heritability along with genetic advance is more applicable than the heritability value alone. Johnson et al. (1955) reported that in study of

estimated heritability in conjunction with genetic advance would provide more reliable information than the study of heritability alone.

Borah and Khan (2000) In their study reported that highly heritable characters *viz.*, number of branches and leaves and plant height, also exhibited high genetic advance as a percentage of mean, indicating additive gene action. The crude protein content, days to 50 per cent flowering, stem thickness and leaf length and width exhibited low genetic advance with high heritability estimates.

Nehru and Manjunath (2001) studied fourteen cowpea genotypes to determine genetic variability for yield and its components and reported high heritability coupled with high genetic advance expressed as per cent of mean for pods plant⁻¹. Whereas, it was moderate for plant height and yield plant⁻¹.

Ramesh et al. (2002) revealed moderate to high heritability for plant height, pod length, number of branches and number of pods plant⁻¹ indicating the role of additive gene effect in controlling these traits in cowpea.

Santosh et al. (2002) conducted an experiment using 5 cowpea cultivars and exhibited high genetic advance for green pod yield, plant height and days to 50 per cent flowering.

Vinieta et al. (2003) in cowpea reported high heritability as well as genetic gain for traits seed yield plant⁻¹, and number of pods plant⁻¹ and numbers of flower clusters plant⁻¹.

Nigude et al. (2004) reported that heritability in broad sense was higher for all the characters. Genetic advance was highest for all characters except number of seeds pod⁻¹.

Anbumalarmathi et al. (2005) observed high heritability as well as high genetic advance for days to 50 per cent flowering, plant height, number of branches plant⁻¹, number of clusters plant⁻¹, pods plant⁻¹ pod length, seeds pod⁻¹ and single plant yield in cowpea.

Malarvizhi et al. (2005) conducted an experiment on variability, heritability and genetic advance in 60 genotypes of cowpea and observed

high heritability and genetic advance for traits viz., number of branches plant⁻¹ and number of leaves plant⁻¹. Hence, the selection was more effective.

Sheela et al. (2006) observed high heritability coupled with high genetic advance for characters plant height, number of branches, number of leaves, leaf length, stem thickness, leaf weight, stem weight, leaf: stem ratio, green fodder yield, dry matter yield and crude protein content in cowpea.

Lal et al. (2007) showed that higher estimates of heritability coupled with the higher genetic advance for number of peduncles plant⁻¹, number of days to flower, number of pods plant⁻¹ and pod yield plant⁻¹ indicated that heritability is mainly due to additive genetic effects in cowpea.

Suganthi and Murugan (2008) recorded high heritability for seed yield plant⁻¹ followed by number of seeds pod⁻¹, pod length and 100-seed weight. Genetic advance as per cent of mean was also highest for seed yield plant⁻¹, followed by number of pods plant⁻¹ and number of clusters plant⁻¹ in cowpea.

Bertini et al. (2009) reported high heritability in cowpea for pod length, number of pods plant⁻¹, number of seeds pods⁻¹, weight of 100 seeds, total yield plant⁻¹. It indicates the possibility of genetic improvement through selection.

Choudhary et al. (2010) revealed that the high estimates of heritability, genetic advance in garden pea were observed for plant height, number of pods plant⁻¹ and green pod yield plant⁻¹.

Singh et al. (2012) reported that high heritability (in narrow sense) estimates were recorded for pods plant⁻¹, seed yield plant⁻¹ and biological yield plant⁻¹. However, high genetic advance was recorded for plant height, pods plant⁻¹, productive branches plant⁻¹, and seeds pod⁻¹, biological yield plant⁻¹ and seed yield plant⁻¹.

Om Vir and Singh (2014) reported that moderate to high heritability coupled with moderate to high expected genetic advance was observed for all studied traits. Number of seeds pod⁻¹, number of pods plant⁻¹, number of pods cluster⁻¹, number of cluster plant⁻¹, days to 50 per cent flowering and days to maturity had positive and significant correlation with seed yield plant⁻¹.

Ramesh et al. (2014) revealed that grain yield plot^{-1} , yield ha^{-1} and 100 grain weights also, showed high value of broad sense heritability and genetic advance in cowpea.

Sapara et al. (2014) conducted studied on heritability and genetic advance in number of genotype of cowpea. They reported differences among the genotypes for all the characters studied except pod width indicating existence of high variability in the experimental material for all the character. They reported for high heritability along with high genetic advance as percentage of mean for number of pods plant^{-1} , 100 fresh seed weight, five pod weights, green pod yield plant^{-1} and plant height.

Pandey, et al. (2014) conducted experiment on 43 diverse genotypes of cowpea to study the genetic variability, heritability, genetic advance, correlations and path coefficient for different traits to identify diverse genotypes of cowpea belonging to different culti-groups through multivariate analysis.

2.3 Correlation coefficient analysis

The statistics, which measure the relationship and its extent between two or more variables, are known as correlation coefficient. Correlation Coefficient is a statistical measure which is used to find out degree and direction of relationship between two or more variables. A positive value of correlation shows that changes of two variables are in the same direction whereas in the negative correlation movements of two variables are in the opposite direction. The knowledge of nature of association between yield and its component character is of great interest in the selection programme.

Kalaiyarasi and Palanistry (2000) studied correlation among 9 traits in cowpea. The result indicated that seed yield plant^{-1} showed strong positive correlation with 100 seed weight, number of seed pod^{-1} , plant height, crude protein content, number of pods plant^{-1} and number of branches plant^{-1} and crude fiber content showed strong negative correlation with seed yield.

Belhekar et al. (2003) reported that seed yield plant^{-1} exhibited positive and significant correlation with plant height, number of pods plant^{-1} and 100 seed weight both at the genotypic and phenotypic levels.

Kutty et al. (2003) in an experiment showed that the number of pods plant⁻¹, number of pickings, average weight of pods and pod length were positively and significantly correlated with yield plant⁻¹ both at phenotypic and genotypic levels. Number of days to first picking showed significant negative correlation with number of pickings.

Venkatesan et al. (2003) reported that the number of branches plant⁻¹, number of clusters plant⁻¹, number of pods cluster⁻¹, number of pods plant⁻¹, and pod yield were positively correlated with seed yield at the genetic and phenotypic levels. The magnitude of genetic correlation was higher than that of phenotypic correlation in cowpea.

Singh et al. (2004) found that green pod yield plant⁻¹ was positively and significantly associated with number of primary branches plant⁻¹, pod length, pod width, number of pod plant⁻¹, number of seeds pod⁻¹ and 100-seed weight. Whereas, days to 50 per cent flowering and days to first green pod picking showed significant negative correlation with green pod yield plant⁻¹.

Xiao-Jie (2004) revealed that positive significant and correlation was observed between the number of peduncles plant⁻¹ and number of branches plant⁻¹, and pod length and pod width.

Anbumalarmathi et al. (2005) revealed that yield plant⁻¹ had positive and significant association with clusters plant⁻¹, pods plant⁻¹, pod length, seeds pod⁻¹ and 100-seed weight.

Patil et al. (2005) revealed that seed yield plant⁻¹ had positive and highly significant correlation with plant height at genotypic levels and number of pods plant⁻¹ at both phenotypic and genotypic levels.

Alege (2007) reported that positive correlations were obtained between leaf number and stem diameter, leaf number and number of seeds pod⁻¹, number of branches and plant height.

Dahiya et al. (2007) in their study revealed that the seed yield plant⁻¹ showed significant and positive association with number of clusters plant⁻¹, number of pods plant⁻¹, pod length, number of seeds pod⁻¹, 100-seed weight and harvest index while, it was negatively correlated with plant height.

Eswaran et al. (2007) investigated that Seed yield plant⁻¹ had high significant positive correlation with total dry matter production and harvest index both at phenotypic and genotypic levels.

Suganthi et al. (2008) reported that the seed yield had a positive and significant association with pod length in cowpea.

Correa et al. (2010) in their study on cowpea observed that positive and significant genetic correlations between all the traits and dry bean yield and the highest for days to flowering, mass of pods and number of seeds pod⁻¹.

Singh et al. (2011) reported that the numbers of pods plant⁻¹, plant height, number of primary branches plant⁻¹, 100 seed weight and number of clusters plant⁻¹ were the major characters contributing to grain yield as these traits were significantly and positively associated with grain yield plant⁻¹ in field pea.

Cholin et al. (2012) found that number of clusters plant⁻¹, pods plant⁻¹ had positive correlation with seed yield whereas, number of clusters plant⁻¹, pod length and test weight had a positive direct effect on seed yield and days to maturity has negative direct effect on seed yield in cowpea.

Manggoel et al. (2012) reported in cowpea that positive correlation between grain yield and number of peduncles plant⁻¹, flowers plant⁻¹, pods plant⁻¹ and 100 seed weight.

Sapara et al. (2014) studied genotypic and phenotypic correlation of green pod yield with different components from 40 genotypes of vegetable cowpea and reported yield contributing character number of pods plant⁻¹ had positive and highly significant association with green pod yield plant⁻¹ at phenotypic level.

Selvakumar et al. (2013) conducted experiment on thirty hybrids involving six cowpea genotypes and five yard long bean and cowpea were evaluated and subjected to correlation and path analyses. The characters viz., number of clusters per plant, number of pods per cluster and 100 grain weight were significantly positive correlation with single plant yield. The direct effect of number of clusters per plant and 100 grain weight on single plant yield was

high. Number of pods per clusters and number of seeds per pod recorded moderate and low level direct effect on single plant yield.

Pandey, et al. (2014) conducted experiment on 43 diverse genotypes of cowpea to study the genetic variability, heritability, genetic advance, correlations and path coefficient for different traits to identify diverse genotypes of cowpea belonging to different culti-groups through multivariate analysis.

Pandey and Singh (2015) studied fifteen F1 hybrids obtained by crossing 6 diverse parental lines of cowpea through diallel excluding reciprocals method was studied to investigate the extent of heterosis for yield and yield contributing characters during kharif, 2007 and spring summer, 2008 season. Among the various components pods per plant and seeds per pods are important factor contributing to yield. IT-97K-1042 and IT-93K-452 were observed to be the top performing parents for total seed yield per plant. The crosses IT-97K-1042 X IT-98K-1111 and IT-97K-1042 X Pusa Komal were best heterotic crosses for seed yield and other characters

Meena, et al (2015) experiment on the correlations and path coefficients for ten quantitative characters among 72 cowpea germplasm. Seed yield per plant had positive significant correlation with days to 50% flowering, plant height, primary branches per plant, pods per plant, pod length, seeds per pod and 100-seed weight at both genotypic and phenotypic levels. Path coefficient analysis revealed that primary branches per plant and 100-seed weight had high direct positive effect on seed yield per plant at both genotypic and phenotypic levels.

2.4 Path coefficient analysis

Path coefficient analysis is simply a standardized partial regression coefficient which splits the correlation coefficient into the measure of direct and indirect effects. The path coefficient analysis was originally developed by Wright (1921), but the technique was first used in plant breeding by Dewey and Lu (1959). It is a technique used to find the relative contribution of component characters directly on the main characters and indirectly through other characters to increase the efficiency in selection programme of the

correlation between dependent and independent characters is due to the direct effect of the characters, it reflects a true relationship between them and selection can be practiced for such a character in order to improve dependent variable. Otherwise, broadly-speaking a breeder has to select for the later through which the indirect effect is exerted.

Belhekar et al. (2003) reported that the seed yield plant⁻¹ exhibited direct effect with plant height, number of pods plant⁻¹ and 100-seed weight in cowpea.

Venkatesan et al. (2003) in their study on path analysis showed positive direct effect on number of pods plant⁻¹, pod length, number of clusters plant⁻¹, number of seeds pod⁻¹, and 100-seed weight on seed yield. Thus, these traits should be given more emphasis during selection for yield improvement in cowpea.

Vinieta et al. (2003) studied in cowpea. Path analysis revealed that the number of clusters plant⁻¹, number of pods and seeds plant⁻¹, and 100-seed weight showed the greatest positive direct effects on seed yield. Whereas, the number of days to maturity and flowering exhibited the greatest negative direct effects on seed yield plant⁻¹.

Nigude et al. (2004) observed that the biomass (dry weight) at harvest and harvest index had the highest direct effect on grain yield. Association of biomass with grain yield was significantly positive.

Chakraborty et al. (2005) revealed that 100 seed weight has the maximum direct effect on yield and has indirect effects on pod yield via nodule fresh weight plant⁻¹, total N content and numbers of pods plant⁻¹ which were also positive.

Mittal and Singh (2005) revealed that pods plant⁻¹, pod length, 100 seed weight and days to flowering had high positive direct effects on seed yield in cowpea.

Mehta et al. (2005) revealed that the number of pods plant⁻¹ and pod length exerted high direct effect on pod yield plant⁻¹.

Lal et al. (2007) observed direct effect on pod yield followed by pod weight, number of peduncles plant⁻¹ and pod length. Selection pressure on these traits may lead to an overall increase in pod yield plant⁻¹.

Sharma et al. (2007) revealed that the highly positive direct effects through pods plant⁻¹, plant height and pod length. Therefore, these traits may be considered as the most reliable selection indices for effective improvement in green pod yield in garden pea.

Nawab et al. (2008) revealed that 100-seed weight, number of pods plant⁻¹, number of seeds pod⁻¹ and days to 50 per cent flowering exhibited maximum positive direct effect on green pod yield plot⁻¹. It indicated that these are main contributors towards yield.

Sharma et al. (2009) in their study on path analysis exhibited that pods plant⁻¹ recorded highest positive direct effect on pod yield plant⁻¹ followed by node at which first flower appears and plant height. Direct contribution of these traits indicated that by making selection for these traits, the yield can be substantially improved.

Singh et al. (2011) reported that the number of pods plant⁻¹ recorded highest positive direct effect on grain yield plant⁻¹ via positive indirect effects of plant height and number of primary branches plant⁻¹.

Manggoel et al. (2012) studied path analysis and concluded that high positive direct effects of number of peduncles plant⁻¹, flowers plant⁻¹ and 100-seed weight in cowpea.

Kharde et al. (2014) the genetic variability was studied in 20 genotypes of cowpea. The results showed significant differences among the genotypes evaluated for all the characters. A wide range of variation was observed among the genotypes for all the character. The phenotypic and genotypic coefficients of variation were higher for plant height, pod length, average pod weight, pod yield per plot, number of seeds per pod and number of pods per plant along with high heritability estimates and high expected genetic advance, indicating the additive gene effects. Selection for such traits might be useful for development of varieties.

Anamika and Tajane (2014) conducted path coefficient analysis studies on 44 genotypes of cowpea. The result revealed that number of pods plant⁻¹, 100 seed weight and number of seeds pod⁻¹ had high positive direct effect on seed yield plant⁻¹ and also these traits had significant and positive correlation with seed yield plant.

Pandey, et al. (2014) conducted experiment on 43 diverse genotypes of cowpea to study the genetic variability, heritability, genetic advance, correlations and path coefficient for different traits to identify diverse genotypes of cowpea belonging to different culti-groups through multivariate analysis.

Sapara et al. (2014) found that the genotypic and phenotypic path analysis revealed the high to moderate direct effect of green pod yield plant⁻¹ with number of pods plant⁻¹ and pod length. Therefore number of pods plant⁻¹ and pod length was important component for improving green pod yield in vegetable cowpea.

Meena, et al (2015) study on the correlations and path coefficients for ten quantitative characters among 72 cowpea germplasm. Seed yield per plant had positive significant correlation with days to 50% flowering, plant height, primary branches per plant, pods per plant, pod length, seeds per pod and 100-seed weight at both genotypic and phenotypic levels. Path coefficient analysis revealed that primary branches per plant and 100-seed weight had high direct positive effect on seed yield per plant at both genotypic and phenotypic levels.

2.5 Seasonal incidence of pest and diseases

Diseases like mosaic virus, rust, powdery mildew and bacterial blight are the major biotic constraints in the production of cowpea. The major insect pests those that cause significant yield losses are flower thrips, Pod borer, aphid and jassids. Developing high yielding varieties with resistance to these diseases and insect pests would be a great achievement in crop improvement

Pakela et al. (2002) reported that, there are three factors that influence anthracnose of cowpea caused by *C. dematium*, namely, age of the plant at inoculation, incubation period of the pathogen, and temperature, were evaluated under greenhouse conditions.

Berg et al. (2003) reported that, *Alternaria cassiae* is the causal pathogen of a new, destructive and foliar disease of cowpea.

Shukla et al. (2009) reported the highest incidence of pod borer during kharif season and the peak (3.44 plant^{-1}) was attained within two weeks of its first appearance and they suggested that the efficient management practices during this period was beneficial in reducing the yield loss.

Cheema et al. (2011) studied Ninety seven genotypes of rice bean along with three checks were screened for various insect pests under natural conditions. Forty two genotypes had low incidence of legume pod borer. Thirty genotypes were higher yielding than the best check. The 22 genotypes were found to be high yielding as well as had low incidence of two or more insect pests observed.

MATERIAL AND METHODS

This chapter comprises of the details about the material used and the methods adopted during the course of present investigation entitled “**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**” which was carried out during the year 2015-16.

3.1 Experimental site

The experiment was conducted at Horticulture complex, Department of Horticulture J.N.K.V.V. Jabalpur (M.P.) during the Kharif season of 2015-16.

3.1.1 Soil

The soil of the experimental field was medium black with good drainage and uniform texture with medium NPK status.

3.2 Climate and weather condition

Jabalpur is situated in "Kymore plateau and Satpura Hills" agro-climatic region of Madhya Pradesh. It falls on 23.9° North latitude and 79.58° East longitudes with an altitude of 411.8 meters above mean sea level. The tropic of cancer passes through the middle of the district. Jabalpur is situated in the semi-arid region having sub-tropical climate with cool winter and hot dry summer. The average annual rainfall is about 1375 mm, which is mainly distributed from the mid June to first week of October from South West monsoon, with occasional rainfall during winter. The mean relative humidity reaches up to 74 per cent during winter (November-February) with occasional frost. The average minimum and maximum temperature ranged from 6.8 °C to 46.6 °C.

The data related to weekly minimum and maximum temperature, sunshine hours, rainfall (mm), relative humidity and rainy days were recorded at Meteorological Observatory Krishi Nagar, J.N.K.V.V., Jabalpur and presented in the Table 3.1 and Fig. 1.

Table 3.1: Weekly meteorological observations during the cropping season (August, 2015- December, 2015)

Standard week	Temperature (⁰ C)		Sun Shine hrs.	Rainfall (mm)	Relative humidity (%)		Wind Speed (km/hr)	Rainy days
	Max.	Min.			Max.	Min.		
32	29.8	24.2	4.6	14.0	91	69	3.7	2
33	31.8	24.5	3.0	116.8	91	73	6.1	4
34	31.2	23.6	7.4	9.4	88	64	6.5	1
35	31.3	22.9	3.0	104.6	93	76	4.9	5
36	30.4	24.2	6.7	8.2	87	57	3.5	1
37	32.2	23.1	8.4	3.4	91	55	3.1	1
38	33.5	23.7	5.6	70.2	92	64	5.5	3
39	32.0	21.1	9.2	0.0	84	45	4.2	0
40	32.6	19.5	9.3	0.0	88	25	2.1	0
41	33.1	17.9	9.5	0.0	88	31	2.2	0
42	35.1	19.0	9.2	0.0	86	36	2.4	0
43	34.0	18.4	6.9	0.0	87	47	2.6	0
44	33.3	17.0	5.8	40.0	92	58	4.1	1
45	31.4	17.9	5.8	0.0	88	40	1.8	0
46	30.9	14.1	7.6	0.0	89	35	1.6	0
47	29.0	12.7	6.7	0.0	89	36	1.7	0
48	30.8	14.5	7.2	0.0	88	34	2.3	0
49	28.1	9.2	7.8	0.0	92	30	2.0	0
50	26.6	9.2	7.6	0.0	82	32	3.0	0
51	24.1	7.0	7.0	0.0	82	37	2.8	0
52	24.2	5.4	8.6	0.0	91	25	1.5	0

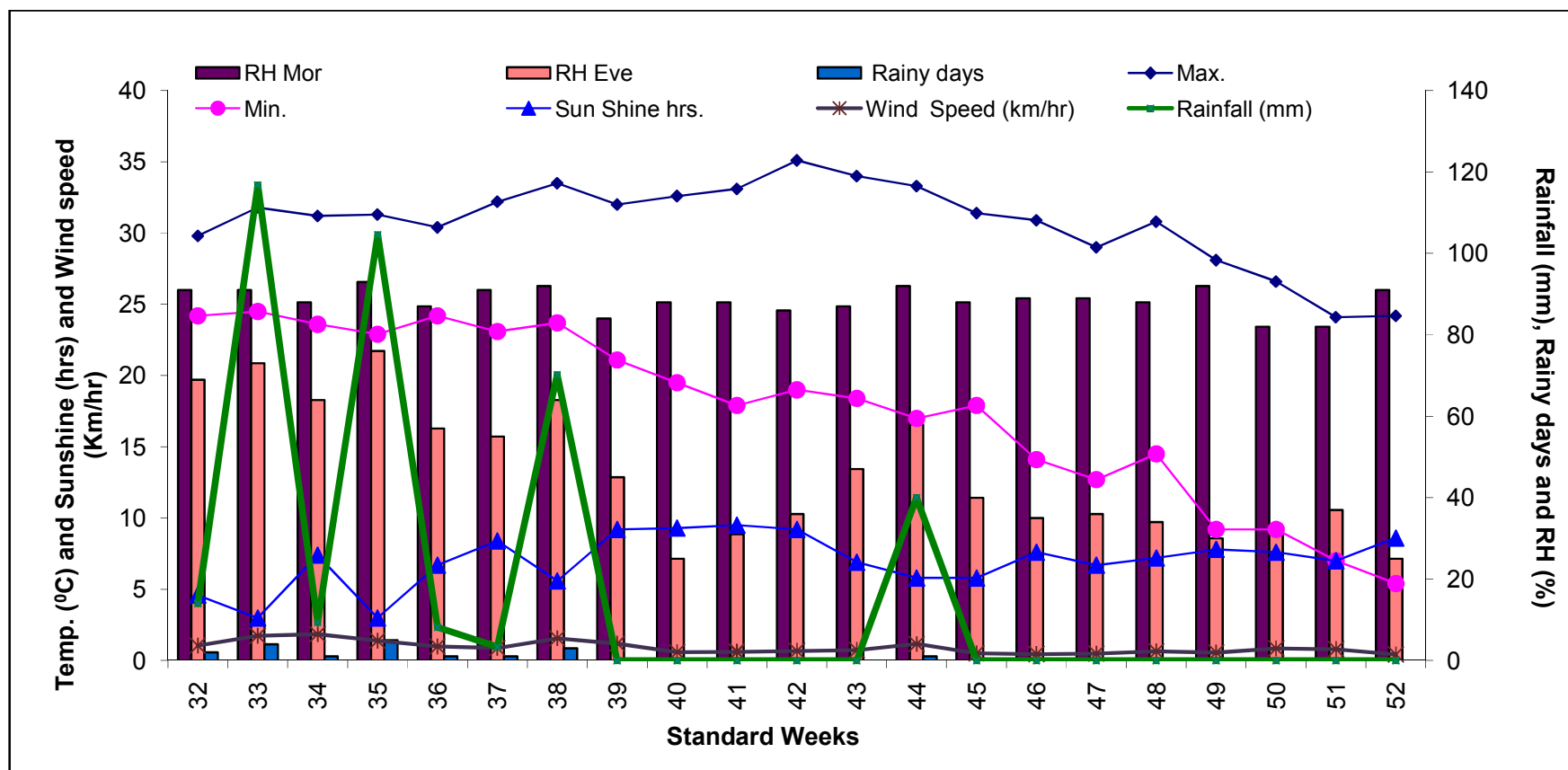


Fig. 1: Meteorological information (week wise) during entire crop season of the year August 2015 to December 2015 at Jabalpur.

Experimental material

The experimental material for this study comprised of 12 genotypes including two checks collected from different research institutes. The genotypes and Commercial checks are presented in Table 3.2

Tables 3.2: Details of Genotypes used in study

S.No.	Genotypes	Source
1	2014/COPBVAR-1	IIVR Varanasi
2	2014/COPBVAR-2	IIVR Varanasi
3	2014/COPBVAR-4	IIVR Varanasi
4	2014/COPBVAR-5	IIVR Varanasi
5	2014/COPBVAR-6	IIVR Varanasi
6	KHASI KANCHAN(check)	IIVR Varanasi
7	ARKA GARIMA(check)	IIHR,BANGLORE
8	GOMTI	ANKUR SEED JALNA (M.H.)
9	LOBIA BANARSI	FAIZABAD
10	SWARNA HARITA	HARP , RACHI
11	KAHINOOR	IIVR Varanasi
12	SHALINI	IIVR Varanasi

3.3 Details of layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication consists of 12 genotypes. All the genotypes were randomized separately in each replication. The plan of layout is given in Fig. 2 and other details are given as below:-

Crop	: Cowpea
Season	: Kharif
Design	: Randomized Complete Block Design (RCBD)
Replication	: Three
Genotypes	: Twelve
Total number of plots	: 36
Plot size	: 3.0 x 2.4 sq. m
Row to row distance	: 60 cm
Plant to plant distance	: 25 cm
Number of rows in each plot	: 4
Number of plants per row	: 12
Total number of plants per plot	: 48
Gross area of experimental field	: 381.8 sq.m
Net area of experiment field	: 259.2 sq.m
Number of plants for observation per plot	: 5
Plot to plot distance	: 0.50 m
Distance between replication	: 1.0 m
Date of sowing	: 21-8-2015

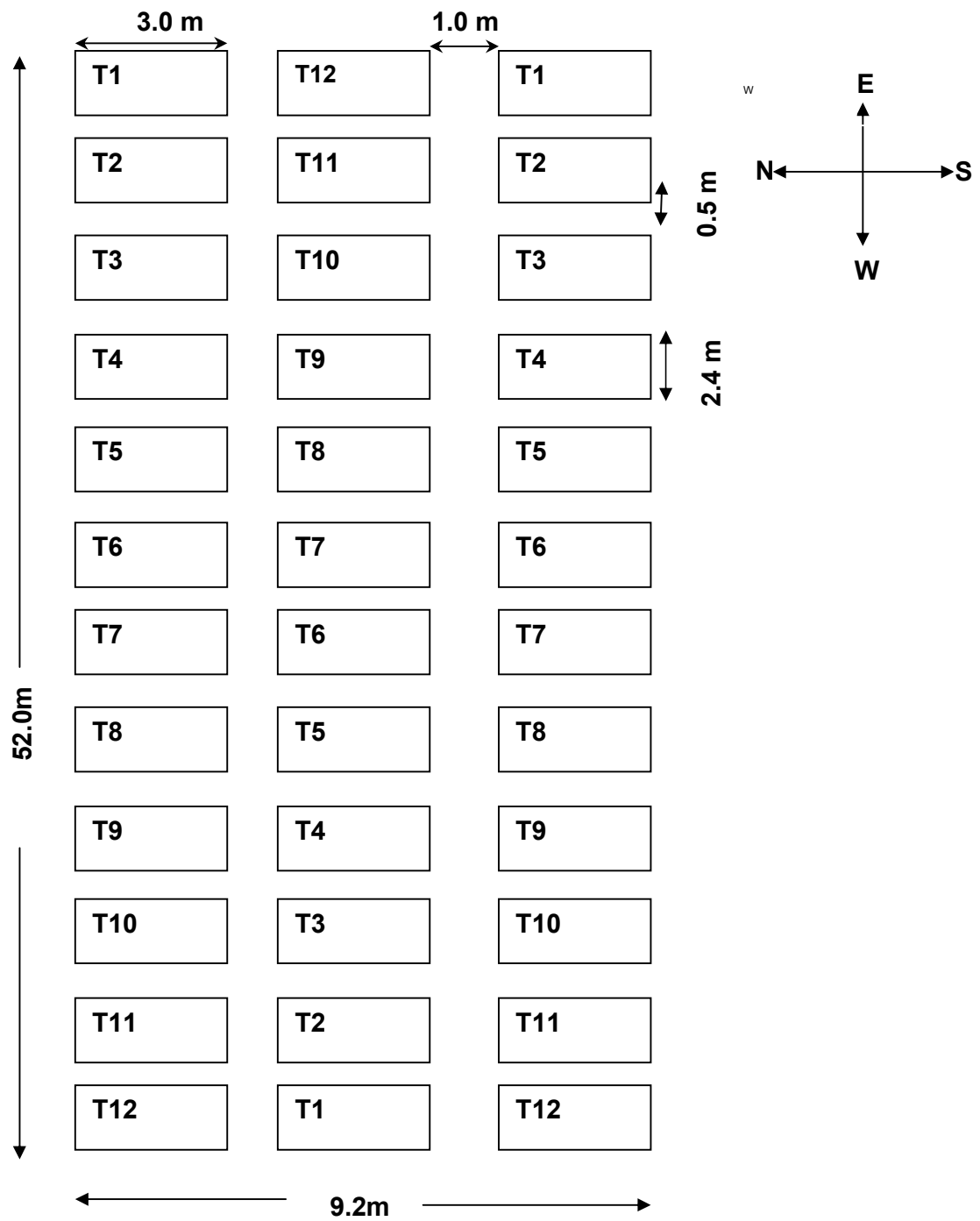


Fig 2: Plan of layout of experiment plot

3.4 Agronomical operations

3.4.1 Field preparation and Layout

In order to get good tilth of the soil for sowing, one cross cultivation was done by tractor drawn cultivator followed by two harrowing and one planking before sowing of seed. The field was laid out for the trial as per given plan of layout.

3.4.2 Seed

The seed rates used for sowing was $12-15 \text{ kg ha}^{-1}$ and before sowing seeds were treated with 2 gm Carbandazim + 1 gm Mancozeb kg^{-1} of seeds.

3.4.3 Sowing

In the beginning of the experiment, seeds were dibbled in rows. After three weeks of sowing, seeds were germinated and thinning was carried out to maintain proper plant population. All the recommended package of practices were followed to raise healthy crop.

3.4.4 Irrigation

The first irrigation was given immediately after sowing to ensure proper germination. Subsequent irrigations were given at an interval of 10-12 days depending upon the soil condition.

3.4.5 Intercultural operations

The experimental plots were kept weed free with four hand weeding. The crop was sprayed with Trizophas (2 ml liter^{-1} of water) alternate to keep the crop free from pest during crop growth period. The crop was sprayed with liquid phosphorus (2 ml liter^{-1} of water) two times at 45 DAS and after 60 DAS.

3.4.6 Fertilizer application

Full dose of organic manure i.e., FYM (20 t ha^{-1}) and one third nitrogen (30 Kg ha^{-1}) and entire quantity of P (80 Kg ha^{-1}) and K (75 Kg ha^{-1}) was applied prior to sowing in the plot. Remaining dose of nitrogen (40 Kg ha^{-1}) was applied in two splits at 30 and 60 days after sowing.

3.5 Sampling

Sampling was done at 30 days interval till harvest for growth analysis. Five plants were randomly selected from each genotype and replication for the study from net plot.

3.6 Observations

The data recorded on various parameters were subdivided into four categories during the period of experimentation.

(A) Morphological characters

3.6.1 Plant Height (cm)

The height of plant was recorded from the base just above the soil surface to growing point (Tip) of the plant. The height was recorded at 30, 60 and 90 days after sowing.

3.6.2 Number of branches plant⁻¹

The number of branches arising from the main stem of each tagged plants were counted at 30, 60 and 90 days after sowing.

(B) Phonological characters

3.6.3 Days to first flowering

Number of days taken beginning from the sowing to the appearance of first flower on the five randomly selected plants in each plot was noted and average was calculated.

3.6.4 Days to 50 per cent flowering

Days required from sowing to flowering in 50 per cent plants in a plot were counted to represent days taken to 50 per cent flowering.

3.6.5 Number of flowers cluster⁻¹

One flower cluster from each of the tagged plants were selected and distinctly labeled. Number of flowers were counted from each cluster and recorded.

3.6.6 Number of flower clusters plant⁻¹

The numbers of flower clusters from observational plants was counted and average number of flower cluster plant⁻¹ was computed.

3.6.7 Days to first picking

Numbers of days required from the date of sowing to first picking of pods were recorded.

(C) Yield characters

3.6.8 Number of pods cluster⁻¹

One flower clusters from each of the tagged plants was selected and distinctly labeled for number of pods and counted from each cluster.

3.6.9 Number of pods plant⁻¹

The numbers of pods from observational plants were counted and average numbers of pods plant⁻¹ was computed.

3.6.10 Pod length (cm)

The length of pod was measured in centimeter with the help of thread and scale from the point it was attached on the bunch up to the tip of the pod and average length was computed. Five pods were randomly selected for this purpose at the time of harvesting.

3.6.11 Pod width (cm)

The widths of the randomly selected pods were recorded from the three different positions such as at base, centre and top with the help of vernier scale.

3.6.12 Pod weight (g)

The weight of five Pods was recorded separately with the help of balance and average pod weight was worked out for each genotype.

3.6.13 Number of seeds pod⁻¹

The number of seeds in five randomly selected pods from observational plants was counted and average number of seeds pod⁻¹ was computed.

3.6.14 Pod yield plant⁻¹ (g)

Weight of fresh marketable pods from the observational plants at each picking was recorded and average pod yield plant⁻¹ was worked out for each treatment.

3.6.15 Pod yield plot⁻¹ (kg)

Weight of fresh marketable pods from each plot throughout the harvesting period was noted and average pod yield plot⁻¹ was worked out for each genotype.

3.6.16 Pod yield ha⁻¹ (q)

The pod yield ha⁻¹ was calculated by multiplying the pod yield plot⁻¹ with the converting factor (9.25).

(D) Other parameters

3.6.17 Flower Colour

Flower colour is determined by visual appearance like:

- White
- Purple
- Light purple

3.6.18 Pod Shape

Shapes of five randomly selected pods were observed visually and were categorized as:

- Straight
- Slightly curved
- Curved

3.6.19 Pod Colour

Colour of five randomly selected pods at marketable stage was observed visually as:

- Dark green
- Light green
- Green

3.6.20 Stringiness in pods

Presence of fibers often randomly selected pods was visually observed:

- Fiber Present
- Fiber Absent

3.6.21 Fleshy or non fleshy green pods

The character was recorded by the peeling of fresh pods in every genotype.

3.6.22 Seed Colour

Seed colour is determined by visual appearance like:

- Light maroon
- Maroon and
- Creamish

3.6.23 Incidence of pests and diseases

Incidence of pod borer

Number of affected pod from each plot separately throughout the harvesting period was recorded and percentage of incidence was calculated in each genotype.

$$\text{Percentage of pod borer incidence} = \frac{\text{Number of pod borer infested pod}}{\text{Total number of pod plot}^{-1}} \times 100$$

Incidence of disease

Number of affected plant affected due to disease Alternaria blight was counted and percentage of incidence was calculated in each genotype.

$$\text{Percentage of pod borer incidence} = \frac{\text{Number of disease infested plant}}{\text{Total number of plant plot}^{-1}} \times 100$$

3.7 Statistical methodology

The data obtained in respect of all the characters have been subjected to the following statistical analyses.

3.7.1 Mean: It was calculated by using following formula

$$\text{Mean} = \frac{\sum x}{N}$$

Where,

$\sum x$ = the sum of all the observations

n = Number of observations

3.7.2 Analysis of variance

The data based on the mean of individual plants selected for observation were statistically analyzed described by Panse and Sukhatme (1967) to find out overall total variability present in the material under study for each character and for all the populations. The first and foremost step is to carry out analysis of variance to test the significance of differences among the populations. The skeleton of analysis of variance used was as follows:

Table 3.3: ANOVA for Randomized Completely Block Design

Source of Variation	d.f.	Sum of square	Mean sum of square	F Value	F_t 5% or 1% table value
Replication	$r-1$	RSS	RMS	RMS/EMS	-
Genotypes	$g-1$	GSS	GMS	GMS/EMS	-
Error	$(r-1)(g-1)$	ESS	EMS	-	-
Total	$rg-1$	TSS	-	-	-

Where,

r = Number of replications

g = Number of genotypes

d.f. = Degree of freedom

RSS = Replication sum of square

GSS = Genotype sum of square

ESS = Error sum of square

TSS = Total sum of square

RMS = Replication mean

GMS = Genotype mean

EMS = Error mean

A significant value of F test indicates that the test entries differ significantly among themselves, which require the computing of C.D.

$$C.V. = \frac{\sqrt{EMS}}{GM} \times 100$$

$$SEm \pm = \frac{\sqrt{EMS}}{r}$$

$$SE \text{ diff} = \frac{\sqrt{2EMS}}{r}$$

CD at 5% prob. Level = SE diff x $t_{5\%}$ table value at error d.f.

Where,

C.V. % = Coefficient of variation

SEm $\pm$ = Standard error of means

S E diff = Standard error of difference of mean

GM = Grand mean

C.D. = Critical difference

$t_{5\%}$ = table value of t at 5% probability level at error d.f.

Estimation of mean, components of variance, phenotypic, genotypic and environmental coefficient of variation, heritability, genetic advance and genetic advance as percentage of mean:

The mean of different characters were calculated by conventional method:-

$$\text{Mean} = \frac{\sum x_i}{N}$$

Where,

Σx_i = The sum of all the observation for i^{th} character.

n = Number of observations.

Range was recorded by observing the lowest and the highest mean values for each character.

3.7.3 Variability studies

The component of variance was calculated as follows:-

Source of variation	M.S.S.	Expected M.S.S.
Replications	-	-
Genotypes	M_i	$\sigma^2_{ei} + r. \sigma^2_{gi}$
Error	E_i	σ^2_{ei}

$$\sigma^2_{gi} = M_i - E_i$$

$$\sigma^2_{ei} = E_i$$

$$\sigma^2_{pi} = \sigma^2_{gi} + \sigma^2_{ei}$$

where,

σ^2_{gi} = Genotypic variance for i^{th} character.

σ^2_{ei} = Environmental variance for i^{th} character.

σ^2_{pi} = Phenotypic variance for i^{th} character.

Phenotypic and genotypic coefficient of variation (expressed in %) were calculated by using the formula given by Burton (1952).

Genotypic coefficient of variation (GCV) was calculated as below:

$$GCV\% = \frac{\sqrt{\sigma^2_{gi}}}{\bar{X}_i} \times 100$$

Phenotypic coefficient of variation (PCV)

$$PCV\% = \frac{\sqrt{\sigma^2_{pi}}}{\bar{X}_i} \times 100$$

where,

$\bar{X}_i$ = General mean of the i^{th} character under consideration.

$\sigma^2_{g_i}$ and $\sigma^2_{p_i}$ = Genotypic and phenotypic variances of the i^{th} character respectively.

The estimates of PCV and GCV were classified as low, moderate and high. According to Sivasubramanian S and Madhava Menon (1973).

0-10%	= Low
10-20%	= Moderate
20% and above	= High

3.7.4 Heritability

Heritability (broad sence) which is ratio of genotypic variance to the total phenotypic variance is symbolized as h^2 (BS) and expressed in percentage. Estimation of heritability was done as per the formula given by Hanson et al. (1956).

$$h^2 \text{ (BS)} = \frac{\sigma^2_{g_i}}{\sigma^2_{p_i}} \times 100$$

or

$$= \frac{\text{Genotypic variance of the } i^{\text{th}} \text{ character}}{\text{Phenotypic variance of the } i^{\text{th}} \text{ character}}$$

Where,

$$\begin{aligned} h^2 \text{ (bs)} &= \text{heritability in broad sense,} \\ \sigma^2_g &= \text{Genotypic variance,} \\ \sigma^2_p &= \text{Phenotypic variance} \end{aligned}$$

3.7.5 Genetic advance

Expected genetic advance was calculated by using the method suggested by Johnson et al. (1955) at 5% selection intensity.

$$\text{Genetic advance (GA)} = K. P_i . h^2_i$$

Genetic advance as percentage of mean was calculated as follows:

$$\frac{\text{Genetic advance}}{\bar{X}}$$

Where,

K = Selection intensity its value at 5% selection level is 2.06.

P_i = Phenotypic standard deviation of the i^{th} character.

h^2_i = Broad sense heritability (fraction) of the i^{th} character.

$\bar{X}_i$ = General mean of the i^{th} character under consideration.

The genetic advance as per cent mean was categorized into low moderate and high by Johnson et al. (1955) and is as follows.

0-10% = Low

10-20% = Moderate

20% and < = High

3.7.6 Correlation coefficients

Correlation coefficients were calculated in all possible combinations taking all the characters into consideration at genotypic, phenotypic and environmental levels by using the formula as proposed by Miller et al. (1958).

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{n}\right) \left(\sum y^2 - \frac{(\sum y)^2}{n}\right)}}$$

Where,

r = Correlation coefficient

n = Number of treatments

X and Y = Characters under study

Genotypic, phenotypic and environmental correlations were computed by substituting corresponding variance and covariance in the above formula, e.g.

$$r_G (X_i X_j) = \frac{G \text{ Cov } (X_i X_j)}{\sqrt{V_G (X_i) \cdot V_G (X_j)}}$$

$$r_P (X_i X_j) = \frac{P \text{ Cov } (X_i X_j)}{\sqrt{V_P (X_i) \cdot V_P (X_j)}}$$

$$r_E (X_i X_j) = \frac{E \text{ Cov } (X_i X_j)}{\sqrt{VE (X_i) \cdot VE (X_j)}}$$

3.7.7 Testing of correlation coefficient:-

The phenotypic correlations were tested for their significance by using the following formula based on “t” test:

$$t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2} \text{ at } (n-2) \text{ d.f.}$$

Where,

n= Number of treatments.

r= phenotypic correlations coefficient.

The calculated value of “t” is compared with table of “t” at (n-2) d.f. If the calculated value is equal to or greater than table value, it is significant at given probability level. If $t_c < t_T$, it is non significant.

3.7.8 Path coefficient analysis:

The cause and effect relationship is well defined in path coefficient analysis. It is possible to represent the whole system of variables in the form of a diagram known as path diagram. Path coefficient analysis can be defined as the ratio of the standard deviation of the effect due to a given cause to the total standard deviation of the effect, in other words it is simply a standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects, i.e. it measures the direct and indirect contribution of various independent characters on a dependent character. Designing new plant type, the knowledge of direct and indirect influence of yield contributing characters, path coefficient analysis was under taken in parents and crosses. Wright (1921) proposed the original technique; analysis was carried out by modified method devised by Dewey and Lu. (1959). Following set of simultaneously equations were formed and solved for estimating direct and indirect effects.

Genotypic path coefficients were calculated separately for yield and yield components. The dependent variable was yield plant⁻¹. The unexplained

variation in the dependent variable was obtained as residual factor from the following equation.

$$r_1Y = P_1Y + r_{12} P_2Y + r_{13} P_3Y + \dots + r_{1i} P_iY.$$

$$r_2Y = r_{21} P_1Y + P_2Y + r_{23} P_3Y + \dots + r_{2i} P_iY.$$

$$r_kY = r_{k1} P_1Y + r_{k2} P_2Y + r_{k3} P_3Y + \dots + r_{ki} P_iY.$$

$$r_kY = r_{k1} P_1Y + r_{k2} P_2Y + r_{k3} P_3Y + \dots + r_{ki} P_iY.$$

Where,

r_1Y to r_kY = Coefficient of correlation between causal factors

1 to i and dependent character

YP_1Y to P_kY = Direct effect of characters 1 to i on character Y.

r_{12} to r_{k-1} , = Coefficient of correlation among causal factors. The above equations were written in a matrix form as under-

$$\begin{matrix} \text{A} & & \text{C} & & \\ \begin{bmatrix} r_1Y \\ r_2Y \\ \cdot \\ \cdot \\ r_kY \end{bmatrix} & & \begin{bmatrix} 1 & r_{12} & r_{13} \dots r_{1i} \\ r_{21} & 1 & r_{23} \dots r_{2i} \\ \cdot & & \\ \cdot & & \\ r_{k1} & r_{k2} & r_{k3} \dots 1 \end{bmatrix} & & \begin{bmatrix} P_1Y \\ P_2Y \\ \cdot \\ \cdot \\ P_kY \end{bmatrix} \end{matrix}$$

Then $B = [C]^{-1} A$

Where,

$$[C]^{-1} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \dots C_{1i} \\ C_{21} & C_{22} & C_{23} & C_{2i} \\ \cdot & & & \\ \cdot & & & \\ C_{i1} & C_{i2} & C_{i3} & C_{ii} \end{bmatrix}$$

Then the direct effects were calculated as follows -

$$P_1Y = \sum_{i=1}^k C_{1i} r_{iy}$$

$$P_2Y = \sum_{i=1}^k C_{2i} r_{iy}$$

$$P_kY = \sum_{i=1}^k C_{ki} r_{ky}$$

Residual effect was obtained as per for formula given below –

$$R = \sqrt{1 - \sum d_i r_{ij}}$$

Where,

d_i = Direct effect of the i^{th} character

r_{ij} = Correlation coefficient of the i^{th} character with j^{th} character.

Path coefficient were to be rated based on the scales given below.

> 1.0 = Very High

0.30 – 0.99 = High

0.2 – 0.29 = Moderate

0.1 – 0.19 = Low

RESULTS

The results obtained from the present investigation “**Genetic variability, correlation and path analysis for yield and it’s attributing traits in Cowpea**” are presented under the following heads;

- 4.1 Analysis of variance
- 4.2 Genetic variability
 - 4.2.1 Range and mean performance
 - 4.2.2 Coefficient of variation
 - 4.2.3 Heritability
 - 4.2.4 Genetic advance
- 4.3 Correlation coefficient analysis
- 4.4 Path coefficient analysis
- 4.5 Quality parameter
- 4.6 Incidence of pest and diseases

4.1 Analysis of variance

The analysis of variances for all the characters studied has been presented in Table 4.1.

Mean square due to genotypes were highly significant for all the characters studied, indicating that the presence of sufficient amount genetic diversity in the existing material.

Eight traits *viz.*, pod yield plant⁻¹, pod yield ha⁻¹ number of pods plant⁻¹, pod weight, number of flower cluster plant⁻¹, pod length, plant height at 90 DAS and incidence of pod borer exhibited the value of higher magnitude.

4.2 Genetic Variability

4.2.1 Range and mean performance of the genotypes

Range and mean performance (maximum and minimum) of the twelve genotypes of cowpea for sixteen characters are presented in Table 4.2 a, b and c.

Table 4.2 (a): Mean performance of morphological characters of cowpea

Genotypes	Plant height (cm)			No. of primary branches per plant		
	30DAS	60 DAS	90DAS	30DAS	60 DAS	90DAS
2014/COPBVAR-1	44.63	75.97	127.40	3.40	21.00	32.27
2014/COPBVAR-2	36.45	64.22	119.67	3.40	22.27	38.20
2014/COPBVAR-4	33.03	44.63	62.07	3.07	17.53	27.07
2014/COPBVAR-5	56.23	81.18	106.93	4.47	21.53	35.53
2014/COPBVAR-6	68.65	95.57	189.03	5.07	28.33	41.87
Gomti	45.29	91.45	168.37	3.33	25.73	33.53
Lobia Banarsi	47.75	88.01	132.03	3.73	23.20	30.70
Swarna Harita	38.00	48.71	65.63	3.73	21.73	28.33
Kohinoor	43.06	59.37	155.97	3.33	20.60	34.00
Shalini	48.28	81.60	167.47	4.00	25.60	36.33
Kashi Kanchan (C)	48.86	78.58	125.83	3.93	27.13	41.93
Arka Garima (C)	43.09	74.99	151.87	3.60	21.67	29.07
S.Em±	1.09	1.23	1.27	0.25	1.27	1.68
C.D.5% level	3.19	3.62	3.72	0.74	3.71	4.94

4.2.1.1 Plant Height (cm)

Plant height varied from (33.03 to 68.65 cm), (44.63 to 95.57 cm) and (62.07 to 189.03 cm) with an overall mean performance of (46.11, 73.69 and 131.02 cm) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-6 was recorded the maximum plant height (68.65 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (33.03 cm). Plant height at 60 DAS genotype 2014/COPBVAR-6 was recorded the maximum plant height (95.57 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (44.63 cm) and plant height at 90 DAS genotype 2014/COPBVAR-6

was recorded the maximum plant height (189.03 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (62.07cm).

4.2.1.2 Number of branches plant⁻¹

Number of branches plant⁻¹ ranged from (3.07 to 5.07), (17.53 to 28.33) and (27.07 to 41.87) with an overall mean performance of (3.76, 23.03 and 34.07) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (5.07) and genotype 2014/COPBVAR-4 was exhibited the minimum (3.07). At 60 DAS genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (28.33) and genotype 2014/COPBVAR-4 was exhibited the minimum (17.53) and plant height at 90 DAS, genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (41.87) and genotype 2014/COPBVAR-4 was exhibited the minimum (27.07cm).

Table 4.2 (b): Mean performance of phenological characters of cowpea

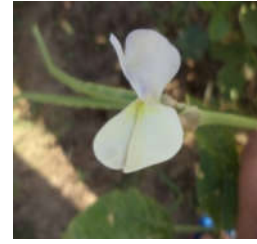
Genotypes	Days to first flowering	Days to 50% flowering	Number of flowers/ cluster	Number of cluster/ plant	Days to first picking	Number of pods/ cluster
2014/COPBVAR-1	40.67	53.33	5.07	34.00	56.33	3.87
2014/COPBVAR-2	37.00	48.67	4.33	28.40	53.67	2.47
2014/COPBVAR-4	36.33	48.67	4.33	15.00	54.33	3.20
2014/COPBVAR-5	34.33	46.67	4.13	15.53	53.33	3.13
2014/COPBVAR-6	36.33	50.33	3.67	20.73	58.67	2.20
Gomti	40.67	54.33	3.33	19.93	62.00	2.53
Lobia Banarsi	39.67	52.33	2.73	12.73	65.00	1.47
Swarna Harita	41.00	52.33	3.67	21.20	65.67	2.60
Kohinoor	42.33	53.67	3.73	18.07	62.00	3.13
Shalini	43.00	54.00	4.00	31.40	66.67	3.27
Kashi Kanchan (C)	37.00	50.00	4.13	13.13	63.33	2.73
Arka Garima (C)	39.33	53.33	3.27	17.80	65.00	2.67
S.Em±	1.11	1.07	0.09	0.25	1.44	0.08
C.D.5% level	3.25	3.13	0.25	0.74	4.22	0.25



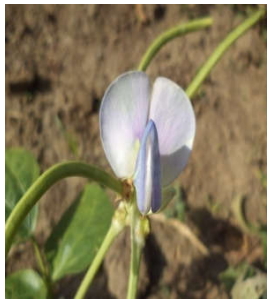
2014/COPBVAR-1



2014/COPBVAR-2



2014/COPBVAR-4



2014/COPBVAR-5



2014/COPBVAR-6



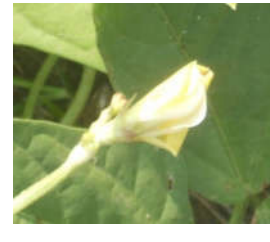
KASHI KANCHAN



ARKA GARIMA



GOMTI



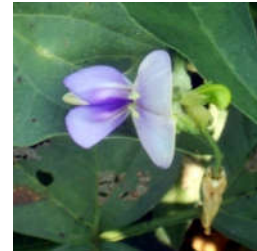
LOBIA BANARSI



SWARNA HARITA



KOHINOOA



SHALINI

Plate 1. Showing variability in flower colour of different genotypes of cowpea

4.2.1.3 Days to first flowering

Days to first flowering varied from (34.33 to 43.00 days) with the average days being (38.97 days). The earliest flowering was observed in genotype 2014/COPBVAR-5 (34.33 days) while, the genotype Shalini (43.00 days) took the maximum days to first flowering.

4.2.1.4 Days to 50 per cent flowering

The average day for 50 per cent flowering was (51.47 days) and it ranged from (46.67 to 54.33 days). The earliest 50 per cent flowering (46.67 days) was recorded in genotype 2014/COPBVAR-5. Gomti and Shalini noted the maximum 54.0 days respectively.

4.2.1.5 Number of flower cluster⁻¹

It ranged from 2.73 to 5.07 and overall mean was calculated (3.87). Maximum number of flower cluster⁻¹ was observed in 2014/COPBVAR-1 (5.07). while, it was recorded the minimum in Lobia Banarsi (2.73).

4.2.1.6 Number of flower cluster plant⁻¹

Ranged from 12.73 to 34.0 and overall mean was calculated (20.66). The Maximum number of flower cluster plant⁻¹ was observed in 2014/COPBVAR-1(34.0). While, it was noted the minimum in Lobia Banarsi (12.73).

4.2.1.7 Days to first picking

Days to first picking ranged from 53.33 to 66.67 days and grand mean was calculated (60.50 days). The Genotype 2014/COPBVAR-5 was earliest for days to first picking (53.33 days), followed by 2014/COPBVAR-2(53.67 days). While, Shalini was the latest for the same (66.67 days).

4.2.1.8 Number of pods cluster⁻¹

The average number of pods cluster⁻¹ was (2.77) and it ranged from (1.47 to 3.87). The maximum number of pods cluster⁻¹ was observed in 2014/COPBVAR-1 (3.87) and the minimum (1.47) was recorded in genotype Lobia Banarsi.

Table 4.2 (C): Mean performance of yield characters of cowpea

Genotypes	Number of pods/ plant	Length of pod (cm)	Width of pod (cm)	Weight of pod (g)	Number of seeds / pod	Pod yield / plant (g)	Pod yield /plot (kg)	Pod yield/ha (q)
2014/COPBVAR-1	67.00	30.64	0.76	7.87	10.67	210.00	8.35	115.94
2014/COPBVAR-2	41.33	26.95	0.91	5.28	9.00	135.00	5.39	74.75
2014/COPBVAR-4	30.73	27.08	0.66	5.43	10.33	138.33	5.50	76.29
2014/COPBVAR-5	23.03	25.55	0.71	4.79	11.27	143.33	5.71	79.30
2014/COPBVAR-6	20.50	25.95	0.68	4.91	12.27	113.33	4.55	63.09
Gomti	13.53	22.55	0.87	6.00	11.20	136.67	5.46	75.74
Lobia Banarsi	14.27	21.46	0.74	3.50	8.47	83.33	3.27	45.34
Swarna Harita	10.83	40.57	0.65	3.94	12.67	141.67	5.67	78.65
Kohinoor	17.80	27.77	0.58	4.73	9.67	125.00	4.99	69.26
Shalini	14.87	25.90	0.63	5.67	8.78	153.33	6.04	83.79
Kashi Kanchan (Check)	27.67	28.05	0.81	7.64	12.47	156.67	6.27	87.05
Arka Garima (Check)	19.93	22.53	1.11	7.19	11.33	141.67	5.72	79.33
S.Em±	2.97	0.51	0.03	0.47	0.41	5.38	0.30	4.10
C.D.5% level	8.72	1.51	0.10	1.37	1.19	15.78	0.87	12.03

4.2.1.9 Number of pods plant⁻¹

The average number of pods plant⁻¹ was 25.13 and ranged from 10.83 to 67.0. The maximum number of pods plant⁻¹ was observed in genotype 2014/COPBVAR-1 (67.00). While, it the was least in genotype Swarna Harita (10.83).

4.2.1.10 Pod length (cm)

The pod length varied from 21.46 to 40.57cm with a mean value of 27.08 cm. Genotype Swarna harita produced considerably longest pod (40.57 cm), while, genotypes Lobia Banarsi produced small pod (21.46 cm).

4.2.1.11 Pod width (cm)

Pod width ranged from 0.58 to 1.11 cm and the average was (0.76 cm). Pod width was observed maximum in genotype Arka Garima (1.11 cm) and it was the minimum in genotype Kohinoor (0.58 cm).

4.2.1.12 Pod weight (g)

The weight of pod range from 3.50 to 7.87 g, while, the average weight of pod was recorded (5.58 g). The maximum pod weight was observed in genotype 2014/COPBVAR-1 (7.87 g) and it was minimum in genotype Lobia Banarsi (3.50 g).

4.2.1.13 Number of seeds pod⁻¹

The average number of seeds pod⁻¹ was recorded 10.68 and it ranged between (8.47 to 12.67) seeds pod⁻¹. The Maximum number of seeds pod⁻¹ was observed in genotype Swarna Harita (12.67), while it was minimum in genotype Lobia Banarsi (8.47)

4.2.1.14 Pod yield plant⁻¹ (g)

The highest pod yield plant⁻¹ was recorded in genotype 2014/COPBVAR-1 (210 g) The genotypes Lobia Banarsi (83.33 g) was recorded the lowest yielder and average yield plant⁻¹ was (139.86 g) and it ranged from (83.33 to 210.0 g).

4.2.1.15 Pod yield plot⁻¹ (Kg)

The highest pod yield plot⁻¹ was recorded in genotype 2014/COPBVAR-1 (8.35 kg). The genotypes Lobia Banarsi (3.27 kg) was low yielder and average yield plot⁻¹ was (5.57 kg) and it ranged from (3.27 to 8.35 kg).

4.2.1.16 Pod yield ha⁻¹ (q)

The highest pod yield ha⁻¹ was recorded in genotype 2014/COPBVAR-1 (115.94 q^{ha}). The genotype Lobia Banarsi (45.34 q^{ha}) was the lowest. The average yield ha⁻¹ was (77.38 q^{ha}) and it ranged from (45.34 to 115.94 q^{ha}).

4.2.2 Coefficient of variation

Estimation of components of genetic parameters of variation for yield and its attributes exhibited a wide range of variation for the character studies (Table 4.3). Result indicated that the value of phenotypic coefficient of variations were higher in magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters.

4.2.2.1 Phenotypic coefficient of variations

The phenotypic coefficient of variation ranged from 5.71% for days to 50 per cent flowering to 64.81% for number of pods plant⁻¹. The phenotypic coefficient of variations was the highest for characters viz., number of pods plant⁻¹ (64.81%), number of cluster plant⁻¹ (34.17%), plant height 90 DAS (29.97%), pod weight (27.57%), number of pods cluster⁻¹ (22.47%), pod yield plot⁻¹ (22.41%), pod yield ha⁻¹ (22.41%), plant height at 60 DAS (22.21%), pod yield plant⁻¹ (21.77%), plant height at 30 DAS (20.71%) and width of pod (20.45%)

However, it was exhibited in moderate for characters like number of seeds pod⁻¹ (14.62%), number of branches at 60 DAS (15.53%), number of flower cluster⁻¹ (16.03%), number of branches at 90 DAS (16.11%), number of branches at 30 DAS (17.64%) and length of pod (18.62%). Days to 50 per cent flowering (5.71%), days to first flowering (8.05%) and days to first picking (8.92%), such as exhibited low phenotypic coefficient of variation.

4.2.2.2 Genotypic coefficient of variation

It is revealed from the Table 4.3 that genotypic coefficient of variation varied from 4.45% for days to 50 per cent flowering to 61.48% for number of pods plant⁻¹.

High genotypic coefficient of variation was observed for number of pods plant⁻¹ (61.48%), number of cluster plant⁻¹ (34.10%), plant height at 90 DAS (29.92%), pod weight (23.43%), number of pods cluster⁻¹ (21.84%), pod yield plot⁻¹ (20.45%), pod yield ha⁻¹ (20.45%), plant height at 60 DAS (22.02%), pod yield plant⁻¹ (20.72%), and plant height at 30 DAS (20.30%).

It was moderate for rest of the characters such as width of pod (18.88%), length of pod (18.33%), number of flower cluster⁻¹ (15.56%), number of branches at 90 DAS (13.64%) number of branches at 30 DAS (13.25%), number of seeds pod⁻¹ (13.05%) and number of branches at 60 DAS (12.27%).

Days to 50 per cent flowering (4.45%), days to first flowering (6.37%) and days to first picking (8.92%), showed low genotypic coefficient of variation

4.2.3 Heritability

The heritability (BS) was computed for each of the characters by the variance components for estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors. The estimates of heritability (BS) for all the characters have been discussed as follows (Table 4.3). It was partitioned as very high (above 90%), high (70 to 90%), medium (50-70%) and low (less than 50%).

The result indicated that the heritability estimates were observed very high for plant height at 90 DAS (99.69%), number of cluster plant⁻¹ (99.61%), plant height at 60 DAS (98.29%), pod length (96.89%), plant height at 30 DAS (96.10%), number of pod cluster⁻¹ (94.48%), number of flower cluster⁻¹ (94.24%) and pod yield plant⁻¹ (90.36%) However, it was recorded to be high for number of pods plant⁻¹ (89.99%), width of pod (85.30%), pod yield plot⁻¹ (83.23%), pod yield ha⁻¹ (83.23%) and number of seeds pod⁻¹ (79.69%), days

to first picking (78.65%), pod weight (72.22%) and number of branches at 90 DAS (71.74%)

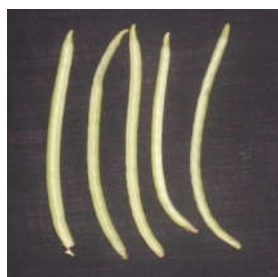
Moderate heritability were recorded for days to first flowering (62.54%), number of branches at 60 DAS (62.43%), days to 50% flowering (60.59%) and number of branches at 30 DAS (56.45%).

4.2.4 Genetic advance

Due to masking influence of environment upon characters concerned, values of genetic advance exhibited high fluctuations. Therefore, to attain relative comparison of the characters in relation to environment genetic advance as percentage of mean was calculated to predict the genetic gain (Table 4.3).

Genetic advance as percentage of mean ranged between 7.13% for days to 50 per cent flowering and 120.13% for number of pods plant⁻¹. The highest estimate of genetic advance as percentage of mean was recorded for number of pods plant⁻¹ (120.13%) followed by number of cluster plant⁻¹ (70.12%), plant height at 90 DAS (61.54%), plant height at 60 DAS (44.96%), number of pod cluster⁻¹ (43.77%) and pod weight (41.01%) and plant height at 30 DAS (41.0%), pod yield plant⁻¹ (40.64%) and pod yield plot⁻¹ (38.46%), pod yield ha⁻¹ (38.42%), length of pod (37.17%), width of pod (35.89%), number of flower cluster⁻¹ (31.09%), number of seed pod⁻¹ (23.99%), number of branches at 90 DAS (23.80%) and number of branches at 30 DAS (20.49%) exhibited moderate value of genetic advance as percentage of mean.

The number of branches at 60 DAS (19.98%), days to first picking (14.45%), days to first flowering (10.37%) and days to 50% flowering (7.13) showed low value of genetic advance as percentage of mean.



2014/COPBVAR-1



2014/COPBVAR-2



2014/COPBVAR-4



2014/COPBVAR-5



2014/COPBVAR-6



KASHI KANCHAN



ARKA GARIMA



GOMTI



LOBIA BANARSI



SWARNA HARITA



KOHINOOR



SHALINI

Plate 2. Showing variability in pod shape size and colour of different genotype of cowpea.

Table 4.3: Genetic parameters 16 different in cowpea.

Characters		Grand Mean	Range		Coefficient of variations		Heritability % (BS)	Genetic Advance	GA as % of mean
			Min.	Max.	Phenotypic	Genotypic			
Plant height (cm)	30 DAS	46.11	33.03	68.65	20.71	20.30	96.10	18.90	41.00
	60 DAS	73.69	44.63	95.57	22.21	22.02	98.29	33.13	44.96
	90 DAS	131.02	62.07	189.03	29.97	29.92	99.69	80.64	61.54
No. of primary branches / plant	30 DAS	3.76	3.07	5.07	17.64	13.25	56.45	0.77	20.49
	60 DAS	23.03	17.53	28.33	15.53	12.27	62.43	4.60	19.98
	90 DAS	34.07	27.07	41.93	16.11	13.64	71.74	8.11	23.80
Days to first flowering		38.97	34.33	43.00	8.05	6.37	62.54	4.04	10.37
Days to 50% flowering		51.47	46.67	54.33	5.71	4.45	60.59	3.67	7.13
Number of flowers/ cluster		3.87	2.73	5.07	16.03	15.56	94.24	1.20	31.09
Number of cluster/ plant		20.66	12.73	34.00	34.17	34.10	99.61	14.49	70.12
Days to first picking		60.50	53.33	66.67	8.92	7.91	78.65	8.74	14.45
Number of pods/ cluster		2.77	1.47	3.87	22.47	21.84	94.48	1.21	43.77
Number of pods/ plant		25.13	10.83	67.00	64.81	61.48	89.99	30.19	120.13
Length of pod (cm)		27.08	21.46	40.57	18.62	18.33	96.89	10.07	37.17
Width of pod (cm)		0.76	0.58	1.11	20.45	18.88	85.30	0.27	35.89
Weight of pod (g)		5.58	3.50	7.87	27.57	23.43	72.22	2.29	41.01
Number of seeds / pod		10.68	8.47	12.67	14.62	13.05	79.69	2.56	23.99
Pod yield / plant (g)		139.86	83.33	210.00	21.77	20.72	90.63	56.84	40.64
Pod yield /plot (kg)		5.57	3.27	8.35	22.41	20.45	83.23	2.14	38.46
Pod yield/ha (q)		77.38	45.34	115.94	22.41	20.45	83.23	29.73	38.42

4.3 Correlation coefficient analysis

Correlation coefficient was worked out at phenotypic, genotypic and environmental levels for all possible combination of eighteen yield and its attributing characters (Table 4.4). Results indicated that genotypic correlation coefficient, in general were of higher magnitude than the corresponding phenotypic correlation coefficient for all the characters.

The results of phenotypic correlation coefficients have been discussed only as the genotypic and environmental correlations were mostly influenced by the environmental conditions, hence phenotypic correlation will give the correct idea about the association between two variables.

4.3.1 Plant Height (cm)

Plant height at 90 DAS (0.408) was significant and positive correlation found with Days at 50% flowering. Significant and negative association of this character was observed with of length of pod (-0.559).

4.3.2 Number of branches plant⁻¹

Number of branches plant⁻¹ at 90 DAS expressed significant and negative correlation with length pod (-0.346), number of pod cluster⁻¹ (-0.389).

4.3.3 Days to first flowering

Association of days to first flowering was recorded significant and positive with days to 50 per cent flowering (0.644), days to first picking (0.453), number of flower cluster⁻¹ (0.352).

4.3.4 Days to 50 per cent flowering

Days to 50 per cent flowering was recorded highly significant and positive with days to first picking (0.624).

Table 4.4: Estimates of genotypic and phenotypic correlation coefficients among pod yield and its attributing traits in cowpea

Characters		No. of primary branches / plant 90 DAS	Days to 1 st flowering	Days to 50% flowering	Number of flowers/ cluster	Number of cluster/ plant	Days to 1 st picking	Number of pods/ cluster	Number of pods/ plant	Length of pod (cm)	Width of pod (cm)	Weight of pod (g)	Number of seeds / pod	Pod yield /plant (g)
Plant height (cm) 90 DAS	G	0.133	0.316	0.517	-0.309	0.203	0.261	-0.176	-0.171	-0.572	0.171	-0.237	-0.140	-0.157
	P	0.127	0.246	0.408*	-0.300	0.203	0.241	-0.170	-0.157	-0.559**	0.152	-0.190	-0.114	-0.144
No. of Branches ⁻¹ 90 DAS	G	1	-0.382	-0.422	-0.093	-0.131	-0.064	-0.459	0.064	-0.413	0.146	-0.258	-0.331	-0.238
	P	1	-0.245	-0.165	-0.046	-0.112	0.002	-0.389*	0.042	-0.346*	0.058	-0.087	-0.148	-0.148
Days to 1 st flowering	G		1	0.751	-0.215	0.468	0.835	0.159	-0.172	0.198	-0.148	0.045	-0.344	0.151
	P		1	0.644**	-0.171	0.352*	0.453**	0.139	-0.184	0.142	-0.209	0.029	-0.276	0.107
Days to 50% flowering	G			1	-0.361	0.350	0.785	0.046	-0.210	0.001	0.081	0.071	-0.221	0.105
	P			1	-0.290	0.276	0.624**	0.014	-0.135	-0.036	0.019	0.057	-0.056	0.105
Number of flowers/ cluster	G				1	0.563	-0.679	0.819	0.831	0.389	-0.181	-0.121	0.067	0.832
	P				1	0.551**	-0.561**	0.781**	0.781**	0.378*	-0.178	-0.051	0.075	0.774**
Number of cluster/ plant	G					1	-0.146	0.498	0.544	0.262	-0.027	-0.188	-0.268	0.617
	P					1	-0.121	0.481**	0.522**	0.256	-0.025	-0.156	-0.239	0.591**
Days to 1 st picking	G						1	-0.377	-0.676	0.103	0.027	0.480	0.046	-0.246
	P						1	-0.279	-0.510**	0.096	0.023	0.407*	0.132	-0.200
Number of pods/ cluster	G							1	0.558	0.308	-0.217	-0.008	0.065	0.874
	P							1	0.513**	0.299	-0.209	0.023	0.065	0.810**
Number of pods/ plant	G								1	0.123	0.166	-0.361	-0.083	0.720
	P								1	0.133	0.122	-0.316	-0.082	0.677**
Length of pod (cm)	G									1	-0.409	0.427	0.452	0.380
	P									1	-0.370*	0.369*	0.407*	0.377*
Width of pod (cm)	G										1	0.331	0.132	0.108
	P										1	0.281	0.073	0.055
Weight of pod (g)	G											1	0.677	0.558
	P											1	0.548**	0.471**
Number of seeds / pod	G												1	0.260
	P												1	0.222

Significant at 5% level = *

Significant at 1% level = **

4.3.5 Number of flower cluster⁻¹

The correlation coefficient of number of flower cluster⁻¹ was found significant and positive correlation with number of pods cluster⁻¹ (0.781), number of pods plant⁻¹ (0.781), pod yield plant⁻¹ (0.774), number of flowers cluster⁻¹ (0.551), and length of pod (0.378) also, significant and negative association was exhibited with days to first picking (-0.561).

4.3.6 Number of flower clusters plant⁻¹

The correlation coefficient of number of flower cluster plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.591), number of pods plant⁻¹ (0.522), and number of pods cluster⁻¹ (0.481).

4.3.7 Days to first picking

Days to first picking was recorded highly significant and positive association with weight of pod (0.407), while, it was found significant and negative with number of pods plant⁻¹ (-0.510)

4.3.8 Number of pods cluster⁻¹

The correlation coefficient of number of pods cluster⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.810), number of pods plant⁻¹ (0.513).

4.3.9 Number of pods plant⁻¹

The correlation coefficient of number of pods plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.677).

4.3.10 Pod length (cm)

Pod length was recorded highly significant and positive association with number of seed pod⁻¹ (0.407), pod yield plant⁻¹ (0.377) and weight of pod (0.369), while, it was found significant and negative with width of pod (-0.370).

4.3.11 Pod weight (g)

The correlation coefficient was found significant and positive correlation with number of seeds pod⁻¹ (0.548) and pod yield plant⁻¹ (0.471).

4.4 Path coefficient analysis

To measure the direct as well as indirect association of one variable through another on the end product, path coefficients were calculated at genotypic and phenotypic levels for all the yield attributing traits. The observed correlation coefficients of yield with its contributing traits were partitioned into direct and indirect effects. In the present investigation, important characters viz., pod yield plant⁻¹ has been used as dependable variables with other traits. Since the values of genotypic path are more reliable in predicting the correct idea about the direct and indirect effects of the component traits, only this has been discussed as below.

The estimates of path coefficient were furnished in the Table 4.5 and 4.6. In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects. The results obtained from genotypic direct and indirect effects are presented as under.

Direct effect

Path coefficient analysis of different characters contributing towards pod yield plant⁻¹ showed that length of pod (27.40) had the highest positive direct effect followed by width of pod (15.501), plant height at 90 DAS (14.523), number of pod cluster⁻¹ (11.999), number of branches at 90 DAS (4.044), days to first flowering (2.015). Whereas, number of cluster plant⁻¹ (-12.201) had the highest negative direct effect on pod yield plant⁻¹ followed by number of seed pod⁻¹ (-9.055), number of pod plant⁻¹ (-8.096), weight of pod (-8.084), days to first picking (-7.448), number of flower cluster⁻¹ (-5.734) and days to 50 per cent flowering (-4.657).

Indirect effect

Plant height at 90 DAS (cm)

Plant height at 90 DAS imparted the highest positive indirect effect on pod yield plant⁻¹ through, width of pod (2.656), weight of pod (1.914), number of flower cluster⁻¹ (1.771), number of pod plant⁻¹ (1.383), number of seed pod⁻¹ (1.271), days to first flowering (0.637) and number of branches at 90 DAS (0.539). Whereas, negative indirect effect was visible to be highest via pod

yield plant⁻¹ (-0.157), days to first picking (-1.944), number of pod cluster⁻¹ (-2.109), days to 50% flowering (-2.410), number of flower cluster plant⁻¹ (-2.478) and length of pod (-15.681).

Number of branches plant⁻¹ at 90 DAS

Number of branches plant⁻¹ at 90 DAS exhibited the highest positive indirect effect pod yield plant⁻¹ via number of seed pod⁻¹ (2.994), width of pod (2.265), weight of pod (2.088), days to 50% flowering (1.967), plant height at 90 DAS (1.932) number of cluster plant⁻¹ (1.60), number of flowers cluster⁻¹ (0.531) and days to first picking (0.476). Whereas, it was expressed high negative indirect effect via pods yield plant⁻¹ (-0.238), number of pods plant⁻¹ (-0.515), days to first flowering (-0.770), number of pods cluster⁻¹ (-5.512), and length of pod (-11.317).

Days to first flowering

Days to first flowering was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, length of pod (5.432), Plant height at 90 DAS (4.589), number of seeds pod⁻¹ (3.113), number of pods cluster⁻¹ (1.908), number of pods plant⁻¹ (1.393), number of flowers cluster⁻¹ (1.234) and pod yield plant⁻¹ (0.151). Whereas, it was expressed high negative indirect effect via weight of pod (-0.361), Number of branches plant⁻¹ at 90 DAS (-1.545) width of pod (-2.290), days to 50 per cent flowering (-3.497), number of cluster plant⁻¹ (-5.714) and days to first picking (-6.222).

Days to 50 per cent flowering

Days to 50 per cent flowering was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, Plant height at 90 DAS (7.508), followed by number of flowers cluster⁻¹ (2.069), number of seeds pod⁻¹ (2.00), number of pods plant⁻¹ (1.701), days to first flowering (1.514) width of pod (1.250), number of pods cluster⁻¹ (0.551) and pod yield plant⁻¹ (0.105). Whereas, it was expressed high negative indirect effect on pod yield plant⁻¹ via pod weight (-0.574), Number of branches plant⁻¹ at 90 DAS (-1.707) number of cluster plant⁻¹ (-4.265) and days to first flowering (-5.844).

Number of flower cluster⁻¹

Number of flower cluster⁻¹ was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, length of pod (10.657), number of pods cluster⁻¹ (9.826), days to first picking (5.055), days to 50% flowering (1.681), pod weight (0.977) and pod yield plant⁻¹ (0.832). Whereas, it was expressed high negative indirect effect via number of branches at 90 DAS (-0.376), days to first flowering (-0.433) number of seeds pod⁻¹ (-0.607), width of pod (-2.808), plant height at 90DAS (-4.488) number of cluster plant⁻¹ (-6.872) and number pods plant⁻¹ (-6.730).

Number of flower clusters plant⁻¹

Number of flower cluster plant⁻¹ was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, length of pod (7.169), number of pods cluster⁻¹ (5.971), plant height at 90 days (2.948), number of seeds pod⁻¹ (2.424) weight of pod (1.524) days to first picking (1.087), days to first flowering (0.943) and pod yield plant⁻¹ (0.617). Whereas, it was expressed high negative indirect effect through width of pod (-0.421), number of branches at 90 DAS (-0.530), days to 50% flowering (-1.630), number of flowers cluster⁻¹ (-3.228) and number of pods plant⁻¹ (-4.402).

Table 4.5: Phenotypic path coefficients showing direct and indirect effects of different characters on pod yield per plant (g) in cowpea

Characters	Plant height (cm) 90 DAS	Primary branches / plant 90 DAS	Days to 1 st flowering	Days to 50% flowering	Number of flowers/ cluster	Number of cluster/ plant	Days to 1 st picking	Number of pods/ cluster	Number of pods/ plant	Length of pod (cm)	Width of pod (cm)	Weight of pod (g)	Number of seeds / pod	“r” value Pod yield /plant (g)
Plant height (cm) 90 DAS	2.0146	-0.0054	0.3739	-0.1606	-0.6103	-0.5134	-0.1556	0.1959	0.0005	-1.4213	0.2015	0.1870	-0.0333	-0.144
Primary branches / plant 90 DAS	0.2559	-0.0423	-0.3725	0.0652	-0.0935	0.2842	-0.0013	0.4487	-0.0001	-0.8798	0.0764	0.0858	-0.0432	-0.148
Days to 1 st flowering	0.4956	0.0104	1.5201	-0.2539	-0.3488	-0.8897	-0.2925	-0.1600	0.0005	0.3610	-0.2769	-0.0286	-0.0805	0.107
Days to 50% flowering	0.8220	0.0070	0.9789	-0.3941	-0.5893	-0.6980	-0.4025	-0.0156	0.0004	-0.0926	0.0247	-0.0558	-0.0163	0.105
Number of flowers/ cluster	-0.6043	0.0019	-0.2599	0.1143	2.0345	-1.3947	0.3618	-0.9006	-0.0023	0.9613	-0.2359	0.0505	0.0218	0.774
Number of cluster/ plant	0.4087	0.0047	0.5351	-0.1088	1.1210	-2.5307	0.0782	-0.5541	-0.0015	0.6515	-0.0336	0.1529	-0.0698	0.591
Days to 1 st picking	0.4857	-0.0001	0.6886	-0.2459	-1.1413	0.3062	-0.6452	0.3212	0.0015	0.2438	0.0304	-0.4003	0.0386	-0.200
Number of pods/ cluster	-0.3425	0.0165	0.2113	-0.0055	1.5889	-1.2173	0.1800	-1.1525	-0.0015	0.7596	-0.2779	-0.0226	0.0189	0.810
Number of pods/ plant	-0.3172	-0.0018	-0.2797	0.0532	1.5889	-1.3210	0.3291	-0.5913	-0.0029	0.3390	0.1621	0.3101	-0.0238	0.677
Length of pod (cm)	-1.1265	0.0146	0.2159	0.0142	0.5656	-0.6479	-0.0619	-0.3446	-0.0004	2.5418	-0.4907	-0.3629	0.1188	0.377
Weight of pod (g)	0.3058	-0.0025	-0.3177	-0.0075	-0.3621	0.0633	-0.0148	0.2409	-0.0004	-0.9405	1.3273	-0.2760	0.0214	0.055
Weight of pod (g)	-0.3833	0.0037	0.0441	-0.0225	-0.1045	0.3938	-0.2626	-0.0265	0.0009	0.9379	0.3730	-0.9828	0.1599	0.171
Number of seeds / pod	-0.2298	0.0063	-0.4192	0.0220	0.1526	0.6054	-0.0852	-0.0749	0.0002	1.0345	0.0969	-0.5386	0.2918	0.222

Residual effect Phenotypic= 0.9808

Table 4.6: Genotypic path coefficients showing direct and indirect effects of different characters on pod yield per plant (g) in cowpea

Characters	Plant height (cm) 90 DAS	Primary branches / plant 90 DAS	Days to 1 st flowering	Days to 50% flowering	Number of flowers/ cluster	Number of cluster/ plant	Days to 1 st picking	Number of pods/ cluster	Number of pods/ plant	Length of pod (cm)	Width of pod (cm)	Weight of pod (g)	Number of seeds / pod	"r" value Pod yield /plant (g)
Plant height (cm) 90 DAS	14.523	0.539	0.637	-2.410	1.771	-2.478	-1.944	-2.109	1.383	-15.681	2.656	1.914	1.271	-0.157
Primary branches / plant 90 DAS	1.932	4.044	-0.770	1.967	0.531	1.600	0.476	-5.512	-0.515	-11.317	2.265	2.088	2.994	-0.238
Days to 1 st flowering	4.589	-1.545	2.015	-3.497	1.234	-5.714	-6.222	1.908	1.393	5.432	-2.290	-0.361	3.113	0.151
Days to 50% flowering	7.508	-1.707	1.514	-4.657	2.069	-4.265	-5.844	0.551	1.701	0.022	1.250	-0.574	2.000	0.105
Number of flowers/ cluster	-4.488	-0.376	-0.433	1.681	-5.734	-6.872	5.055	9.826	-6.730	10.657	-2.808	0.977	-0.607	0.832
Number of cluster/ plant	2.948	-0.530	0.943	-1.630	-3.228	-12.201	1.087	5.971	-4.402	7.169	-0.421	1.524	2.424	0.617
Days to 1 st picking	3.790	-0.259	1.683	-3.656	3.893	1.781	-7.448	-4.519	5.477	2.817	0.416	-3.880	-0.413	-0.246
Number of pods/ cluster	-2.556	-1.856	0.320	-0.214	-4.696	-6.076	2.808	11.999	-4.514	8.438	-3.368	0.064	-0.592	0.874
Number of pods/ plant	-2.483	0.259	-0.347	0.978	-4.765	-6.637	5.035	6.696	-8.096	3.365	2.569	2.922	0.749	0.720
Length of pod (cm)	-8.307	-1.670	0.399	-0.005	-2.230	-3.197	-0.767	3.696	-0.996	27.400	-6.337	-3.455	-4.095	0.380
Weight of pod (g)	2.483	0.590	-0.298	-0.377	1.038	0.329	-0.201	-2.604	-1.344	-11.207	15.501	-2.674	-1.200	0.108
Weight of pod (g)	-3.442	-1.043	0.091	-0.331	0.694	2.294	-3.575	-0.096	2.923	11.700	5.131	-8.084	-6.130	0.158
Number of seeds / pod	-2.033	-1.339	-0.693	1.029	-0.384	3.270	-0.343	0.780	0.672	12.385	2.046	-5.473	-9.055	0.260

Residual effect Genotypic= 1.3342

Days to first picking

Days to first picking was expressed the highest positive indirect effect through, number of pods plant⁻¹ (5.477), number of flowers cluster⁻¹ (3.893), plant height at 90 days (3.790) length of pod (2.817), number of cluster plant⁻¹ (1.781), days to first flowering (1.683), width of pod (0.416). It's indirect negative effect was high via pod yield plant⁻¹ (-0.246), number of branches at 90 DAS (-0.259), days to 50% flowering (-3.656), number of seeds pod⁻¹ (-0.413), weight of pod (-3.880) and number of pods cluster⁻¹ (-4.519).

Number of pods cluster⁻¹

The Highest positive indirect effect of number of pods cluster⁻¹ on pod yield plant⁻¹ was recorded through, length of pod (8.438), days to first picking (2.808), pod yield plant⁻¹ (0.874), days to first flowering (0.320) and weight of pod (0.064). It's negative indirect effect was high via days to 50% flowering (-0.214), number of seeds pod⁻¹ (-0.592), number of branches at 90 DAS (-1.856), plant height at 90 DAS (-2.556) width of pod (-3.368), number of pods plant⁻¹ (-4.514), number of flowers cluster⁻¹ (-4.696) and number cluster plant⁻¹ (-6.076)

Number of pods plant⁻¹

The Highest positive indirect effect of number of pods plant⁻¹ on pod yield plant⁻¹ was recorded through number of pods cluster⁻¹ (6.696) days to first picking (5.035), length of pod (3.365), weight of pod (2.922), width of pod (2.569), days to 50% flowering (0.978), number of seeds pod⁻¹ (0.749), pod yield plant⁻¹ (0.720) and number of branches at 90 DAS (0.259). While, the remaining characters showed high negative indirect effect i.e. days to first flowering (-0.347), plant height at 90 DAS (-2.483), number of flowers cluster⁻¹ (-4.765), number of flowers cluster plant⁻¹ (-6.637).

Pod length

Pod length revealed high values of positive indirect effect on pod yield plant⁻¹ through number of pods cluster⁻¹, pod yield plant⁻¹ (0.380) and days to first flowering (0.339). While, the remaining characters showed high negative indirect effect i.e. days to 50% flowering (-0.005), days to first picking (-0.767), number of pods plant⁻¹ (-0.996), number of branches at 90 DAS (-1.67), number of flower cluster⁻¹ (-2.230), number of cluster plant⁻¹ (-3.197), weight

of pod (-3.455), number of seeds pod⁻¹ (-4.095), width of pod (-6.337) and plant height at 90 DAS (-8.307)

Pod width

Pod width revealed high values of positive indirect effect on pod yield plant⁻¹ through plant height at 90 DAS (2.483), number of flowers cluster⁻¹ (1.038), number of branches at 90 DAS (0.590), number of cluster plant⁻¹ (0.329), and pod yield plant⁻¹ (0.108). Indirect effect i.e. days to first picking (-0.201), days to first flowering (-0.298), days to 50% flowering (-0.377), number of seeds pod⁻¹ (-1.20), number of pods plant⁻¹ (-1.344), number of pods cluster⁻¹ (-2.604), and weight of pod (-2.674)

Pod weight

The Highest positive indirect effect of pod weight on pod yield plant⁻¹ was recorded through length of pod (11.70), width of pod (5.131), number of pods plant⁻¹ (2.923), number of cluster plant⁻¹ (2.294), number of flowers cluster⁻¹ (0.694), pod yield plant⁻¹ (0.158), and days to first flowering (0.091). It showed negative indirect effect through number of pods cluster⁻¹ (-0.096), days to 50% flowering (-0.331), number of branches at 90 DAS (-1.043), plant height at 90 DAS (-3.442), days to first picking (-3.575) and number of seeds pod⁻¹ (-6.130).

Number of seeds pod⁻¹

Number of seeds pod⁻¹ manifested positive indirect effect through length of pod (12.385), number of cluster plant⁻¹ (3.270), width of pod (2.046), days to 50% flowering (1.029), number of pods cluster⁻¹ (0.780), number of pods plant⁻¹ (0.672) and pod yield plant⁻¹ (0.258). The negative indirect effect through days to first picking (-0.0343), number of flowers cluster⁻¹ (-0.384), days to first flowering (-0.693), number of branches at 90 DAS (-1.339), plant height at 90 DAS (-2.033) and weight of pod (-5.473).

Quality parameters 4.5

Qualitative characters like colour of flowers, shape of pods, colour of pods, seed colour, stringiness in pods and fleshy or non fleshy pods are summarized in Table 4.7.

Colour of flower

Colour of flower was observed as white, purple, light purple. Genotypes Arka Garima exhibited purple colour flower. White colour flowers were observed in genotype 2014/COPBVAR-1, 2014/COPBVAR-4, Gomti, Lobia Banarsi and Swarna Harita. Whereas, genotypes 2014/COPBVAR-2, 2014/COPBVAR-5, 2014/COPBVAR-6, Kashi Kanchan, kohinoor and Shalini exhibited light purple flowers.

Colour of pod

Colour of pods was observed as dark green, green and light green. Genotypes 2014/COPBVAR-6 exhibited dark green pods. Whereas, genotypes 2014/COPBVAR-2, 2014/COPBVAR-4, Kashi Kanchan, Gomti, and Swarna Harita were observed green pods. the, genotypes 2014/COPBVAR-1, 2014/COPBVAR-5, Arka Garima, Lobia Banarsi, Kohinoor and Shalini exhibited light green pods colour.

Shape of pod

Wide variation was observed among the genotypes for shape of pods i.e. straight, slightly curved and curved (Table 4.7). Shape of pods was observed to be straight in genotypes 2014/COPBVAR-1, 2014/COPBVAR-2, Arka Garima, and Shalini. Genotypes 2014/COPBVAR-6, Gomti and Swarna Harita were produced curved pod. Whereas, genotypes 2014/COPBVAR-4, 2014/COPBVAR-5, Kashi Kanchan, Lobia Banarsi, and Kohinoor produced slightly curved pods.

Stringiness in pods

Variation was observed among the genotypes for stringiness in pods i.e. fiber present or absent (Table 4.7). Fiber was present in genotypes 2014/COPBVAR-5, 2014/COPBVAR-6, Arka Garima and Shalini. Fiber was absent in remaining genotypes.

Fleshy or non fleshy green pods

Wide variation was observed among the genotypes for fleshy or non fleshy pods. Non fleshy pods were observed in genotypes 2012/COPBVAR-6, and Shalini. Whereas, genotypes 2014/COPBVAR -4, Kashi Kanchan and Swarna Harita produced less fleshy pods. The remaining genotypes produced fleshy pods.

Table 4.7: Qualitative characters in cowpea genotypes

Genotypes	Flower colour	Pod colour	Shape of pod	Stringiness in pods	Fleshy or non fleshy green pods	Seed colour
2014/COPBVAR-1	White	Light green	Straight	Fiber absent	Fleshy	Dark creamish
2014/COPBVAR-2	Light purple	Green	Straight	Fiber absent	Fleshy	Dark creamish
2014/COPBVAR-4	White	Green	Slightly curved	Fiber absent	Less fleshy	Light maroon
2014/COPBVAR-5	Light purple	Light green	Slightly curved	Fiber present	Fleshy	Dark creamish
2014/COPBVAR-6	Light purple	Dark green	Curved	Fiber present	Non fleshy	Black
Kashi Kanchan (C)	Light purple	Green	Slightly curved	Fiber absent	Less fleshy	Dark maroon
Arka Garima (C)	Purple	Light green	Straight	Fiber present	Fleshy	Cream and maroon
Gomti	White	Green	Curved	Fiber absent	Fleshy	Creamish
Lobia Banarsi	White	Light green	Slightly curved	Fiber absent	Fleshy	Light maroon
Swarna Harita	White	Green	Curved	Fiber absent	Less fleshy	Light maroon
Kohinoor	Light purple	Light green	Slightly curved	Fiber present	Fleshy	Dark creamish
Shalini	Light purple	Light green	Straight	Fiber absent	Non fleshy	Cremish



2014/COPBVAR-1



2014/COPBVAR-2



2014/COPBVAR-4



2014/COPBVAR-5



2014/COPBVAR-6



KASHI KANCHAN



ARKA GARIMA



GOMTI



LOBIA BANARSI



SWARNA HARITA



KOHINOOR



SHALINI

Plate 3. Sowing seed of different genotype under investigation

Seed colure

Colure of seeds was observed to be cream, dark maroon, maroon and light maroon. Genotypes 2014/COPBVAR-1, Lobia Banarsi and Swarna Harita exhibited light maroon seeds. Whereas, genotypes, 2011/COPBVAR-6 was observed maroon seeds was observed Genotype Kashi Kanchan were observed dark maroon colour. Genotype 2014/COPBVAR-6 observed black colour. Remaining genotypes exhibited creamish seeds.

4.6 Incidence of pest and diseases

The result of percentage of disease incidence and insect pest has been depicted in the Table 4.8. The results are based on the total score of disease and insect pest in a given genotype.

4.6.1 Incidence of pod borer (%)

Pod borer incidence was observed the maximum in genotypes 2014/COPBVAR-5 (8.32) followed by 2014/COPBVAR-4 (7.63) and 2014/COPBVAR-1 (6.24) was found susceptible to pod borer. The low incidence of pod borer was found in genotypes Kohinoor (2.08) and Kashi kanchan (3.47).

4.6.2 Incidence of Alternaria Blight (%)

The incidence of Alternaria blight was observed the maximum in genotypes Lobia Banarsi (31.20 %), 2014/COPBVAR-4 (4.85%) and Kashi kanchan (4.85%). Whereas, genotypes 2014/COPBVAR-2 (2.08%), 2014/COPBVAR-6 (2.08%) and 2014/COPBVAR-1 (2.77%) were slightly tolerant to the same.

Table 4.8: Mean performance of incidence of disease and insect pest of cowpea

Genotypes	Pod borer (%)	Incidence of Alternaria blight (%)
2014/COPBVAR-1	6.24	2.77
2014/COPBVAR-2	4.16	2.08
2014/COPBVAR-4	7.63	4.85
2014/COPBVAR-5	8.32	2.77
2014/COPBVAR-6	4.16	2.08
Gomti	4.16	3.47
Lobia Banarsi	5.55	31.20
Swarna Harita	4.85	4.16
Kohinoor	2.08	2.77
Shalini	5.55	4.16
Kashi Kanchan (C)	3.47	4.85
Arka Garima (C)	4.85	4.16
S.Em±	1.19	2.74
C.D. 5%	N.S.	5.69

DISCUSSION

The results obtained from the present investigation “**Genetic variability, correlation and path analysis for yield and it’s attributing traits in Cowpea**” are presented under the following heads;

- 5.1 Analysis of variance
- 5.2 Genetic variability
 - 5.2.1 Range and mean performance
 - 5.2.2 Coefficient of variation
 - 5.2.3 Heritability
 - 5.2.4 Genetic advance
- 5.3 Correlation coefficient analysis
- 5.4 Path coefficient analysis
- 5.5 Quality parameter
- 5.6 Incidence of pest and diseases

5.1 Analysis of variance

The main objective of the present investigation was to study the diversity present in twelve diverse genotypes of cowpea. The present investigation resulted that the mean sum of square due to genotypes were highly significant for all the characters. The mean square due to genotypes were highly significant for all the characters studied, indicating that the presence of sufficient amount genetic diversity in the existing material. The following eight traits viz., pod yield plant⁻¹, pod yield ha⁻¹ number of pods plant⁻¹, pod weight, number of flower cluster plant⁻¹, pod length, plant height at 90 DAS and incidence of pod borer exhibited the value of higher magnitude. The present finding also collaborated with findings of Rangaiah and Mahadevu (2000), Ramesh et al. (2002) Rocha et al. (2003), Venkatesan et al. (2003), Kumawat et al. (2005), Bertini et al. (2009), Prasad et al. (2004), Girish et al.

(2006), Lal et al. (2007), Eswaran et al. (2007), Pandey and Singh (2011) and Manggoel et al. (2012).

5.2 Genetic Variability

5.2.1 Range and mean performance of the genotypes

The range and mean performance (maximum and minimum) of the twelve genotypes of cowpea for sixteen characters are presented here that, Plant height varied from (33.03 to 68.65 cm), (44.63 to 95.57 cm) and (62.07 to 189.03 cm) with an overall mean performance of (46.11, 73.69 and 131.02 cm) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-6 was recorded the maximum plant height (68.65 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (33.03 cm). Plant height at 60 DAS genotype 2014/COPBVAR-6 was recorded the maximum plant height (95.57 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (44.63 cm) and plant height at 90 DAS genotype 2014/COPBVAR-6 was recorded the maximum plant height (189.03 cm) and genotype 2014/COPBVAR-4 was exhibited the minimum (62.07cm). Number of branches plant⁻¹ ranged from (3.07 to 5.07), (17.53 to 28.33) and (27.07 to 41.87) with an overall mean performance of (3.76, 23.03 and 34.07) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (5.07) and genotype 2014/COPBVAR-4 was exhibited the minimum (3.07). At 60 DAS genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (28.33) and genotype 2014/COPBVAR-4 was exhibited the minimum (17.53) and plant height at 90 DAS, genotype 2014/COPBVAR-6 was recorded the maximum branches plant⁻¹ (41.87) and genotype 2014/COPBVAR-4 was exhibited the minimum (27.07cm). Days to first flowering varied from (34.33 to 43.00 days) with the average days being (38.97 days). The earliest flowering was observed in genotype 2014/COPBVAR-5 (34.33 days) While, the genotype Shalini (43.00 days) took the maximum days to first flowering.

The average days for 50 per cent flowering was (51.47 days) and it ranged from (46.67 to 54.33 days). The earliest 50 per cent flowering (46.67

days) was recorded in genotype 2014/COPBVAR-5. Gomti and Shalini was noted the maximum 54.0 days respectively.

It ranged from (2.73 to 5.07) and overall mean was calculated (3.87). Maximum number of flower cluster⁻¹ was observed in 2014/COPBVAR-1 (5.07), while, it was recorded the minimum in Lobia Banarsi (2.73). Ranged from (12.73 to 34.0) and overall mean was calculated (20.66). the Maximum number of flower cluster plant⁻¹ was observed in 2014/COPBVAR-1 (34.0), while, it was noted the minimum in Lobia Banarsi (12.73). Days to first picking ranged from (53.33 to 66.67 days) and grand mean was calculated (60.50 days). Genotype 2014/COPBVAR-3 was the earliest for days to first picking (53.33 days), followed by 2014/COPBVAR-5(53.33 days), while, Shalini was latest for the same (66.67 days).

The average number of pods cluster⁻¹ was (2.77) and it ranged from (1.47 to 3.87). The maximum number of pods cluster⁻¹ was observed in 2014/COPBVAR-1 (3.87), and the minimum (1.47) was recorded in genotype Lobia Banarsi. The average number of pods plant⁻¹ was (25.13) and ranged from (10.83 to 67.0). The maximum number of pods plant⁻¹ was observed in genotype 2014/COPBVAR-1 (67.00), while, it was the least in genotype Swarna Harita (10.83). The pod length varied from (21.46 to 40.57cm) with a mean value of (27.08 cm). Genotype swarna harita produced considerably long pod (40.57 cm), while, genotypes Lobia Banarsi produced small pod (21.46 cm). Pod width ranged from (0.58 to 1.11 cm) and the average was recorded (0.76 cm). The pod width was observed the maximum in genotype Arka Garima (1.11 cm) and it was the minimum in genotype Kohinoor (0.58 cm). The weight of pod from (3.50 to 7.87 g), while, the average weight of pod was recorded (5.58 g). The maximum pod weight was observed in genotype 2014/COPBVAR-1 (7.87 g) and it was minimum in genotype Lobia Banarsi (3.50 g). The average number of seeds pod⁻¹ was recorded (10.68) and it ranged between (8.47 to 12.67) seeds pod⁻¹. The maximum number of seeds pod⁻¹ was observed in genotype Swarna Harita (12.67), while it was minimum in genotype Lobia Banarsi (8.47). The highest pod yield plant⁻¹ was recorded in genotype 2014/COPBVAR-1 (210 g) where the genotypes Lobia Banarsi (83.33 g) was recorded the lowest yielder and average yield plant⁻¹ was

(139.86 g) and it ranged from (83.33 to 210.0 g). The maximum pod yield plot^{-1} was recorded in genotype 2014/COPBVAR-1 (8.35 kg) the genotypes Lobia Banarsi (3.27 kg) was low yielder and average yield plot^{-1} was (5.57 kg) and it ranged from (3.27 to 8.35 kg). The highest pod yield ha^{-1} was recorded in genotype 2014/COPBVAR-1 (115.94 q) the genotype Lobia Banarsi (45.34 q) was lowest. The average yield ha^{-1} was (77.38 q) and it ranged from (45.34 to 115.94 q).

The findings were quite similar to as reported by Kalaiyarasi et al. (2000) who observed variability for number of pods plant^{-1} , number of seeds pod^{-1} and plant height. Bezerra et al. (2001) found wide range of variability for days to first flowering, number of pods plant^{-1} , pod length and number of seeds pod^{-1} . Pathak and Jamwal (2002) reported variation for pod yield plant^{-1} , number of days to 50 per cent flowering and plant height. It was low for number of days to first picking, pod length and average pod weight. Narayanankutty et al. (2003) found variation for pod yield and pods plant^{-1} and weight of pod. Nigude et al. (2004) reported that variation was higher for plant height and number of pods plant^{-1} . Malarvizhi et al. (2005) studied variability for days to 50 per cent flowering, plant height and number of branches plant^{-1} . Girish et al. (2006) studied wide range of variability for number of pods plant^{-1} and plant height. Eswaran et al. (2007) *revealed that* high estimates of genetic variability were observed for plant height at the time of first flowering, plant height at the time of 50 per cent flowering and plant height at the time of 50 per cent maturity. Suganthi et al. (2008) reported that variation was higher for number of pods plant^{-1} and number of cluster plant^{-1} . Bertini et al. (2009) found that time to first flowering, number of pods plant^{-1} , total production ha^{-1} (q) and production plant^{-1} (g) in different cultivars showed high levels of genetic variability. Pandey and Singh (2011) reported that significant differences for days to first flowering, pod plant^{-1} , pod length and number of seeds pod^{-1} . Manggoel et al. (2012) observed significant variability for days to 50 per cent flowering, flowers plant^{-1} and pods plant^{-1} . Om Vir and Singh (2014) revealed high degree of genetic variability number of seeds pod^{-1} , number of pods plant^{-1} , number of pods cluster $^{-1}$, number of branches plant^{-1} , number of cluster plant^{-1} , plant height and number of days to 50 per cent

flowering. Ramesh et al. (2014) reported high variation number of clusters plant⁻¹ and pod length. It was low for traits days to flower initiation and days to 50 per cent flowering.

5.2.2 Coefficient of variation

The estimation of components of genetic parameters of variation for yield and its attributes exhibited a wide range of variation for the character studied. Results indicated that the value of phenotypic coefficient of variations were higher in magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters. The findings of Venkatesan et al. (2003), Vinieta et al. (2003), Prasad et al. (2004), Nigude et al. (2004) and Saini et al. (2005) were similar to that of the present findings.

6.2.2.1 Phenotypic coefficient of variations

The phenotypic coefficient of variation ranged from 5.71% for days to 50 per cent flowering to 64.81% for number of pods plant⁻¹. The phenotypic coefficient of variations was the highest for characters viz., number of pods plant⁻¹ (64.81%), number of cluster plant⁻¹ (34.17%), plant height 90 DAS (29.97%), pod weight (27.57%), number of pods cluster⁻¹ (22.47%), pod yield plot⁻¹ (22.41%), pod yield ha⁻¹ (22.41%), plant height at 60 DAS (22.21%), pod yield plant⁻¹ (21.77%), plant height at 30 DAS (20.71%) and width of pod (20.45%). The findings are in close harmony with the result of Nehru et al. (2001) for number of pods plant⁻¹, number of branches plant⁻¹ and pod yield plant⁻¹, Ramesh et al. (2002) and Narayanankutty et al. (2003) for number of pods plant⁻¹ and pod weight, Nigude et al. (2004) Prasanthi (2004) and Girish et al. (2006) for number of pods plant⁻¹ and plant height, Vinieta et al. (2003) and Suganthi et al. (2008) for number of pods plant⁻¹. However, it was exhibited in moderate for characters like number of seeds pod⁻¹ (14.62%), number of branches at 60 DAS (15.53%), number of flower cluster⁻¹ (16.03%), number of branches at 90 DAS (16.11%), number of branches at 30 DAS (17.64%) and pod weight (18.62%). Days to 50 per cent flowering (5.71%), days to first flowering (8.05%) and days to first picking (8.92%). Prasanthi (2004) and Manggoel et al. (2012) for number of seeds pod⁻¹ were similar to

the present finding. Rest of the characters such as exhibited low phenotypic coefficient of variation. Pathak and Jamwal (2002) for days to 50 per cent flowering.

6.2.2.2 Genotypic coefficient of variation

It is revealed from the data that genotypic coefficient of variation varied from 4.45% for days to 50 per cent flowering to 61.48% for number of pods plant⁻¹. High genotypic coefficient of variation was observed for number of pods plant⁻¹ (61.48%), number of cluster plant⁻¹ (34.10%), plant height 90 DAS (29.92%), pod weight (23.43%), number of pods cluster⁻¹ (21.84%), pod yield plot⁻¹ (20.45%), pod yield ha⁻¹ (20.45%), plant height at 60 DAS (22.02%), pod yield plant⁻¹ (20.72%), and plant height at 30 DAS (20.30%). The findings are in close harmony with the results of Narayanankutty et al. (2003) for number of pods plant⁻¹ and pod weight, Venkatesan et al. (2003) and Omoigui et al. (2006) for plant height, Nigude et al. (2004), Prasanthi (2004) and Omoigui et al. (2006) for plant height and number of pods plant⁻¹, Vinieta et al. (2003) for number of pods plant⁻¹. The high values of GCV suggested greater phenotypic genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. It was moderate for rest of the characters such as width of pod (18.88%), length of pod (18.33%), number of flower cluster⁻¹ (15.56%), number of branches at 90 DAS (13.64%) number of branches at 30 DAS (13.25%), number of seeds pod⁻¹ (13.05%) and number of branches at 60 DAS (12.27%). Days to 50 per cent flowering (4.45%), days to first flowering (6.37%) and days to first picking (8.92%), showed low genotypic coefficient of variation. The finding of Pathak and Jamwal (2002) for number of days to first picking and Manggoel et al. (2012) for number of seeds pod⁻¹ were similar to the present finding which indicated that there is limited scope for improvement.

5.2.3 Heritability

The heritability (BS) was computed for each of the characters by the variance components for estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors.

Results indicated that the heritability estimates were observed very high for plant height at 90 DAS (99.69%), number of cluster plant⁻¹ (99.61%), plant height at 60 DAS (98.29%), pod length (96.89%), plant height at 30 DAS (96.10%), number of pod cluster⁻¹ (94.48%), number of flower cluster⁻¹ (94.24%) and pod yield plant⁻¹ (90.36%) However, it was recorded to be high for number of pods plant⁻¹ (89.99%), width of pod (85.30%), pod yield plot⁻¹ (83.23%), pod yield ha⁻¹ (83.23%) and number of seeds pod⁻¹ (79.69%), days to first picking (78.65%), pod weight (72.22%) and number of branches at 90 DAS (71.74%). The results were in close proximate to that of Borah and Khan. (2000) and Pal et al. (2003) for plant height, Shinde (2000) for pod weight. Pathak and Jamwal (2002) for pod length and average pod weight, Venkatesan et al. (2003) for plant height and pod length. Nigude et al. (2004) plant height, branches plant⁻¹, pod length and seeds pod⁻¹, Suganthi et al. (2008) and Bertini et al. (2009) for number of seeds pod⁻¹ and pod length, Sharma et al. (2007) for number of pods plant⁻¹, Choudhary et al. (2010) for plant height, number of pods plant⁻¹ and green pod yield plant⁻¹, Singh et al. (2012) for pods plant⁻¹, plant height, pods plant⁻¹, branches plant⁻¹, and seeds pod⁻¹, yield plant⁻¹, Sapara et al. (2014) for green pod yield plant⁻¹ and plant height. Ramesh et al. (2014) for pod yield ha⁻¹. Om Vir and Singh (2014), Pandey et al. (2014) for number of seeds pod⁻¹ number of pod plant⁻¹, number of pods cluster⁻¹ and number of cluster plant⁻¹.

Moderate heritability were recorded for days to first flowering (62.54%), number of branches at 60 DAS (62.43%), days to 50% flowering (60.59%) and number of branches at 30 DAS (56.45%). The results were in closing proximate to that of Ramesh et al. (2002) for number of branches, Nigude et al. (2004) for days to 50 per cent flowering. Om Vir and Singh (2014) for days to 50 per cent flowering, Sapara et al. (2014), Pandey et al. (2014) pod for yield plant⁻¹ and plant height.

5.2.4 Genetic advance

Genetic advance as percentage of mean ranged between 7.13% for days to 50 per cent flowering and 120.13% for number of pods plant⁻¹. The highest estimate of genetic advance as percentage of mean was recorded for number of pods plant⁻¹ (120.13%) followed by number of cluster plant⁻¹

(70.12%), plant height at 90 DAS (61.54%), plant height at 60 DAS (44.96%), number of pod cluster⁻¹ (43.77%) and pod weight (41.01%), plant height at 30 DAS (41.0%), pod yield plant⁻¹ (40.64%) and pod yield plot⁻¹ (38.46%), pod yield ha⁻¹ (38.42%), length of pod (37.17%), width of pod (35.89%), number of flower cluster⁻¹ (31.09%), number of seed pod⁻¹ (23.99%), number of branches at 90 DAS (23.80%) and number of branches at 30 DAS (20.49%). The results were in consonance with Santosh et al. (2002) and Choudhary et al. (2010) for pod yield plant⁻¹, Shinde (2000), Pathak and Jamwal (2002) Lal et al. (2007) and Singh et al. (2012) for pod yield plant⁻¹, Nehru et al. (2001), Vinieta et al. (2003), Girish et al. (2006), Lal et al. (2007), Suganthi et al. (2008) and Choudhary et al. (2010) for number of pods plant⁻¹, Anbumalarmathi et al. (2005) and Singh et al. (2012) for number of pods plant⁻¹ and number of seeds pod⁻¹, Anbumalarmathi et al. (2005) for pod length, Nigude et al. (2004), Pandey et al. (2014) for all characters except number of seeds pod⁻¹.

Number of branches at 60 DAS (19.98%), days to first picking (14.45%), days to first flowering (10.37%), showed moderate value of genetic advance as percentage of mean. The findings were in agreement to the findings of Anbumalarmathi et al. (2005) and Singh et al. (2012) for plant height, number of branches plant⁻¹, Malarvizhi et al. (2005) for number of branches plant⁻¹.

Whereas, low estimates were observed for days to 50% flowering (7.13%). Similar results were reporting Pathak and Jamwal (2002) for days to 50 per cent flowering, Kharde et al. (2014), Om Vir and Singh (2014), Animasaun et al (2015) for 50 per cent flowering.

5.3 Correlation coefficient analysis

The variation in quantitative and quantitative traits provides the basic idea for selection of desirable traits to specific breeding programmers in distribute of yield and biotic a biotic stress. The strong knowledge of association among the characters is useful to breeder for improving the efficiency of selection. Correlation coefficient analysis measures the mutual relationship between plant characters and determines the component

character on which selection can be made for genetic improvement of yield. Investigation regarding the presence of component and nature of association among themselves is essential and pre-requisite for improvement in yield. Correlation coefficient provides a clear picture of the extent of association between a pair of traits and indicates whether simultaneous improvement of the correlated traits may be possible or not. The knowledge of genetic association between yield and its component characters help in improving the efficiency of selection for yield by making proper choice and balancing one component with another, Miller et al. (1958).

The magnitude of genotypic correlation was higher than the phenotypic correlation for all the traits that indicated inherent association between various characters. The findings were in agreement to Pathak and Jamwal (2002) and Venkatesan et al. (2003).

In the present findings significant positive phenotypic correlation of pod yield plant⁻¹ was observed with number of pods cluster⁻¹, pod weight and number of pods plant⁻¹, indicating that these characters are the primary yield determinant in cowpea. These findings corroborated the earlier findings of Pathak and Jamwal (2002), Kutty et al. (2003) and Lal et al. (2007) for pod weight and number of pods plant⁻¹, Venkatesan et al. (2003) for number of pods cluster⁻¹ and number of pod plant⁻¹, Singh et al. (2004), Anbumalarmathi et al. (2005) and Sharma et al. (2007), Pandey et al. (2014), Animasaun et al (2015) for number of pods plant⁻¹.

Days 50% flowering show significant and positive correlation with plant height at 90 DAS (0.408), While, Significant and negative association of this character was observed with length of pod (-0.559). These results are in close harmony with the findings of Pathak and Jamwal (2002) for pod length and pod weight, Alege and Singh (2007) and Nehru et al. (2009) for plant height. the Number of branches plant⁻¹ at 90 DAS expressed significant and negative correlation with length pod (-0.346), number of pod cluster⁻¹ (-0.389). These results are in close harmony with the findings of Venkatesan et al. (2003) and Alege (2007). Singh et al. (2004) for pod yield plant⁻¹. The Association of days to first flowering was recorded significant and positive with days to 50 per cent flowering (0.644), days to first picking (0.453), number of flower cluster⁻¹

(0.352). These results are in close harmony with the findings of Pathak and Jamwal (2002) and Correa et al. (2010). Days to 50 per cent flowering was recorded highly significant and positive with days to first picking (0.624). These results are in close harmony with the findings of Singh et al. (2004) for pod yield plant⁻¹. The correlation coefficient of number of flower cluster⁻¹ was found significant and positive correlation with number of pods cluster⁻¹ (0.781), number of pods plant⁻¹ (0.781), pod yield plant⁻¹ (0.774), number of flowers cluster⁻¹ (0.551), length of pod (0.378). While, significant and negative association was exhibited with days to first picking (-0.561). These results are in close harmony with the findings of Patil et al. (2005), Venkatesan et al. (2003) and Lal et al. (2007), Meena et al. (2015). The correlation coefficient of number of flower cluster plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.591), number of pods plant⁻¹ (0.522), and number of pods cluster⁻¹ (0.481). These results are in close harmony with the findings of Dahiya et al. (2007) Cholin et al. (2012) and Singh et al. (2011). Days to first picking was recorded highly significant and positive association with weight of pod (0.407), while, it was found significant and negative with number of pods plant⁻¹ (-0.510). These results are in close harmony with the findings of Pathak and Jamwal (2002) and Venkatesan et al. (2003) and Kuty et al. (2003), Kharde et al. (2014), Pandey et al. (2014), and Animasaun et al (2015).

The correlation coefficient of number of pods cluster⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.810), number of pods plant⁻¹ (0.513). These results are in close harmony with the findings of Venkatesan et al. (2003). The correlation coefficient of number of pods plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹ (0.677). These results are in close harmony with the findings of Dahiya et al. (2007), Cholin et al. (2012). Pod length was recorded highly significant and positive association with number of seed pod⁻¹ (0.407), pod yield plant⁻¹ (0.377) and weight of pod (0.369), while, it was found significant and negative with width of pod (-0.370). These results are in close harmony with the findings of Pathak and Jamwal (2002) for pod weight and Xiao-Jie (2004) for pod width. Pod width showed significant and positive correlation with pod weight (0.472). The correlation coefficient was found significant and positive correlation with

number of seeds pod⁻¹ (0.548) and pod yield plant⁻¹ (0.471). These results are in close harmony with the findings of Pathak and Jamwal (2002) for number of seeds pod⁻¹, Kutty et al. (2003) and Lal et al. (2007) for pod yield plant⁻¹. Dahiya et al. (2007). The correlation coefficient was found significant and positive correlation with number of seeds pod⁻¹ (0.548) and pod yield plant⁻¹ (0.471). These results are in close harmony with the findings of Pathak and Jamwal (2002) Alege et al. (2007), Sharma et al. (2007), Selvakumar et al. (2013), Kharde et al. (2014), Meena et al.(2015).

5.4 Path coefficient analysis

To measure the direct as well as indirect association of one variable through another on the end product, path coefficients were calculated at genotypic and phenotypic levels for all the yield attributing traits. The observed correlation coefficients of yield with its contributing traits were partitioned into direct and indirect effects. In the present investigation, important characters viz., pod yield plant⁻¹ has been used as dependable variables with other traits. Since the values of genotypic path are more reliable in predicting the correct idea about the direct and indirect effects of the component traits, only this has been discussed as below.

In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects. The results obtained from genotypic direct and indirect effects are presented as under.

Direct effect

Path coefficient analysis of different characters contributing towards pod yield plant⁻¹ showed that length of pod (27.40) had highest positive direct effect followed by width of pod (15.50), plant height at 90 DAS (14.52), no of pod cluster⁻¹ (11.99), number of branches at 90 DAS (4.04), days to first flowering (2.01). The results are in propinquity with Lal et al. (2007) for pod length, Sharma et al. (2007) for plant height, pods plant⁻¹ and pod length, Venkatesan et al. (2003) for number of pods plant⁻¹ and pod length, Nawab et al. (2008), Singh et al. (2011) and Anamika and Tajane (2014) for number of

pods plant⁻¹, Mittal and Singh (2005), Sapara et al. (2014), Animasaun et al (2015) for number of pods plant⁻¹ and pod length.

Whereas, no of cluster plant⁻¹ (-12.20) had the highest negative direct effect on pod yield plant⁻¹ followed by number of seed pod⁻¹ (-9.05), number of pod plant⁻¹ (-8.09), weight of pod (-8.08), days to first picking (-7.44), number of flower cluster⁻¹ (-5.73) and days to 50 per cent flowering (-4.65). The results corroborated the findings of Vinieta et al. (2003), Mittal and Singh (2005), Meena et al. (2015), for days to first flowering.

Indirect effect

Plant height at 90 DAS imparted highest positive indirect effect on pod yield plant⁻¹ through, width of pod (2.656), weight of pod (1.91), number of flower cluster⁻¹ (1.77), number of pod plant⁻¹ (1.38), number of seed pod⁻¹ (1.27), days to first flowering (0.63) and number of branches at 90 DAS (0.53). Whereas, negative indirect effect was visible to be highest via pod yield plant⁻¹ (-0.16), days to first picking (-1.94), number of pod cluster⁻¹ (-2.11), days to 50% flowering (-2.41), number of flower cluster plant⁻¹ (-2.47) and length of pod (-15.68). Number of branches plant⁻¹ at 90 DAS exhibited the highest positive indirect effect pod yield plant⁻¹ via number of seed pod⁻¹ (2.99), width of pod (2.26), weight of pod (2.088), days to 50% flowering (1.96), Plant height at 90 DAS (1.93) number of cluster plant⁻¹ (1.60), number of flowers cluster⁻¹ (0.53) and days to first picking (0.47). Whereas, it was expressed high negative indirect effect via pods yield plant⁻¹ (-0.24), number of pods plant⁻¹ (-0.51), days to first flowering (-0.77), number of pods cluster⁻¹ (-5.5), and length of pod (-11.31).

Days to first flowering was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, length of pod (5.43), plant height at 90 DAS (4.589), number of seeds pod⁻¹ (3.11), number of pods cluster⁻¹ (1.90), number of pods plant⁻¹ (1.39), number of flowers cluster⁻¹ (1.23) and pod yield plant⁻¹ (0.151). Whereas, it was expressed high negative indirect effect via weight of pod (-0.361), Number of branches plant⁻¹ at 90 DAS (-1.54) width of pod (-2.29), days to 50 per cent flowering (-3.49), number of cluster plant⁻¹ (-5.71) and days to first picking (-6.22). Days to 50 per cent flowering was

reported to have the highest positive indirect effect on Plant height at 90 DAS (7.50) pod yield plant⁻¹ through, number of flowers cluster⁻¹ (2.06), followed by number of seeds pod⁻¹ (2.0), number of pods plant⁻¹ (1.70), days to first flowering (1.51) width of pod (1.25), number of pods cluster⁻¹ (0.551) and pod yield plant⁻¹ (0.105). Whereas, it was expressed high negative indirect effect on pod yield plant⁻¹ via pod weight (-0.574), Number of branches plant⁻¹ at 90 DAS (-1.70) number of cluster plant⁻¹ (-4.26), and days to first flowering (-5.84). Number of flower cluster⁻¹ was reported to have the highest positive indirect effect on pod yield plant⁻¹ through, length of pod (10.65), number of pods cluster⁻¹ (9.82), days to first picking (5.05), days to 50% flowering (1.68), pod weight (0.977) and pod yield plant⁻¹ (0.832). Whereas, it was expressed high negative indirect effect via number of branches at 90 DAS (-0.376), days to first flowering (-0.433) number of seeds pod⁻¹ (-0.607), width of pod (-2.80), plant height at 90DAS (-4.48) number of cluster plant⁻¹ (-6.87) and number pods plant⁻¹ (-6.73). Number of flower cluster plant⁻¹ was reported to have highest positive indirect effect on pod yield plant⁻¹ through, length of pod (7.169), number of pods cluster⁻¹ (5.97), plant height at 90 days (2.94), number of seeds pod⁻¹ (2.42) weight of pod (1.52) days to first picking (1.08), days to first flowering (0.94) and pod yield plant⁻¹ (0.617). Whereas, it was expressed high negative indirect effect through width of pod (-0.421), number of branches at 90 DAS (-0.530), days to 50% flowering (-1.63), number of flowers cluster⁻¹ (-3.22) and number of pods plant⁻¹ (-4.40).

Days to first picking expressed the highest positive indirect effect through, number of pods plant⁻¹ (5.47), number of flowers cluster⁻¹ (3.89), plant height at 90 days (3.79) length of pod (2.81), number of cluster plant⁻¹ (1.78), days to first flowering (1.68), width of pod (0.41). Its indirect negative effect was high via pod yield plant⁻¹ (-0.24), number of branches at 90 DAS (-0.25), days to 50% flowering (-3.65), number of seeds pod⁻¹ (-0.41), weight of pod (-3.88) and number of pods cluster⁻¹ (-4.51).

The Highest positive indirect effect of number of pods cluster⁻¹ on pod yield plant⁻¹ was recorded through, length of pod (8.43), days to first picking (2.80), pod yield plant⁻¹ (0.87), days to first flowering (0.32) and weight of pod (0.064). It's negative indirect effect was high via days to 50% flowering

(-0.21), number of seeds pod⁻¹ (-0.59), number of branches at 90 DAS (-1.85), plant height at 90 DAS (-2.55) width of pod (-3.36), number of pods plant⁻¹ (-4.51), number of flowers cluster⁻¹ (-4.69), number cluster plant⁻¹ (-6.07). Highest positive indirect effect of number of pods plant⁻¹ on pod yield plant⁻¹ was recorded through number of pods cluster⁻¹ (6.69) days to first flowering (5.03), length of pod (3.36), weight of pod (2.92), width of pod (2.56), days to 50% flowering (0.97), number of seeds pod⁻¹ (0.74), pod yield plant⁻¹ (0.72) and number of branches at 90 DAS (0.259). While, the remaining characters showed high negative indirect effect i.e. days to first flowering (-0.34), plant height at 90 DAS (-2.48), number of flowers cluster⁻¹ (-4.76), number of flowers cluster plant⁻¹ (-6.63).

Pod length revealed high values of positive indirect on pod yield plant⁻¹ through number of pod per cluster (3.69) ,pod yield plant⁻¹ (0.38) and days to first flowering (0.33). While, the remaining characters showed high negative indirect effect i.e. days to 50% flowering (-0.005), days to first picking (-0.76), number of pods plant⁻¹ (-0.99), number of branches at 90 DAS (-1.67), number of flower cluster⁻¹ (-2.23), number of cluster plant⁻¹ (-3.19), weight of pod (-3.45), number of pods cluster⁻¹ (-3.69), number of seeds pod⁻¹ (-4.09), width of pod (-6.33) and plant height at 90 DAS (-8.30) Pod width revealed high values of positive indirect on pod yield plant⁻¹ through plant height at 90 DAS (2.48), number of flowers cluster⁻¹ (1.03), number of branches at 90 DAS (0.59), number of cluster plant⁻¹ (0.32), and pod yield plant⁻¹ (0.10). Indirect effect i.e. days to first picking (-0.20), days to first flowering (-0.29), days to 50% flowering (-0.37), number of seeds pod⁻¹ (-1.20), number of pods plant⁻¹ (-1.34), number of pods cluster⁻¹ (-2.60), and weight of pod (-2.67).

The Highest positive indirect effect of pod weight on pod yield plant⁻¹ was recorded through length of pod (11.70), width of pod (5.13), number of pods plant⁻¹ (2.92), number of cluster plant⁻¹ (2.29), number of flowers cluster⁻¹ (0.69), pod yield plant⁻¹ (0.15), and days to first flowering (0.091). It showed negative indirect effect through number of pods cluster⁻¹ (-0.096), days to 50% flowering (-0.331), number of branches at 90 DAS (-1.04), plant height at 90 DAS (-3.44), days to first picking (-3.57) and number of seeds pod⁻¹ (-6.13).

Number of seeds pod⁻¹ manifested positive indirect effect through length of pod (12.38), number of cluster plant⁻¹ (3.27), width of pod (2.04), days to 50% flowering (1.02), number of pods cluster⁻¹ (0.78), number of pods plant⁻¹ (0.67) and pod yield plant⁻¹ (0.258). The negative indirect effect through days to first picking (-0.034), number of flowers cluster⁻¹ (-0.38), days to first flowering (-0.69), number of branches at 90 DAS (-1.33), plant height at 90 DAS (-2.033) and weight of pod (-5.473). The present findings are in propinquity with Animasaun et al (2015), Meena et al.(2015), Pandey and Singh (2015) who studied that the various components pods per plant and seeds per pods are important factor contributing to yield.

5.5 Qualitative parameters

Qualitative characters like colour of flowers, shape of pods, colour of pods, seed colour, stringiness in pods and fleshy or non fleshy pods are discussed here, the colour of flower was observed to be white, purple, light purple. Genotypes Arka Garima exhibited purple colour flower. White colour flowers were observed in genotype 2014/COPBVAR-1, 2014/COPBVAR-4, Gomti, Lobia Banarsi and Swarna Harita. Whereas, genotypes 2014/COPBVAR-2, 2014/COPBVAR-5, 2014/COPBVAR-6, Kashi Kanchan, kohinoor and Shalini exhibited light purple flowers. The results corroborated the findings of Kehind (2001). Colour of pods was observed to be dark green, green and light green. Genotypes 2014/COPBVAR-6 and Kohinoor exhibited dark green pods. Whereas, genotypes 2014/COPBVAR-2, 2014/COPBVAR-4, Kashi Kanchan, Gomti, and Swarna Harita were observed green pods. Whereas, genotypes 2014/COPBVAR-1, 2014/COPBVAR-5, Arka Garima, Lobia Banarsi, and Shalini exhibited light green pods. The wide variation was observed among the genotypes for shape of pods i.e. straight, slightly curved and curved (Table 4.7). Shape of pods was observed to be straight in genotypes 2014/COPBVAR-1, 2014/COPBVAR-2, Arka Garima, and Shalini. Genotypes 2014/COPBVAR-6, Gomti and Swarna Harita were produced curved pod. Whereas, genotypes 2014/COPBVAR-4, 2014/COPBVAR-5, Kashi Kanchan, Lobia Banarsi, and Kohinoor produced slightly curved pods. The variation was observed among the genotypes for stringiness in pods i.e. fiber present or absent (Table 4.7). Fiber was present in genotypes 2014/COPBVAR-5, 2014/COPBVAR-6, Arka

Garima and Shalini. Fiber was absent in remaining genotypes. The wide variation was observed among the genotypes for fleshy or non fleshy pods. Non fleshy pods were observed in genotypes 2012/COPBVAR-6, and Shalini. Whereas, genotypes 2014/COPBVAR -4, Kashi Kanchan produced and Swarna Harita less fleshy pods. The remaining genotypes produced fleshy pods. Color of seeds was observed to be cream, dark maroon, maroon and light maroon. Genotypes 2014/COPBVAR-1, Lobia Banarsi and Swarna Harita exhibited light maroon seeds. Whereas, genotypes, 2011/COPBVAR-6 was observed maroon seeds. Genotype Kashi Kanchan were observed dark maroon colour. Genotype 2014/COPBVAR-6 observed black colour. Remaining genotypes exhibited creamish seeds.

5.6 Incidence of pest and diseases

The result of percentage of disease incidence and insect pest has been depicted in the Table 4.8. The results are based on the total score of disease and insect pest in a given genotype.

5.6.1 Incidence of pod borer (%)

Pod borer incidence was observed the maximum in genotypes 2014/COPBVAR-5 (8.32) followed by 2014/COPBVAR-4 (7.63) and 2014/COPBVAR-1 (6.24) these lines was found susceptible to pod borer. The low incidence of pod borer was found in genotypes Kohinoor (2.08) and Kashi kanchan (3.47). The results corroborated the findings of Shukla et al. (2009) and Cheema et al. (2011).

5.6.2 Incidence of Alternaria blight (%)

The incidence of Alternaria blight was observed the maximum in genotypes Lobia Banarsi (31.20%), 2014/COPBVAR-4 (4.85%) and Kashi kanchan (4.85%). Whereas, genotypes 2014/COPBVAR-2(2.08%), 2014/COPBVAR-6 (2.08%) and 2014/COPBVAR-1(2.77%) were slightly tolerant to the same. The results corroborated the findings of Berg et al. (2003).

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The present investigation entitled “**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**” was conducted at Horticulture Complex, Maharajpur JNKVV, Jabalpur (M.P.) during the year 2015-16. The experimental material consisting of twelve genotypes of Cowpea were sown on plot size of 3.0 m × 2.4 m in a Randomized Complete Block Design with three replications to estimate the genetic variability and association analysis. The row and plant spacing was maintained 60 × 25 cm respectively and each plot accommodated 48 plants. The experimental data was subjected to appropriate statistical analysis for elucidating the information on genetic variation existing for different components of growth and yield. The genetic variability was assessed using the parameters like genotypic and phenotypic variance. Genotypic coefficient variation and phenotypic coefficient of variation, heritability and genetic advance at per cent of mean, correlation and path coefficient analysis. The variance components and coefficient of variation were determined according to Burton (1952). The heritability (BS) and genetic advance was calculated using formula proposed by Hanson et al. (1956) and Johnson et al. (1955). The correlation coefficient and path coefficient was computed by the formula suggested by Miller et al. (1958) and Dewey and Lu (1958). On the basis of results, the present investigation is summarized as follows.

Analysis of variance revealed highly significant difference among the genotypes for all the characters studied.

The mean performance of the genotypes were highly significant for all the characters studied, indicating that the presence of sufficient amount genetic diversity in the existing material. The variation was the maximum for plant height at 90 days after sowing followed by pod yield plant⁻¹, pod yield ha⁻¹, number of pods plant⁻¹ and plant height at 60 DAS.

The phenotypic coefficient of variations were higher in magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters. The phenotypic coefficient of variation ranged from for days to 50 per cent flowering to for number of pods plant⁻¹. The phenotypic coefficient of variation was highest for characters viz., number of pods plant⁻¹, number of cluster plant⁻¹, plant height 90 DAS, pod weight, number of pods cluster⁻¹, pod yield plot⁻¹, pod yield ha⁻¹, plant height at 60 DAS , pod yield plant⁻¹, plant height at 30 DAS and width of pod . The high value of GCV suggests greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. However, it was exhibited in moderate for characters like number of seeds pod⁻¹, number of branches at 60 DAS, number of flower cluster⁻¹, number of branches at 90 DAS, number of branches at 30 DAS and pod weight. Days to 50 per cent flowering, days to first flowering and days to first picking, Rest of the characters such as exhibited low phenotypic coefficient of variation indicating their limited scope for improvement.

The heritability was computed for each of the characters by the variance components for estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors. The heritability estimates were observed very high for plant height at 90 DAS , number of cluster plant⁻¹, plant height at 60 DAS , pod length , plant height at 30 DAS , number of pod cluster⁻¹, number of flower cluster⁻¹ and pod yield plant⁻¹ However, it was recorded to be high for number of pods plant⁻¹, width of pod , pod yield plot⁻¹, pod yield ha⁻¹ and number of seeds pod⁻¹, days to first picking , pod weight and number of branches at 90 DAS. The Moderate heritability was recorded for days to first flowering , number of branches at 60 DAS, days to 50% flowering and number of branches at 30 DAS.

Due to masking influence of environment upon characters concerned, values of genetic advance exhibited high fluctuations. Therefore, to attain relative comparison of the characters in relation to environment genetic advance as percentage of mean was calculated to predict the genetic gain. Genetic advance as percentage of mean ranged between for days to 50 per

cent flowering and for number of pods plant⁻¹. The highest estimate of genetic advance as percentage of mean was recorded for number of pods plant⁻¹ followed by number of cluster plant⁻¹, plant height at 90 DAS, plant height at 60 DAS, number of pod cluster⁻¹ and pod weight, plant height at 30 DAS, pod yield plant⁻¹ and pod yield plot⁻¹, pod yield ha⁻¹, length of pod, width of pod, number of flower cluster⁻¹, number of seed pod⁻¹, number of branches at 90 DAS and number of branches at 30 DAS. Number of branches at 60 DAS, days to first picking, days to first flowering, showed moderate value of genetic advance as percentage of mean. Whereas, low estimates were observed for days to 50% flowering.

The magnitude of genotypic correlation was higher than the phenotypic correlation for all the traits that indicated inherent association between various characters. Days 50% flowering significant and positive correlation with plant height at 90 DAS, Significant and negative association of this character was observed with length of pod. Number of branches plant⁻¹ at 90 DAS expressed significant and negative correlation with length pod, number of pod cluster⁻¹. Association of days to first flowering was recorded significant and positive with days to 50 per cent flowering, days to first picking, number of flower cluster⁻¹. Days to 50 per cent flowering was recorded highly significant and positive with days to first picking. The correlation coefficient of number of flower cluster⁻¹ was found significant and positive correlation with number of pods cluster⁻¹, number of pods plant⁻¹, pod yield plant⁻¹, number of flowers cluster⁻¹, length of pod Also significant and negative association was exhibited with days to first picking. The correlation coefficient of number of flower cluster plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹, number of pods plant⁻¹, and number of pods cluster⁻¹ Days to first picking was recorded highly significant and positive association with weight of pod, while, it was found significant and negative with number of pods plant⁻¹. The correlation coefficient of number of pods cluster⁻¹ was found significant and positive correlation with pod yield plant⁻¹, number of pods plant⁻¹. The correlation coefficient of number of pods plant⁻¹ was found significant and positive correlation with pod yield plant⁻¹. Pod length was recorded highly significant and positive association with number of seed pod⁻¹, pod yield plant⁻¹ and

weight of pod, while, it was found significant and negative with width of pod. The correlation coefficient was found significant and positive correlation with number of seeds pod⁻¹ and pod yield plant⁻¹.

In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects. Path coefficient analysis of different characters contributing towards pod yield plant⁻¹ showed that length of pod had highest positive direct effect followed by width of pod, plant height at 90 DAS, number of pod cluster⁻¹, number of branches at 90 DAS, days to first flowering. Whereas, number of cluster plant⁻¹ had the highest negative direct effect on pod yield plant⁻¹ followed by number of seed pod⁻¹, number of pod plant⁻¹, weight of pod, days to first picking, number of flower cluster⁻¹ and days to 50 per cent flowering.

The low incidence of pod borer was found in genotypes Kohinoor and Kashi Kanchan. The incidence of Alternaria blight was observed the minimum in genotypes 2014/COPBVAR-2, 2014/COPBVAR-6 and 2014/COPBVAR-1 were slightly tolerant to the same.

Considerable variability was observed among the genotypes for colour of flower, shape of pod, colour of pod, seed colour, stringiness in pod and fleshly or non fleshly pods, pod colour, pod shape, stringiness in pods and fleshly or non fleshly pods are the most important characteristics of cowpea to help customers in choosing cultivars on the market. Light green and fleshy pods are the first choice of consumers.

6.2 Conclusion

Analysis of variance revealed highly significant difference among the genotypes for all the characters studied. The wide range of variability for all the traits. The variation was maximum for plant height at 90 days after sowing followed by pod yield plant⁻¹, pod yield ha⁻¹, number of pods plant⁻¹ and plant height at 60 DAS. The PCV was the higher than GCV for all the traits. Under study The PCV was highest for characters viz., number of pods plant⁻¹, number of cluster plant⁻¹, plant height 90 DAS, pod weight, number of pods cluster⁻¹, pod yield plot⁻¹, pod yield ha⁻¹, plant height at 60 DAS, pod yield

plant⁻¹, plant height at 30 DAS and width of pod. The highest estimate of GA as percentage of mean was recorded for number of pods plant⁻¹ followed by number of cluster plant⁻¹, plant height at 90 DAS, plant height at 60 DAS, number of pod cluster⁻¹, and pod weight, plant height at 30 DAS, pod yield plant⁻¹ and pod yield plot⁻¹, pod yield ha⁻¹, length of pod, width of pod, number of flower cluster⁻¹, number of seed pod⁻¹, number of branches at 90 DAS and number of branches at 30 DAS. The correlation coefficient of number of pods cluster⁻¹ was found significant and positive correlation with pod yield plant⁻¹ and number of pods plant⁻¹, number of pods plant⁻¹ with pod yield plant⁻¹, pod length with number of seed pod⁻¹, pod yield plant⁻¹ and weigh of pod, while, it was found significant and negative with width of pod. Path coefficient analysis of different characters contributing towards pod yield plant⁻¹ showed that length of pod had the highest positive direct effect followed by width of pod, plant height at 90 DAS, number of pod cluster⁻¹, number of branches at 90 DAS, days to first flowering. The low incidence of pod borer was found in genotypes Kohinoor and Kashi Kanchan. The incidence of Alternaria blight was observed the minimum in genotypes 2014/COPBVAR-2, 2014/COPBVAR-6 and 2014/COPBVAR-1 were slightly tolerant to the same.

6.3 Suggestions for further work

- 1) Identify promising genotypes for yield over location and year. So that they can be recommended for commercial cultivation.
- 2) Identify most potential genotypes can be subjected to varying levels of intensive management situations to assess maximization of yield levels to be achieved in case of these superior genotypes.
- 3) Traits identified for high heritability coupled with high or moderate genetic gain may be considered well in selection for improvement of the crop.
- 4) The characters having desirable association and direct effects with pod yield should be given due consideration for genetic improvement in cowpea.
- 5) The genotypes of cowpea may be screened against disease and insect pest for locating tolerant genotypes under field condition.

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Appendices

Annexure: Analysis of variance for different characters in cowpea (mean sum of squares)

Source of variance	D.F.	Plant height (cm)			No. of primary branches per plant		
		30DAS	60 DAS	90DAS	30DAS	60 DAS	90DAS
Replications	2	0.580	0.854	0.153	5.124	213.381	427.325
Genotypes	11	266.449**	794.172**	4615.968**	0.934**	28.774**	73.317**
Error	22	3.554	4.571	4.829	0.191	4.807	8.511

Source of variance	D.F.	Days to first flowering	Days to 50% flowering	Number of flowers/ cluster	Number of cluster/ plant	Days to first picking
Replications	2	78.111	67.861	0.063	1.407	17.333
Genotypes	11	22.148**	19.118**	1.107**	149.111**	74.878**
Error	22	3.686	3.406	0.022	0.192	6.212

Source of variance	D.F.	Number of pods/cluster	Number of pods/plant	Length of pod (cm)	Width of pod (cm)	Weight of pod (g)
Replications	2	0.004	113.812	1.559	0.018	8.841
Genotypes	11	1.121**	742.437**	74.728**	0.065**	5.782**
Error	22	0.021	26.531	0.790	0.003	0.657

Source of variance	D.F.	Number of seeds/pod	Pod yield /plant (g)	Pod yield /plot (kg)	Pod yield/ha (q)
Replications	2	1.358	369.444	1.359	261.948
Genotypes	11	6.317**	2606.755**	4.159**	801.297**
Error	22	0.494	86.868	0.261	50.441

Source of Variance	D.F.	Per cent incidence of pod borer	Per cent incidence of Alternaria blight
Replications	2	8.772	9.494
Genotypes	11	9.002	195.168**
Error	22	4.315	11.329

CURRICULUM VITAE

The author of this thesis **Shivraj Singh Rajput** S/O Shri Prem Singh Rajput was born on 3rd April, 1990 at Bhopal (M.P.). He passed the High School Examination in the year 2006 with 54.0% marks from S.V.M. Vidhiya Vihar Narela, Berasia Bhopal (M.P.) and Intermediate Public Examination in the year 2008 acquiring 71.33% marks from Govt. B. H. Sec. School Berasia, Bhopal (M.P.).



He joined the Jawaharlal Nahru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) in the year 2010 and successfully completed the degree of B.Sc. (Ag) from Jawaharlal Nahru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during the year June, 2014 with First Division (6.98) OGPA out of 10.00 point scale).

After graduation, he was selected for M.Sc. (Agri.) Horticulture degree programme in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, in 2014 for specialization in Vegetable Science. He successfully completed all the course requirements for master's degree with first division securing an OGPA of 7.59 out of 10 point scale.

For the fulfillment of the master's degree programme he was allotted a research problem on "**Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea**" This is duly completed by him and presented in the form of this thesis.

Part I of Abstract

- 1 Title of the thesis : **“Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea (*Vigna unguiculata* L.)”**
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- 6 Major subject : Horticulture (Vegetable Science)
- 7 Total number of pages in the thesis : 87
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ABSTRACT

The present investigation entitled **“Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea”** was conducted at Horticulture Complex, JNKVV, Jabalpur (M.P.) during the year 2015-16. The experimental material consisting of twelve genotypes of Cowpea were sown on plot size of 3.0 m × 2.4 m in a Randomized Complete Block Design with three replications to estimate the genetic variability and association analysis (Correlation and path coefficient). The row and plant spacing was maintained at 60 cm and 25 cm respectively and each plot accommodated 48 plants. The main objectives were in investigation first one to estimate the genetic variability, heritability and genetic advance of yield and its characters. Second to study the correlation between yield and its attributing parameters. Third to estimate the direct and indirect effect of yield contributing characters on pod yield of cowpea and fourth was to identify the suitable and better performing genotype for central place of India.

Analysis of variance revealed highly significant difference among the genotypes for all the characters studied. The variation was maximum for pod yield ha⁻¹ followed by number of pods plant⁻¹, number of flower cluster plant⁻¹, pod weight, pod length, plant height at 90 DAS and days to first picking. The present study revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits. High phenotypic and genotypic coefficient of variation was recorded for number of flower cluster plant⁻¹ followed by number of pod plant⁻¹, number of pods cluster⁻¹, number of branches at 30 DAS, pod weight, pod length and pod width. However, days to 50 per cent flowering, days to first picking, days to first flowering, plant height at 60 DAS, plant height at 30 DAS, number of branches at 90 DAS and plant height at 90 DAS were exhibited low estimates of phenotypic and genotypic coefficient of variation indicating limited scope of there character for improvement. The heritability estimate were observed very high for pod length followed by number of pods plant⁻¹, pod weight, number of flower cluster plant⁻¹ and pod width⁻¹. However, It was high for plant height at 90 DAS, number of flower cluster⁻¹, number of pods cluster⁻¹, days to first

picking and number of seeds pod⁻¹. It was moderate for pod yield plot⁻¹, pod yield ha⁻¹, pod yield plant⁻¹, number of branches at 60 DAS, days to 50 per cent flowering, number of branches at 90 DAS, plant height at 60 DAS, plant height at 30 DAS and days to first flowering. The highest estimate of genetic advance was recorded for number of flower cluster plant⁻¹, number of pods plant⁻¹, pod length, number of pods cluster⁻¹, pod weight pod width, number of flower cluster⁻¹, number of branches at 30 DAS, pod yield plot⁻¹, pod yield ha⁻¹ and pod yield plant⁻¹. Number of seeds pod⁻¹, number of branches at 60 DAS, plant height at 90 DAS and number of branches at 90 DAS showed moderate value of genetic advance as percentage of mean. Association analysis revealed that the magnitude of genotypic correlation was higher than phenotypic correlation for all the traits that indicated inherent association between various characters. High significant and positive correlation of pod yield plant⁻¹ were observed with number of pod plant⁻¹ followed by days to 50 per cent flowering, number of flower cluster plant⁻¹ and number of seeds pod⁻¹. Path coefficient analysis of the different characters revealed that number of pods plant⁻¹ had the highest positive direct effect on pod yield plant⁻¹ followed by pod weight, number of flower cluster⁻¹, pod width, number of branches at 90 DAS, number of flower cluster plant⁻¹, days to first picking, plant height at 90 DAS and pod length. Whereas, days to first flowering had the highest negative direct effect on pod yield plant⁻¹ followed by days to 50 per cent first flowering, number of seeds pod⁻¹ and pods cluster⁻¹. Other characters like number of branches plant⁻¹ did not exhibit, higher direct effect on pod yield, they expressed higher indirect effect on it through pod weight, plant height and pod width and hence, simultaneous selection for these characters can be made for the improvement of yield. The low incidence of pod borer was found in genotypes Kashi Kanchan and 2011/COPBVAR-7 whereas, Pod borer incidence was observed maximum in genotypes 2014/COPBVAR-4, 2014/COPBVAR-3, 2014/COPBVAR-5 and Gomti. The incidence of Alternaria blight was observed maximum in genotypes 2012/COPBVAR-1, 2014/COPBVAR-1 and 2011/COPBVAR-7. Whereas, genotypes 2014/COPBVAR-6, 2014/COPBVAR-2 and 2014/COPBVAR-5 were slightly tolerant to the same. The highest was production observed in genotype 2012/COPBVAR-6 (134.38 q ha⁻¹) and 2014/COPBVAR (130.93 q ha⁻¹).