Genetic Variability, Correlation and Path Coefficient Analysis for Yield and Its Attributing Traits in Cowpea (*Vigna unguiculata* L.)

THESIS

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HORTICULTURE (VEGETABLE SCIENCE)

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2015

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 (Vigna unguiculata* **(L.)** *Walp.)"* *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* ***Ramnarayan khandait*** *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 (Vigna unguiculata** **(L.)** **Walp.)"** submitted by Mr. Ramnarayan khandait 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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DECLARATION AND UNDERTAKING BY THE CANDIDATE

I, Ramnarayan Khandait S/o Shri Gurudas Khandait Certify the work embodied in thesis entitled " Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea (*Vigna unguiculata* (L.) Walp.)" 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 2014-2015.

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Place : Jabalpur

Date : **(Ramnarayan Khandait)**

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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.	Et al (And other or co-worker)
M	Meter
Fig.	Figure
GA	Genetic Advance
GCV	Genotypic coefficient of variation
G	Gram
Ha	Hectare
Kg	Kilogram
Max.	Maximum
Min.	Minimum
M.S.S.	Mean Sum of Squares
No.	Number
PCV	Phenotypic coefficient of variation
SEm±	Standard error mean
%	Percentage

INTRODUCTION

Cowpea [*Vigna unguiculata* (L) Walp.], a legume, is one of the most ancient crops known to man. It belongs to the family Papilionaceae and sub family Fabaceae. Its primary center of origin is Africa. It is widely adopted and grown all over the world.

India is next only to the China in area and production of vegetables. Immature cowpea green pods are commonly referred to as southern pea, black eye pea, crowder pea, lobia, niebe, caupi or frijole. The name "cowpea" probably derives from when, it was an important livestock feed for cows in the United States. Among the different pulses grown in the world, this crop can be grown in kharif and summer season in North India, while, in South India it is grown throughout the year. Cowpea is grown in small scale throughout the country for long green pods as a vegetable, seeds as pulses and foliage as fodder for milch animal. In India, the cowpea is grown in an area of about 3.9 million ha with a production of 2.2 million tonnes having a productivity of 564 kg seed ha^{-1} (Shivnandam 2005). In Madhya Pradesh it's covering area and production is very minor.

Cowpea is required for growth and maintenance of body, green pod of cowpea contains 85 g moisture, 3 g protein, 1 g minerals, 2.0 g fiber, 8.0 g carbohydrates, 72 mg calcium, 59 mg phosphorus, 2 mg iron, 0.09 mg riboflavin and 0.07 mg thiamin per 100 g of edible portion (Ananomus, 2011). Cowpea plant is herbaceous, warm season, annual requiring temperature of at least 18^{o}c thought all stage of development and having an optimal growing temperature about 28^{0}c.

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 germaplasm for studying genetic variability of economically important traits is one of the basic steps for initiating breeding programmed for genetic improvement of cowpea.

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 characters.
2) To study the correlation between yield and its attributing parameters.
3) To estimate the direct and indirect effect of yield contributing characters on pod yield of cowpea.
4) To identify the suitable and better performing genotype for central place 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 [*Vigna unguiculata* (L.) Walp]”. 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 pest-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 reproduct and qualitative characteristics has been reported in cowpea by many workers.

Kalaiyarasi *et al.* (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) an experiment was studied 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 *et al.* (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 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 *et al.* (2005) studied variability, heritability and genetic advance in 60 genotypes of cowpea [*Vigna unguiculata* (L.)]. 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 *et al.* (2008) reported that genotypic coefficient of variation was higher than the phenotypic coefficient of 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}.

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.

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 *et al.* (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 *et al.* (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 [*Vigna unguiculata* (L.) Walp]. 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 *et al. (*2008) recorded high heritability for seed yield plant^{-1} followed by number of seeds pod^{-1}, p0od 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.

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 Palanismy (2001) 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) reported 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 vegetables 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.

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}, 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.

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.

Sapara *et al.* (2014) founded 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.

2.5 SEASONAL INCIDENSE 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 (*Vigna unguiculata*).

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 *Maruca vitrata.* 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 [*Vigna unguiculata* (L.)]" which was carried out during the year 2014-15

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 2014-15.

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

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Table 3.1 "Weather Parameter 2014 During crop period From 29 SW – 46 SW"												
		Tem.		RH (%)		Wind Velocity (Km/hrs.)	Sunshine (Per hrs.)	Rainfall (mm)	No. of rainy days	Vapour Pressure (mm)		Evaporation (mm)
		Maximum	Minimum	Mornning	Evening					Mornning	Evening	
16-22 July	SW 29	29.7	24.5	90	79	5.8	3.2	160.4	6	22.3	22.4	3.3
23-29 July	SW 30	27.8	23.3	91	79	5.5	3.4	55.8	3	21	21.3	2.9
30-5 Aug.	SW 31	31.1	24.6	92	79	5.4	2.3	137.3	5	23	22.1	3.4
6-12 Aug.	SW 32	28.5	23.7	86	73	7.9	4.9	97.8	5	21	21.5	3.7
13-19 Aug.	SW 33	30	24	86	63	6.1	5	80.2	2	22.3	19.6	3
20-26 Aug.	SW 34	34.1	25.1	83	58	3.1	6.7	0	0	22	22.2	4.4
27-2 Sep.	SW 35	32.9	24.2	88	65	4.1	7.8	47.6	2	22	21.8	4.3
3-9 Sep.	SW 36	30.1	23.7	91	71	4.1	2.4	100.2	7	22	22.4	2
10-16 Sep.	SW 37	30.2	23.4	91	72	4.8	3.8	50.4	6	21.1	22.5	2.6
17-23 Sep.	SW 38	32.3	23.5	89	55	4.2	8.5	11.8	1	21	19.9	3.6
24-30 Sep.	SW 39	33.4	21.6	85	41	2.5	10	0	0	19	15.8	3.9
1-7 Oct.	SW 40	33.3	21	86	53	2.3	9.4	5	1	19	17.6	4.1
8-14 Oct.	SW 41	31.1	20.4	88	55	4.7	8.4	36.6	2	18.1	16.8	3.2
15-21 Oct.	SW 42	31.2	18.8	91	44	2.3	7.9	0	0	16.1	15.3	2.3
22-28 Oct.	SW 43	29.5	16.6	89	41	1.7	8.8	0	0	14.5	12.1	2.6
29-4 Nov.	SW 44	30.8	14.4	87	29	1.6	8.6	0	0	14.5	13.2	2.5
5-11 Nov.	SW 45	31	13.9	87	29	2.6	8.2	0	0	13.2	11.1	2.5
12-18Nov	SW 46	30.4	14.4	83	26	2.5	6	0	0	12.4	11.7	2.4

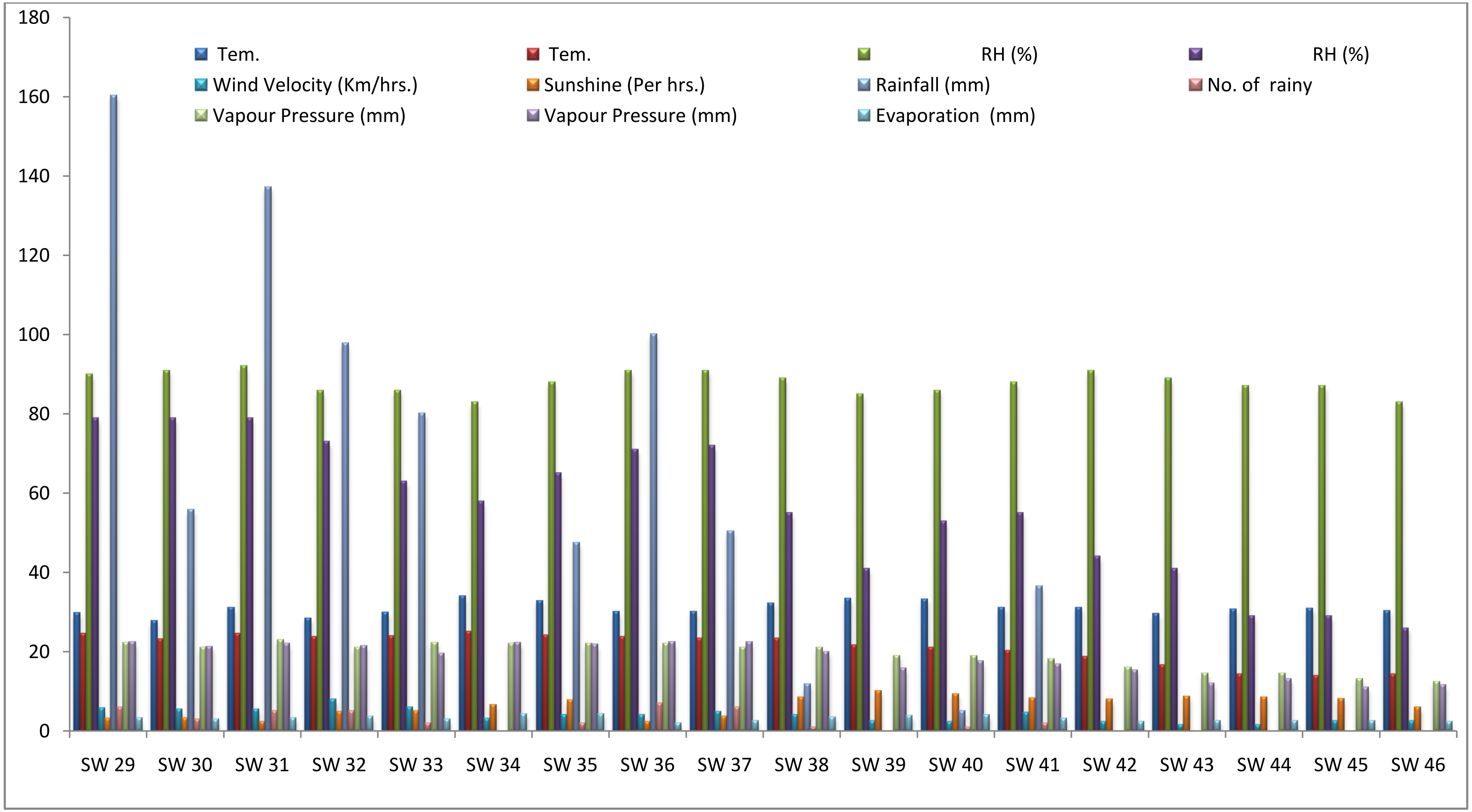


Fig . 1 Metrological information (week wise) during entire crop season of the year 2014-2015

Experimental material

The experimental material for this study comprised of 15 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

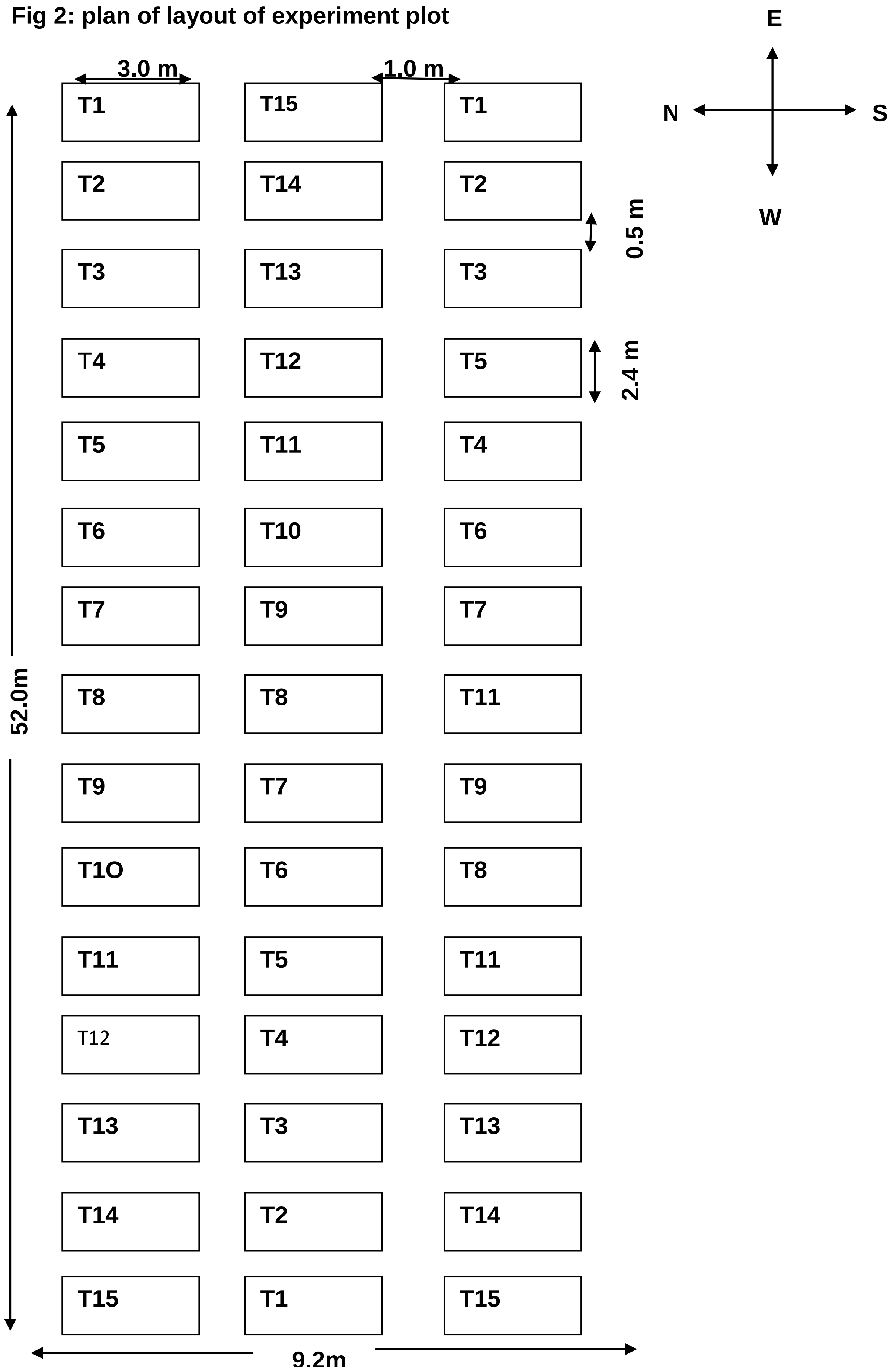
S.No.	Genotypes	Source
1	2011/COPBVAR-7	IIVR Varanasi
2	2012/COPBVAR-1	IIVR Varanasi
3	2012/COPBVAR-2	IIVR Varanasi
4	2012/COPBVAR-3	IIVR Varanasi
5	2012/COPBVAR-5	IIVR Varanasi
6	2012/COPBVAR-6	IIVR Varanasi
7	2014/COPBVAR-1	IIVR Varanasi
8	2014/COPBVAR-2	IIVR Varanasi
9	2014/COPBVAR-3	IIVR Varanasi
10	2014/COPBVAR-4	IIVR Varanasi
11	2014/COPBVAR-5	IIVR Varanasi
12	2014/COPBVAR-6	IIVR Varanasi
13	GOMTI	IIVR Varanasi
14	KASHI KANCHAN(Check)	IIVR Varanasi
15	ARKA GARIMA(check)	IIHR Banglore

3.3 Details of layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication consists of 15 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:-

Design	: RCBD
Replication	: Three
Genotypes	: Fifteen
Total number of plots	: 45
Plot size	: 3.0 x 2.4 sq. m
Row to row distance	: 60 cm
Plant to plant distance	: 30 cm
Number of rows in each plot	: 5
Number of plants per row	: 8
Total number of plants per plot	: 40
Gross area of experimental field	: 473.0 sq.m
Net area of experiment field	: 324.0 sq.m
Number of plants for observation per plot	: 5
Plot to plot distance	: 0.50 m
Distance between replication	: 1.0 m
Crop	: Cowpea
Season	: Kharif
Date of sowing	: 18-7-2014

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 trail as per given plan of layout.

3.4.2 Seed

The seed rates used for sowing was 12-15 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 (2ml $liter^{-1}$ of water) alternate to keep the crop free from pest during crop growth period. The crop also 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) Phenological 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 were 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 were 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 thread and 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 conversing 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 pealing 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 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 has 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,

Σx = 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.

$$C.V. = \frac{\sqrt{EMS}}{GM} X100$$

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

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

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

Where,

C.V. %	=	Coefficient of variation
SEm±	=	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:

$$GCV\% = \frac{\sqrt{\sigma^2 g_i}}{\overline{X}_i} X100$$

Phenotypic coefficient of variation (PCV)

$$PCV\% = \frac{\sqrt{\sigma^2 P_i}}{\overline{X}_i} X100$$

Where,

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

σ^2_{gi} and σ^2_{pi} = 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).

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

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

Where,

h^2 (bs) = heritability in broad sense,

$\sigma^2 g$ = Genotypic variance,

$\sigma^2 p$ = Phenotypic variance

3.7.5 Genetic advance

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

Genetic advance (GA) = K. P_i .h^2_i

Genetic advance as percentage of mean was calculated as follows:

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

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 sence heritability (fraction) of the i^{th} character.

$\overline{X}_i$ = 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).

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

Where,

r	=	Correlation coeff…
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.

$$r_G\,(Xi\ Xj) = \frac{G\ Cov\,(Xi\ Xj)}{\sqrt{VG\,(Xi).\ VG\,(Xj)}}$$

$$r_P\,(Xi\ Xj) = \frac{P \qquad P\ Cov\,(Xi\ Xj)}{\sqrt{VP\,(Xi).\ VP\,(Xj)}}$$

$$r_E\,(Xi\ Xj) = \frac{E\ Cov\,(Xi\ Xj)}{\sqrt{VE\,(Xi).\ VE\,(Xj)}}$$

3.7.7 Testing of correlation coefficient:-

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

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

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.

$r_1Y = P_1Y + r_{12} P_2Y + r_{13} P_3 Y + \ldots\ldots\ldots\ldots + r_1i P_1Y.$

$r_2Y = r_{21} P_1Y + P_2 Y + r_{23} P_3Y + \ldots\ldots\ldots\ldots + r_{21} p_1Y.$

$r_ky = r_{k1} P_1Y + r_{k2} P_2Y + r_{k3}P_3Y + \ldots\ldots\ldots\ldots + r_k P_kY.$

$r_ky = r_{k1} P_1Y + r_{k2} P_2Y + r_{k3}P_3Y + \ldots\ldots\ldots\ldots + r_k P_kY.$

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-

A C

$$\begin{bmatrix} r_1Y \\ r_2Y \\ \cdot \\ \cdot \\ r_kY \end{bmatrix} \quad \begin{bmatrix} 1 & r_{12} & r_{13}\ldots\ldots r_{1i} \\ r_{21} & 1 & r_{23}\ldots\ldots r_{2i} \\ \cdot & & \\ \cdot & & \\ r_{k1} & r_{k2} & r_{k3}\ldots\ldots 1 \end{bmatrix} \quad \begin{bmatrix} P_1Y \\ P_2Y \\ \cdot \\ \cdot \\ P_kY \end{bmatrix}$$

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

Where,

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

Then the direct effects were calculated as follows -

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

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

$$P_kY = \sum_{i=1}^{k} C_{ki} r_k y$$

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 [*Vigna unguiculata* (L.)]" 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 fifteen genotypes of cowpea for twenty characters are presented in Table 4.2 a, b and c.

4.2.1.1 Plant height (cm)

Plant height varied from (11.18 to 14.06 cm), (25.88 to 33.57 cm) and (44.72 to 62.88 cm) with an overall mean performance of (12.49, 30.78 and 54.97 cm) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-4 recorded the maximum plant height (14.06 cm) and genotype 2014/COPBVAR-1 exhibited the minimum (11.18 cm). Plant height at 60 DAS genotype 2014/COPBVAR-4 was recorded the maximum plant height (33.57 cm) and genotype 2014/COPBVAR-1 was exhibited the minimum (25.88 cm) and plant height at 90 DAS genotype 2014/COPBVAR-4 was recorded the maximum plant height (62.88 cm) and genotype 2014/COPBVAR-1 was exhibited the minimum (44.72 cm).

4.2.1.2 Number of branches plant^{-1}

Number of branches plant^{-1} ranged from (1.40 to 2.73), (2.53 to 4.26) and (6.26 to 7.80) with an overall mean performance of (1.83, 3.46 and 6.92) at 30, 60 and 90 DAS respectively. At 30 DAS genotype 2014/COPBVAR-4 was recorded the maximum branches plant^{-1} (2.73) and genotype Arka Garima was exhibited the minimum (1.40). At 60 DAS genotype 2014/COPBVAR-4 was recorded the maximum branches plant^{-1} (4.26) and genotype Arka Garima was exhibited the minimum (2.53) and plant height at 90 DAS, genotype 2014/COPBVAR-4 was recorded the maximum branches plant^{-1} (7.73) and genotype Arka Garima was exhibited the minimum (6.26).

4.2.1.3 Days to first flowering

Days to first flowering varied from (53.33 to 59.33 days) with the average days being (55.64 days). The earliest flowering was observed in genotype 2014/COPBVAR-3 (53.33 days) while, the genotype 2014/COPBVAR-6 (59.33 days) took maximum days to first flowering.

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

Genotypes	Plant height (cm)			No. of branches		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
2011/COPBVAR-7	11.72	30.82	47.28	1.80	3.07	6.27
2012/COPBVAR-1	12.27	32.33	57.37	2.00	3.47	6.53
2012/COPBVAR-2	12.06	29.49	55.50	1.73	3.53	6.67
2012/COPBVAR-3	12.50	29.98	54.78	1.53	3.53	7.53
2012/COPBVAR-5	12.08	31.65	56.72	1.53	3.40	7.07
2012/C0PBVAR-6	12.57	31.94	48.27	1.67	3.40	6.93
2014/COPBVAR-1	11.18	25.88	44.72	1.73	3.47	6.53
2014/COPBVAR-2	11.57	30.71	53.38	1.67	3.40	7.00
2014/COPBVAR-3	12.31	32.88	59.99	2.27	4.00	7.80
2014/COPBVAR-4	14.06	33.57	62.88	2.73	4.26	7.73
2014/COPBVAR-5	12.80	31.11	53.45	1.93	3.33	6.47
2014/COPBVR-6	11.91	29.16	56.80	1.47	3.13	6.93
Gomti	13.51	30.21	56.63	1.80	3.40	6.60
Arka Garima (C)	12.73	29.77	54.65	1.40	2.53	6.27
Kashi Kanchan (C)	13.45	32.20	62.16	2.27	4.07	7.53
S.Em±	0.39	0.85	1.01	0.20	0.16	0.22
C.D. 5%	1.12	2.47	2.93	0.58	0.48	0.64

4.2.1.4 Days to 50 per cent flowering

The average days for 50 per cent flowering was (66.95 days) and it ranged from (64.0 to 70.0 days). The earliest 50 per cent flowering (64.00 days) was recorded in genotype 2014/COPBVAR-3 and Kashi Kanchan and the genotype 2014/COPBVAR-6 noted maximum 70.0 days.

4.2.1.5 Number of flower cluster^{-1}

It ranged from (2.93 to 5.53) and overall mean was calculated (3.91). Maximum number of flower cluster^{-1} was observed in 2014/COPBVAR-3 (5.53), while, it was recorded minimum in 2012/COPBVAR-3 (2.93).

4.2.1.6 Number of flower cluster plant^{-1}

Ranged from (11.90 to 49.66) and overall mean was calculated (22.15). Maximum number of flower cluster plant^{-1} was observed in 2012/COPBVAR-6 (49.66), while, it was noted minimum in 2011/COPBVAR-7 (11.90).

4.2.1.7 Days to first picking

Days to first picking ranged from (74.50 to 84.16 days) and grand mean was calculated (78.68 days). Genotype 2014/COPBVAR-3 was earliest for days to first picking (74.50 days), followed by 2012/COPBVAR-1(74.66 days), while, 2014/COPBVAR-6 was latest for the same (84.16 days).

4.2.1.8 Number of pods cluster^{-1}

The average number of pods cluster^{-1} was (2.25) and it ranged from (1.53 to 3.46). The maximum number of pods cluster^{-1} was observed in 2014/COPBVAR-3 (3.46), and minimum (1.53) was recorded in genotype 2012/COPBVAR-2, 2012/COPBVAR-3 and 2012/COPBVAR-6.

4.2.1.9 Number of pods plant^{-1}

The average number of pods plant^{-1} was (46.11) and ranged from (29.33 to 77.0). The maximum number of pods plant^{-1} was observed in genotype 2012/COPBVAR-6 (77.00), while, it was least in genotype 2011/COPBVAR-7 (29.33).

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

Character	Days to First Flowering	Days to 50 per cent Flowering	NO. of Flowers Cluster^{-1}	No. of Flower Clusters Plant^{-1}	Days to First Picking
2011/COPBVAR-7	53.67	64.67	4.80	11.90	78.57
2012/COPBVAR-1	58.00	67.00	3.60	19.37	74.67
2012/COPBVAR-2	54.67	67.33	3.07	37.12	78.83
2012/COPBVAR-3	56.67	66.67	2.93	18.17	78.63
2012/COPBVAR-5	57.00	68.00	3.27	25.70	80.53
2012/C0PBVAR-6	54.33	66.67	3.07	49.66	77.67
2014/COPBVAR-1	57.33	66.67	3.87	32.35	80.33
2014/COPBVAR-2	57.67	68.33	4.27	28.17	78.17
2014/COPBVAR-3	53.33	64.00	5.53	13.53	74.50
2014/COPBVAR-4	53.67	65.67	5.07	13.88	78.90
2014/COPBVAR-5	55.33	69.33	4.13	14.43	81.43
2014/COPBVR-6	59.33	70.00	3.80	19.85	84.16
Gomti	54.67	68.00	3.33	19.35	77.87
Arka Garima (C)	55.33	68.00	3.73	16.40	78.07
Kashi Kanchan (C)	53.67	64.00	4.20	12.47	77.93
S.Em±	0.94	0.76	0.18	1.88	0.80
C.D.5%	2.73	2.19	0.51	5.45	2.30

4.2.1.10 Pod length (cm)

The pod length varied from (14.87 to 33.28 cm) with a mean value of (22.72 cm). Genotype 2012/COPBVAR-3 produced considerably long pod (33.28 cm), while, genotypes 2014/COPBVAR-2 produced small pod (14.87 cm).

4.2.1.11 Pod width (cm)

Pod width ranged from (0.55 to 1.07 cm) and the average was (0.78 cm). Pod width was observed maximum in genotype Arka Garima (1.07 cm) and it was minimum in genotype 2012/COPBVAR-6 (0.55 cm).

4.2.1.12 Pod weight (g)

The weight of pod from (28.33 to 63.00 g), while, the average weight of pod was recorded (46.62 g). The maximum pod weight was observed in genotype 2012/COPBVAR-3 (63.00 g) and it was minimum in genotype 2014/COPBVAR–2 (28.33 g).

4.2.1.13 Number of seeds pod^{-1}

The average number of seeds pod^{-1} was recorded (11.09) and it ranged between (8.80 to13.86) seeds pod^{-1}. Maximum number of seeds pod^{-1} was observed in genotype 2012/COPBVAR-3 (13.86), while it was minimum in genotype 2014/COPBVAR-2 (8.80).

4.2.1.14 Pod yield plant^{-1} (g)

The highest pod yield plant^{-1} was recorded in genotype 2012/COPBVAR-6 (240 g) which was closely followed by genotype 2014/COPBVAR-6 (236.66 g). The genotypes 2011/COPBVAR-7 (153.0 g) was recorded the lowest yielder and average yield plant^{-1} was (199.68 g) and it ranged from (153.0 to 240.0 g).

4.2.1.15 Pod yield plot^{-1} (Kg)

The highest pod yield plot^{-1} was recorded in genotype 2012/COPBVAR-6 (9.6 kg) which was closely followed by genotype 2014/COPBVAR-6 (9.43 kg)

Table 4.2 (c): Mean performance of yield characters of cowpea.

Character	Pods Cluster^{-1}	Pods Plant^{-1}	Pod Length (cm)	Pod Width (cm)	Pod Weight (g)	Seeds Pod^{-1}	Pod Yield Plant^{-1} (g)	Yield Plot^{-1} (kg)	Yield ha^{-1} (q)
2011/COPBVAR-7	1.93	29.33	20.59	0.67	49.33	12.47	153.00	6.13	85.13
2012/COPBVAR-1	1.93	35.67	23.85	0.78	48.33	10.73	173.67	6.95	96.42
2012/COPBVAR-2	1.53	75.67	17.25	0.65	30.66	11.33	215.00	8.57	118.91
2012/COPBVAR-3	1.33	30.00	33.28	0.67	63.00	13.86	186.67	7.48	103.87
2012/COPBVAR-5	1.66	39.33	32.34	0.61	45.33	12.20	176.67	7.05	97.86
2012/C0PBVAR-6	1.53	77.00	26.05	0.55	42.33	10.13	240.00	9.68	134.38
2014/COPBVAR-1	2.33	56.00	15.45	0.71	28.33	10.33	218.67	8.78	121.87
2014/COPBVAR-2	2.40	67.67	14.87	0.79	28.33	8.80	206.67	8.30	115.16
2014/COPBVAR-3	3.47	47.00	22.99	0.85	45.00	10.00	211.67	8.42	116.82
2014/COPBVAR-4	3.20	44.00	21.54	0.77	40.67	9.40	180.00	7.20	99.94
2014/COPBVAR-5	2.73	39.33	19.57	1.04	57.33	10.93	226.67	9.07	125.85
2014/COPBVR-6	2.13	42.33	21.19	0.99	56.00	11.53	236.67	9.43	130.93
Gomti	2.33	45.00	22.30	0.82	48.33	11.07	216.67	8.67	120.29
Arka Garima (C)	2.47	31.00	21.83	1.07	62.67	11.07	183.33	7.34	101.91
Kashi Kanchan (C)	2.57	32.00	27.81	0.75	53.67	12.53	170.00	6.77	93.92
S.Em±	0.15	2.68	0.41	0.03	1.89	0.45	9.93	0.38	5.27
C.D. 5%	0.43	7.77	1.18	0.08	5.48	1.31	28.75	1.10	15.25

The genotypes 2011/COPBVAR-7 (6.13 kg) was low yielder and average yield plot^{-1} was (7.98 kg) and it ranged from (6.13 to 9.68 kg).

4.2.1.16 Pod yield ha^{-1} (q)

The highest pod yield ha^{-1} was recorded in genotype 2012/COPBVAR-6 (134.38 q) which was closely followed by genotype 2014/COPBVAR-6 (130.93 q). The genotype 2011/COPBVAR-7 (85.13 q) was lowest. The average yield ha^{-1} was (110.88 q) and it ranged from (85.13 to 134.38 q).

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 3.11% for days to 50 per cent flowering to 49.79% for number of cluster plant^{-1}. The phenotypic coefficient of variations was highest for characters *viz*., number of flower cluster plant^{-1} (49.79%), number of pods plant^{-1} (35.69%), number of pods cluster^{-1} (27.86%), number of branches at 30 DAS (24.94%), pod weight (24.81%), pod length (23.83%), number of flower cluster^{-1} (20.69%) and pod width (20.41%).

However, it was exhibited in moderate for characters like number of seeds pod^{-1} (13.15%), number of branches at 60 DAS (13.86%), pod yield plot^{-1} (14.98%), pod yield ha^{-1} (14.98%) and pod yield plant^{-1} (15.05%). Days to 50 per cent flowering (3.11%), days to first picking (3.36%). days to first flowering (4.15%), plant height at 60 DAS (7.23%), plant height at 30 DAS (7.64%), number of branches at 90 DAS (8.74%) and plant height at 90 DAS (9.69%)Rest of the characters 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 2.42% for days to 50 per cent flowering to 47.57% for number of cluster plant^{-1}.

High genotypic coefficient of variation was observed for number of flower cluster plant^{-1} (47.57%), number of pods plant^{-1} (34.24%), number of pods cluster^{-1} (25.44%), pod weight (23.79%) and pod length (23.62%).

It was moderate for rest of the characters such as pod width (19.45%), number of flower cluster^{-1} (19.15%), number of branches at 30 DAS (16.20%), pod yield plot^{-1} (12.52%), pod yield ha^{-1} (12.52%), pod yield plant^{-1} (12.35%), number of branches at 60 DAS (11.15%) and number of seeds pod^{-1} (11.11%).

While, days to 50 per cent flowering (2.42%), days to first picking (2.87%), days to first flowering (2.94%), plant height at 60 DAS (5.42%), plant height at 30 DAS (5.43%), number of branches at 90 DAS (6.74%) and plant height at 90 DAS (9.15%) 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%).

Result indicated that the heritability estimates were observed very high for pod length (98.29%), number of pods plant^{-1} (92.04%), pod weight (91.98%), number of flower cluster plant^{-1} (91.28%) and pod width (91.78%). However, it was recorded to be high for plant height at 90 DAS (89.20%), number of flower cluster^{-1} (85.61%), number of pods cluster^{-1} (83.36%), days to first picking (72.91%) and number of seeds pod^{-1} (71.33%).

Moderate heritability were recorded for pod yield plot^{-1} (69.84%), pod yield ha^{-1} (69.84%), pod yield plant^{-1} (67.28%), number of branches at 60 DAS (64.75%), days to 50 per cent flowering (60.51%), number of branches at 90 DAS (59.52%), plant height at 60 DAS (56.17%), plant height at 30 DAS (50.40%) and days to first flowering (50.21%).

Whereas, Low estimate of heritability was recorded for number of branches at 30 DAS (42.21%).

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 3.88% for days to 50 per cent flowering and 93.63% for number of flower cluster plant^{-1}. The highest estimate of genetic advance as percentage of mean was recorded for number of flower cluster plant^{-1} (93.63%) followed by number of pods plant^{-1} (67.67%), pod length (48.24%), number of pods cluster^{-1} (47.84%), pod weight (47.01%) and pod width (38.17%), number of flower cluster^{-1} (36.49%), number of branches at 30 DAS (21.68%), pod yield plot^{-1} (21.55%) and pod yield ha^{-1} (21.55%) and pod yield plant^{-1} (20.86%).

Number of seeds pod^{-1} (19.33%), number of branches at 60 DAS (18.48%), plant height at 90 DAS (17.81%), number of branches at 90 DAS (10.71%) showed moderate value of genetic advance as percentage of mean. Whereas, low estimates were observed for plant height at 60 DAS (8.37%), plant height at 30 DAS (7.93%), days to first picking (5.05%), days to first flowering (4.29%) and days to 50 per cent flowering (3.88%).

Table 4.3: Genetic parameters in twenty characters in Cowpea.

Characters	Grand mean	range		CV		Heritibility (%)	Genetic advance	GA as 5 % of mean
		Min.	Max	Phenotypic	Genotypic			
Plant height at 30DAS	12.49	11.18	14.06	7.64	5.43	50.40	0.99	7.93
Plant height at 60DAS	30.78	25.88	33.57	7.23	5.42	56.17	2.58	8.37
Plant height at 90 DAS	54.97	44.72	62.88	9.69	9.15	89.20	9.79	17.81
No. of branches at 30 DAS	1.83	1.40	2.73	24.94	16.20	42.21	0.40	21.68
No. of branches at 60 DAS	3.46	2.53	4.26	13.86	11.15	64.75	0.64	18.48
No. of branches at 90 DAS	6.92	6.26	7.80	8.74	6.74	59.52	0.74	10.71
Days to first flowering	55.64	53.33	59.33	4.15	2.94	50.21	2.38	4.29
Days to 50 per cent flowering	66.95	64.00	70.00	3.11	2.42	60.51	2.80	3.88
No. of flower cluster^{-1}	3.91	2.93	5.53	20.69	19.15	85.61	1.43	36.49
No. of flower cluster plant^{-1}	22.15	11.90	49.66	49.79	47.57	91.28	20.74	93.63
Days to first picking	78.68	74.50	84.16	3.36	2.87	72.91	3.98	5.05
No. of pod cluster^{-1}	2.251	1.53	3.46	27.86	25.44	83.36	1.08	47.84
No. of pod plant^{-1}	46.11	29.33	77.00	35.69	34.24	92.04	31.22	67.67
Pod length(cm)	22.72	14.87	33.28	23.83	23.62	98.29	10.96	48.24
Pod width(cm)	0.78	0.55	1.07	20.41	19.45	90.78	0.30	38.17
Pod weight (g)	46.62	28.33	63.00	24.81	23.79	91.98	21.92	47.01
No. of seed pod^{-1}	11.09	8.80	13.86	13.15	11.11	71.33	2.14	19.33
Pod yield plant^{-1}(g)	199.68	153.0	240.0	15.05	12.35	67.28	41.66	20.86
Pod yield plot^{-1}(kg)	7.98	6.13	9.68	14.98	12.52	69.84	1.72	21.55
Pod yield ha^{-1}.(q)	110.88	85.13	134.38	14.98	12.52	69.84	23.89	21.55

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 30 DAS showed significant and positive correlation with plant height at 90 DAS (0.546), number of branches plant^{-1} at 30 DAS (0.389), plant height at 60 DAS (0.350) and pod weight (0.304). Significant and negative association of this character was observed with number of flower cluster plant^{-1} (-0.340) and pods plant^{-1} (-0.372).

Correlation coefficient of plant height at 60 DAS showed highly significant and positive with number of branches plant^{-1} at 60 DAS (0.511), number of branches plant^{-1} at 90 DAS (0.422), plant height at 90 DAS (0.406), number of branches plant^{-1} at 30 DAS (0.314).

Plant height at 90 DAS expressed a highly significant and positive correlation coefficient with number of branches plant^{-1} at 90 DAS (0.537), number of branches plant^{-1} at 60 DAS (0.458), number of branches plant^{-1} at 30 DAS (0.443), pods cluster^{-1} (0.391) and pod length (0.309)). But it was exhibited significant and negative with number of flower cluster plant^{-1} (-0.388) and pods plant^{-1} (-0.361).

4.3.2 Number of branches plant^{-1}

Number of branches plant^{-1} at 30 DAS expressed significant and positive correlation with number of branches plant^{-1} at 60 DAS (0.501), number of branches plant^{-1} at 90 DAS (0.501), pods cluster^{-1} (0.500) and flower cluster^{-1} (0.420), while, it was found significant and negative correlation with other traits like days to first flowering (-0.454) and days to 50 per cent flowering (-0.423).

Number of branches plant^{-1} at 60 DAS expressed significantly and positively associated with number of branches plant^{-1} at 90 DAS (0.732), pods cluster^{-1} (0.416) and flower cluster^{-1} (0.377), while, it was found significant and negative association with days to 50 per cent flowering (-0.421) and pod weight (-0.296).

Number of branches plant^{-1} at 90 DAS expressed significantly and positively association with pod length (0.387) and pods cluster^{-1} (0.334), while, it was found significant and negative with days to 50 per cent flowering (-0.429).

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 (0.428), while, it was found significant and negative with number of flower cluster^{-1} (-0.312) and number of pods cluster^{-1} (-0.307).

4.3.4 Days to 50 per cent flowering

Days to 50 per cent flowering was recorded highly significant and positive with pods yield plant^{-1} (0.415) and pod width (0.330). It was observed significant and negative with flower cluster^{-1} (-0.447).

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} (0.785). Also,

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

character		Plant height			No. of branches			Days to First flowering	Days to 50 per cent flowering	Flower Cluster^{-1}	number of flower Cluster Plant^{-1}	Days to First picking	Pods Cluster^{-1}	Pods Plant^{-1}	Pod length (cm)	Pod Width(cm)	Pod weight	Seeds Pod^{-1}	Pod yield Plant^{-1}
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS												
Plant height 30 DAS	G	1.000	0.474	0.766	0.796	0.424	0.532	-0.821	-0.304	0.203	-0.549	-0.287	0.494	-0.507	0.371	0.222	0.427	0.009	-0.160
	p	1.000	0.350*	0.546***	0.389**	0.214	0.170	-0.267	-0.012	0.004	-0.340*	-0.036	0.272	-0.372*	0.272	0.111	0.304*	-0.028	-0.153
Plant height 60 DAS	G		1.000	0.634	0.718	0.784	0.765	-0.211	-0.230	0.114	-0.153	-0.143	0.450	0.040	0.320	-0.030	-0.092	-0.221	0.100
	P		1.000	0.402**	0.314*	0.511***	0.422**	0.016	-0.161	0.089	-0.056	-0.142	0.282	0.057	0.217	-0.044	-0.091	-0.203	0.120
Plant Height 90 DAS	G			1.000	0.656	0.572	0.6968	-0.208	-0.210	0.296	-0.446	-0.129	0.475	-0.381	0.334	0.255	0.251	0.037	-0.246
	P			1.000	0.443**	0.458**	0.537***	-0.155	-0.128	0.202	-0.388**	-0.097	0.391**	-0.361*	0.309*	0.226	0.252	0.067	-0.230
Branches at 30 DAS	G				1.000	1.040	0.661	-0.673	-0.715	0.902	-0.407	0.005	0.848	-0.089	-0.093	-0.083	-0.219	-0.310	-0.336
	P				1.000	0.501***	0.501*	-0.454**	-0.423**	0.420**	-0.265	-0.016	0.500***	-0.040	-0.040	0.021	-0.118	-0.260	-0.155
Branches at 60 DAS	G					1.000	0.880	-0.548	-0.737	0.448	-0.038	-0.021	0.472	0.169	0.193	-0.362	-0.299	-0.095	-0.003
	P					1.000	0.732***	-0.198	-0.421**	0.377*	-0.075	0.021	0.416**	0.125	0.125	-0.274	-0.296*	-0.135	-0.044
Branches at 90 DAS	G						1.000	-0.284	-0.574	0.326	-0.228	-0.275	0.380	-0.089	0.526	-0.273	0.046	0.026	-0.006
	P						1.000	-0.180	-0.429**	0.262	-0.201	-0.152	0.334*	-0.129	0.387**	-0.156	0.013	0.053	-0.145
Days to first flowering	G							1.000	0.812	-0.483	0.150	-0.223	-0.408	0.144	-0.072	0.215	-0.004	-0.010	0.234
	P							1.000	0.428**	-0.312*	0.163	-0.130	-0.307*	0.125	-0.049	0.121	0.007	-0.049	0.195
Days to 50 per cent flowering	G								1.000	-0.529	0.215	0.225	-0.310	0.135	-0.227	0.520	0.124	-0.194	0.564
	P								1.000	-0.447**	0.159	0.232	-0.214	0.136	-0.194	0.330*	0.086	-0.143	0.415**
Flower cluster^{-1}	G									1.000	-0.544	0.067	0.861	-0.129	-0.338	0.294	-0.068	-0.351	-0.281
	P									1.000	-0.506***	0.007	0.785***	-0.094	-0.310*	0.267	-0.085	-0.255	-0.171
number of flower Cluster plant^{-1}	G										1.000	0.547	-0.600	0.841	-0.286	-0.580	-0.753	-0.186	0.481
	P										1.000	0.407**	-0.610***	0.763***	-0.263	-0.533***	-0.664***	-0.129	0.372*
Days to first picking	G											1.000	-0.015	0.593	-0.496	0.018	-0.518	-0.110	0.391
	P											1.000	0.062	0.462**	-0.415**	0.009	-0.429**	-0.043	0.222
Pods cluster^{-1}	G												1.000	-0.098	-0.315	0.582	0.053	-0.459	0.012
	P												1.000	-0.087	-0.296*	0.502***	0.039	-0.351*	0.014
Pods plant^{-1}	G													1.000	-0.641	-0.313	-0.918	-0.515	0.550
	P													1.000	-0.610***	-0.295*	-0.871***	-0.467**	0.589***
Pod length	G														1.000	-0.328	0.571	0.567	-0.371
	P														1.000	0.300*	0.554***	0.493***	0.304*
Pod width	G															1.000	0.500	-0.157	0.221
	P															1.000	0.472**	-0.099	0.145
Pod weight	G																1.000	0.519	-0.234
	P																1.000	0.464**	-0.232
Seeds pod^{-1}	G																	1.000	-0.414
	P																	1.000	0.395**
Pod yield/ plant^{-1}	G																		1.000
	P																		1.000

***Significant at 5% level = (0.361) ** Significant at 1% level = (0.463)**

significant and negative association was exhibited with number of flower cluster plant^{-1} (-0.506) and pod length (-0.310).

4.3.6 Number of flower cluster plant^{-1}

The correlation coefficient of number of flower cluster plant^{1} was found significant and positive correlation with pods plant^{-1} (0.763), days to first picking (0.407), and pod yield plant^{-1} (0.372), while, it was exhibited significantly and negatively association with pod weight (-0.664), pods cluster^{-1} (-0.610) and pod length (-0.533)

4.3.7 Days to first picking

Days to first picking recorded highly significant and positive association with pods plant^{-1} (0.462), while, it was found significant and negative with pod weight (-0.429) and pod length (-0.415).

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 width (0.502). Also, significant and negative association was exhibited with number of seeds pod^{-1} (-0.351) and pod length (-0.296).

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} (0.589). Also, significant and negative association was exhibited with pod weight (-0.871), pod length (-0.610), seeds pod^{-1} (-0.467) and pod width (-0.295).

4.3.10 Pod length (cm)

Pod length was recorded highly significant and positive association with pod weight (0.554), seeds pod^{-1} (0.493), pod yield plant^{-1} (0.304) and pods width (0.300).

4.3.11 Pod width (cm)

Pod width showed significant and positive correlation with pod weight (0.472).

4.3.12 Pod weight (g)

Pod weight expressed highly significant and positive association with number of seeds pod^{-1} (0.464).

4.3.13 Number of seeds pod^{-1}

The correlation coefficient was found significant and positive correlation with pod yield plant^{-1} (0.395).

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 number of pods plant^{-1} (2.108) had highest positive direct effect followed by pod weight (2.054), number of flower cluster^{-1} (0.347), pod width (0.298), number of branches at 90 DAS (0.256), number of flower cluster plant^{-1} (0.154), days to first picking (0.128), plant height at 90 DAS (0.081) and pod length (0.033). Whereas, days to first flowering (-0.061) had the highest negative direct effect on pod yield plant^{-1} followed by days to 50 per cent flowering (-0.121), number of seeds pod^{-1} (-0.563) and pods cluster^{-1} (-0.712).

Indirect effect

Plant height at 90 DAS (cm)

Plant height at 90 DAS imparted highest positive indirect effect on pod yield plant^{-1} through, number of branches at 90 DAS (0.056), pods cluster^{-1} (0.038), pod length (0.027), flower cluster^{-1} (0.024), pod width (0.020) and pod weight (0.020). Whereas, negative indirect effect was visible to be highest via days to first picking (-0.010), days to first flowering (-0.017), days to 50 per cent flowering (-0.017), pods plant^{-1} (-0.031) and number of flower cluster plant $^{-1}$ (-0.036).

Number of branches plant^{-1} at 90 DAS

Number of branches plant^{-1} at 90 DAS exhibited highest positive indirect effect pod yield plant^{-1} via plant height at 90 DAS (0.174), pod length (0.131), pods cluster^{-1} (0.095), and flower cluster^{-1} (0.081). Whereas, it was expressed high negative indirect effect via pods plant^{-1} (-0.022), number of flower cluster plant^{-1} (-0.057), pods width (-0.068), days to first picking (-0.069), days to first flowering (-0.071) and days to 50 per cent flowering (-0.143).

Days to first flowering

Days to first flowering was reported to have highest positive indirect effect on pod yield plant^{-1} through, number of flower cluster^{-1} (0.029), pods cluster^{-1} (0.025), number of branches at 90 DAS (0.017), days to first picking (0.013) and plant height at 90 DAS (0.012). Whereas, it was expressed high negative indirect effect via pods plant^{-1} (-0.008), number of flower clusters plant^{-1} (-0.009), days to 50 per cent flowering (-0.050) and pod width (-0.013).

Days to 50 per cent flowering

Days to 50 per cent flowering was reported to have highest positive indirect effect on pod yield plant^{-1} through, number of branches plant^{-1} at 90 DAS (0.069), followed by flower cluster $^{-1}$ (0.064), pods cluster^{-1} (0.037), pod length (0.027), plant height at 90 DAS (0.025) and seeds pod^{-1} (0.023). Whereas, it was expressed high negative indirect effect on pod yield plant^{-1} via pod weight (-0.015), pods plant^{-1} (-0.016), number of flower cluster plant^{-1} (-0.026), days to first picking (-0.027), pod width (-0.063) and days to first flowering (-0.098).

Number of flower cluster^{-1}

Number of flower cluster^{-1} was reported to have highest positive indirect effect on pod yield plant^{-1} through, pods cluster^{-1} (0.298), number of branches at 90 DAS (0.113), plant height at 90 DAS (0.102), pod width (0.102) and days to first picking (0.035). Whereas, it was expressed high negative indirect effect via pod weight (-0.023), pods plant^{-1} (-0.045), pod length (-0.117), seeds pod^{-1} (-0.122), days to first flowering (-0.167), days to 50 per cent flowering (-0.183) and number of flower cluster plant^{-1} (-0.188).

Number of flower cluster plant^{-1}

Number of flower cluster plant^{-1} was reported to have highest positive indirect effect on pod yield plant^{-1} through, pods plant^{-1} (0.130), days to first picking (0.084), days to 50 per cent flowering (0.033) and days to first flowering (0.023). Whereas, it was expressed high negative indirect effect through seeds pod^{-1} (-0.028), number of branches at 90 DAS (-0.035), plant height at 90 DAS (-0.069), flowers cluster^{-1} (-0.084), pod width (-0.089), pods cluster^{-1} (-0.092) and pod weight (-0.116).

Days to first picking

Days to first picking expressed highest positive indirect effect through, pods plant^{-1} (0.076), number of flower cluster plant^{-1} (0.070), days to 50 per cent flowering (0.029). It's indirect negative effect was high via pods cluster^{-1} (-0.002), seeds pod^{-1} (-0.014), plant height at 90 DAS (-0.016), days to first flowering

Table 4.5: Phenotypic path coefficients showing direct and indirect effects of different characters on pod yield plant^{-1} (g).

Character	Plant Height At 90 DAS	Branch At 90 DAS	Days to first Flowering	Days to 50 per cent Flowering	Flowes Cluster^{-1}	Clusters Plant^{-1}	Days to first Picking	Pods Cluster^{-1}	Pods Plant^{-1}	Pod Length (cm)	Pod Width (cm)	Pod Weight (g)	Seeds Pod^{-1}
Plant Height At 90 DAS	**-0.040**	-0.022	0.006	0.005	-0.008	0.015	0.004	-0.016	0.014	-0.012	-0.009	-0.010	-0.002
Branch At 90 DAS	0.002	**0.003**	-0.000	-0.001	0.001	-0.000	-0.000	0.001	-0.000	0.001	-0.0006	0.000	0.0002
Days to first Flowering	0.012	0.015	**-0.082**	-0.035	0.025	-0.013	0.010	0.025	-0.010	0.004	-0.010	-0.000	0.004
Days to 50 per cent flowering	-0.026	-0.088	0.088	**0.206**	-0.092	0.032	0.047	-0.044	0.028	-0.040	0.068	0.017	-0.029
Flowers Cluster^{-1}	0.041	0.054	-0.064	-0.092	**0.207**	-0.104	0.001	0.162	-0.019	-0.064	0.055	-0.017	-0.053
Clusters Plant^{-1}	0.018	0.009	-0.007	-0.007	0.024	**-0.047**	-0.019	0.029	-0.036	0.012	0.025	0.031	0.006
Days to first Picking	0.001	0.001	0.001	-0.002	-0.000	-0.004	**-0.010**	-0.000	-0.004	0.004	-0.000	0.004	0.0004
Pods Cluster^{-1}	-0.031	-0.027	0.024	0.017	-0.063	0.049	-0.005	**-0.081**	0.007	0.024	-0.040	-0.003	0.028
Pods Plant^{-1}	-0.606	-0.217	0.211	0.228	-0.158	1.282	0.776	-0.146	**1.679**	-1.024	-0.496	-1.463	-0.785
Pod Length(cm)	0.118	0.148	-0.018	-0.074	-0.118	-0.100	-0.159	-0.113	-0.233	**0.383**	-0.115	0.212	0.189
Pod Width(cm)	0.038	-0.026	0.020	0.056	0.045	-0.090	0.001	0.085	-0.050	-0.051	**0.170**	0.080	-0.017
Pod Weight (g)	0.255	0.014	0.007	0.087	-0.086	-0.671	-0.434	0.040	-0.880	0.560	0.477	**1.010**	0.468
Seeds/ Pod	-0.013	-0.011	0.010	0.029	0.052	0.026	0.008	0.072	0.09	-0.101	0.020	-0.095	**-0.205**
Pod Yield Plant^{-1} (g)	**-0.230**	**-0.145**	**0.195**	**0.415**	**-0.171**	**0.372**	**0.222**	**0.014**	**0.589**	**-0.304**	**0.145**	**-0.232**	**-0.395**

Residual Effect = 0.4834

(-0.028), branches at 90 DAS (-0.035), pod length (-0.063) and pod weight (-0.066).

Number of pods cluster^{-1}

Highest positive indirect effect of number of pods cluster^{-1} on pod yield plant^{-1} was recorded through, cluster plant^{-1} (0.427), seed pod^{-1} (0.327), pod length (0.224), days to first flowering (0.291), days to 50 per cent flowering (0.221), pods plant^{-1} (0.070), and days to first picking (0.011). It's negative indirect effect was high via pod weight (-0.038), number of branches at 90 DAS (-0.271), plant height at 90 DAS (-0.338), pod width (-0.414) and flower cluster^{-1} (-0.613).

Number of pods plant^{-1}

Highest positive indirect effect of number of pods plant^{-1} on pod yield plant^{-1} was recorded through number of flower cluster plant^{-1} (1.773), days to first picking (1.251), days to first flowering (0.304), days to 50 per cent flowering (0.284). It's indirect negative effect was high via pod width (-0.660), plant height at 90 DAS (-0.803), branches at 90 DAS (-0.188), pods cluster^{-1} (-0.208), flower cluster^{-1} (-0.273), seeds pod^{-1} (-1.087), pod length (-1.353) and pod weight (-1.936).

Pod length

Pod length revealed high values of positive indirect effect on pod yield plant^{-1} through pod weight (0.019), seeds pod^{-1} (0.019), branches at 90 DAS (0.017) and plant height at 90 DAS (0.011). While, the remaining characters showed high negative indirect effect i.e. pod width (-0.011), pods cluster^{-1} (-0.010), flowers cluster^{-1} (-0.011), days to first picking (-0.016) and pods plant^{-1} (-0.021).

Pod width

Pod width revealed high values of positive indirect effect on pod yield plant^{-1} through pods cluster^{-1} (0.174), pod weight (0.149), days to 50 per cent flowering (0.155), flowers cluster^{-1} (0.088), plant height at 90 DAS (0.076) and

Table 4.6 Genotypic path coefficient showing direct and indirect effect of different character on pod yield plant^{-1} (g)

Character	Plant Height At 90 DAS	Branch At 90 DAS	Days to first Flowering	Days to 50 per cent Flowering	Flowers Cluster^{-1}	Clusters Plant^{-1}	Days to first Picking	Pods Cluster^{-1}	Pods Plant^{-1}	Pod Length (cm)	Pod Width (cm)	Pod Weight (g)	Seeds Pod^{-1}	Pod Yield Plant^{-1} (g)
Plant Height At 90 DAS	**0.081**	0.056	-0.017	-0.017	0.024	-0.036	-0.010	0.038	-0.031	0.027	0.020	0.020	0.003	-0.246
Branch At 90 DAS	0.174	**0.250**	-0.071	-0.143	0.081	-0.057	-0.069	0.095	-0.022	0.131	-0.068	0.011	0.006	-0.006
Days to first Flowering	0.012	0.017	**-0.061**	-0.050	0.029	-0.009	0.013	0.025	-0.008	0.004	-0.013	0.000	0.000	0.234
Days to 50 per cent flowering	0.025	0.069	-0.098	**-0.121**	0.064	-0.026	-0.027	0.037	-0.016	0.027	-0.063	-0.015	0.023	0.564
Flowers Cluster^{-1}	0.102	0.113	-0.167	-0.183	**0.347**	-0.188	0.023	0.298	-0.045	-0.117	0.102	-0.023	-0.122	-0.281
Clusters Plant^{-1}	-0.069	-0.035	0.023	0.033	-0.084	**0.154**	0.084	-0.092	0.130	-0.044	-0.089	-0.116	-0.028	0.481
Days to first Picking	-0.016	-0.035	-0.028	0.029	0.008	0.070	**0.128**	-0.002	0.076	-0.063	0.002	-0.066	-0.014	0.391
Pods Cluster^{-1}	-0.338	-0.271	0.291	0.221	-0.613	0.427	0.011	**-0.712**	0.070	0.224	-0.414	-0.038	0.327	0.012
Pods Plant^{-1}	-0.803	-0.188	0.304	0.284	-0.273	1.774	1.251	-0.208	**2.108**	-1.353	-0.660	-1.936	-1.087	0.550
Pod Length(cm)	0.011	0.017	-0.002	-0.007	-0.011	-0.009	-0.016	-0.010	-0.021	**0.033**	-0.011	0.019	0.019	-0.371
Pod Width(cm)	0.076	-0.081	0.064	0.155	0.088	-0.173	0.005	0.174	-0.093	-0.098	**0.298**	0.149	-0.046	0.221
Pod Weight (g)	0.517	0.094	-0.008	0.254	-0.141	-1.548	-1.065	0.110	-1.886	1.174	1.029	**2.054**	1.067	-0.234
Seeds Pod^{-1}	-0.021	-0.014	0.006	0.109	0.198	0.104	0.062	0.258	0.290	-0.319	0.088	-0.292	**-0.563**	**-0.414**

Residual Effect = 0.346

days to first flowering (0.064). Indirect effect i.e. seeds pod^{-1} (-0.046), branches plant^{-1} at 90 DAS (-0.081), pods plant^{-1} (-0.093) pod length (-0.098) and number of flower cluster plant^{-1} (-0.173).

Pod weight

Highest positive indirect effect of pod weight on pod yield plant^{-1} was recorded through pod length (1.174), seeds pod^{-1} (1.067), pod width (1.029), plant height at 90 DAS (0.517), days to 50 per cent flowering (0.254) pods cluster^{-1} (0.110), and number of branches at 90 DAS (0.094). It showed negative indirect effect through days to first flowering (-0.008), flower cluster^{-1} (-0.141), days to first picking (-1.065), number of flower cluster plant^{-1} (-1.548) and pods plant^{-1} (-1.886).

Number of seeds pod^{-1}

Number of seeds pod^{-1} manifested positive indirect effect through pods cluster^{-1} (0.258), pods plant^{-1} (0.290), flower cluster^{-1} (0.198), days to 50 per cent flowering (0.109), number of flower cluster plant^{-1} (0.104), pod width (0.088) and days to first picking (0.062). Whereas, it was expressed high negative indirect effect via number of branches plant^{-1} at 90 DAS (-0.014), plant height at 90 DAS (-0.021), pod weight (-0.292) and pod length (-0.301).

4.5 Quality 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 summarized in Table 4.7

Colour of flower

Colour of flower was observed to be white, purple, light purple. Genotypes 2011/COPBVAR-7, 2012/COPBVAR -1, 2012/COPBVAR-2, 2014/COPBVAR-3 and Arka Garima exhibited purple colour flower. White colour flowers were observed in genotype 2012/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-4 and Gomti. Whereas, genotypes 2012/COPBVAR-3, 2012/COPBVAR-5, 2014/COPBVAR-2, Kasha Kanchan, 2014/COPBVAR-5 and 2014/COPBVAR-6 exhibited light purple flowers.

Colour of pod

Colour of pods was observed to be dark green, green and light green. Genotypes 2012/COPBVAR-2 and 2014/COPBVAR-6 exhibited dark green pods. Whereas, genotypes 2011/COPBVAR-7, 2012/COPBVAR-1, 2012/COPBVAR-3, 2012/COPBVAR-5, 2012/COPBVAR-6, 2014/COPBVAR-2, 2014/COPBVAR-4 and Kashi Kanchan were observed green pods. Remaining genotypes exhibited light green pods.

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 2012/COPBVAR-1, 2012/COPBVAR-2, 2014/COPBVAR-1, 2014/COPBVAR-2 and Arka Garima. Genotypes 2011/COPBVAR-7, 2014/COPBVAR-3, Gomti and 2014/COPBVAR-6 were produced curved pod. The remaining genotypes 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 2012/COPBVAR-2, 2012/COPBVAR-3, 2014/COPBVAR-3, 2014/COPBVAR-6, 2014/COPBVAR -5 and Arka Garima. 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-3, 2012/COPBVAR-6 and 2014/COPBVAR-6. Whereas, genotypes 2014/ COPBVAR -3, 2014/COPBVAR -4 and Arka Garima 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
2011/COPBVAR-7	Purple	Green	Curved	Fiber Present	Fleshy	Dark Maroon
2012/COPBVAR-1	Purple	Green	Straight	Fiber Absent	Less Fleshy	Maroon
2012/COPBVAR-2	Purple	Dark green	Straight	Fiber Present	Fleshy	Light maroon
2012/COPBVAR-3	Light Purple	Green	Slightly curved	Fiber present	non Fleshy	Dark Maroon
2012/COPBVAR-5	Light Purple	Green	Slightly curved	Fiber absent	Fleshy	Dark Maroon
2012/C0PBVAR-6	White	Green	Curved	Fiber Absent	Non Fleshy	Creamish
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-3	Purple	Light green	curved	Fiber Present	Less 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/COPBVR-6	Light purple	Dark Green	Curved	Fiber Present	Non Fleshy	Black
Gomti	White	Light Green	curved	Fiber absent	Fleshy	Creamish
Arka Garima (C)	Purple	Light Green	Straight	Fiber Present	Fleshy	Cream and Maroon
Kashi Kanchan (C)	Light Purple	Green	Slightly curved	Fiber Absent	Less Fleshy	Dark Maroon

Seed colour

Color of seeds was observed to be cream, dark maroon, maroon and light maroon. Genotypes 2012/COPBVAR-2 and 2014/COPBVAR-4 exhibited light maroon seeds. Whereas, genotypes 2012/COPBVAR-1, 2011/COPBVAR-6 was observed maroon seeds. Genotypes 2011/COPBVAR-7, 2012/COPBVAR-3, 2012/COPBVAR-5 and 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 maximum in genotypes 2014/COPBVAR-4 (29.23%) followed by 2014/COPBVAR-3 (28.60), 2014/COPBVAR-5 (27.60) and Gomti (26.63) was found to highly susceptible to pod borer. The low incidence of pod borer was found in genotypes Kashi Kanchan (15.26) and 2011/COPBVAR-7 (16.40).

4.6.2 Incidence of Alterneria blight (%)

The incidence of Alterneria blight was observed maximum in genotypes 2012/COPBVAR-1 (3.67 %), 2014/COPBVAR-1 (3.33%) and 2011/COPBVAR-7 (3.33%). Whereas, genotypes 2014/COPBVAR-6 (1.00%), 2014/COPBVAR-2 (1.33%) and 2014/COPBVAR-5 (1.33%) 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 Alterneria blight (%)
2011/COPBVAR-7	16.40	3.33
2012/COPBVAR-1	18.47	3.67
2012/COPBVAR-2	18.37	1.67
2012/COPBVAR-3	22.80	2.00
2012/COPBVAR-5	20.03	1.67
2012/C0PBVAR-6	19.47	2.33
2014/COPBVAR-1	21.60	3.33
2014/COPBVAR-2	19.63	1.33
2014/COPBVAR-3	28.60	1.67
2014/COPBVAR-4	29.33	1.67
2014/COPBVAR-5	27.60	1.33
2014/COPBVR-6	24.10	1.00
Gomti	26.63	1.66
Arka Garima (C)	22.80	2.66
Kashi Kanchan (C)	15.33	1.66
S.Em±	1.60	0.49
C.D. 5%	4.63	1.42

DISCUSSION

The experimental findings of the present investigation "Genetic variability, correlation and path coefficient analysis for yield and its attributing traits in cowpea [*Vigna unguiculata* (L.)]" have been discussed on the following heads in the light of the available literature.

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 parameters

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 fifteen genotypes of cowpea. The estimates of mean sum of square due to genotypes were highly significant for all the characters, indicating the presence of genetic diversity in the existing material (Table 4.1). The findings of Rangaiah and Mahadevu (2000), Ramesh *et al.* (2002) Rocha *et al.* (2003), Venkatesan *et al.* (2003)**,** Kumawat *et al.* (2005), Prasad *et al.* (2004), Girish *et al.* (2006), Lal *et al.* (2007), Eswaran *et al.* (2007), Bertini *et al.* (2009), Pandey and Singh (2011), Manggoel *et al.* (2012) are similar to that of the present findings.

5.2 Genetic variability

5.2.1 Mean performance of the genotypes

The mean performance of the genotypes (Table 4.3) revealed a wide range of variability for all the traits. The variation was highest for pod yield plant^{-1} (153 - 240 g), followed by pod yield ha^{-1} (85.13 - 134.39 q), number of pods plant^{-1} (29.33 - 77.00), number of flower cluster plant^{-1} (11.90 - 49.66), pod weight (28.33 - 63.0 g), pod length (14.87 - 33.28 cm), plant height at 90 DAS (44.72 - 62.88 cm), days to first picking (80.00 - 90.67 days), plant height at 60 DAS (25.88 - 33.57 cm), days to 50 per cent flowering (64.00 - 70.00 days), days to first flowering (55.33 - 59.33 days), pod yield plot^{-1} (6.13 - 9.68 kg), number of flower cluster^{-1} (2.93 - 5.53), plant height at 30 DAS (11.18 - 14.06 cm), number of pods cluster^{-1}(1.53 - 3.46), number of branches at 60 DAS (2.53 - 4.26), number of branches at 90 DAS (6.26 - 7.80) and number of branches at 30 DAS (1.40 - 2.73). The findings were quite similar to as reported by Kalaiyarasi *et al.* (2000) 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, pods 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

In the present findings phenotypic coefficient of variations were observed to be higher than the corresponding genotypic coefficient of variations for all the characters studied, however, the differences was narrow which implied their relative resistance to environmental variation. It also described that genetic factors were predominantly responsible for expression of those attributes and selection could be made effectively on the basis of phenotypic performance. 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.

5.2.2.1 Phenotypic coefficient of variations

The phenotypic coefficient of variation ranged from 3.11% for days to 50 per cent flowering to 49.66% for days to first picking. The phenotypic coefficient of variation was high for characters *viz*., number of flower cluster plant^{-1}, number of pods plant^{-1}, number of pods cluster^{-1}, number of branches at 30 DAS, pod weight, pod length, number of flower cluster^{-1} and pod width. 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}.

Rest of the characters such as number of seeds pod^{-1}, number of branches at 60 DAS, pod yield plot^{-1}, pod yield ha^{-1} and pod yield plant^{-1} exhibited moderate phenotypic coefficient of variation. Prasanthi (2004) and Manggoel *et al.* (2012) for number of seeds pod^{-1} were similar to the present finding.

However, it was exhibited in low for characters like 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. Pathak and Jamwal (2002) for days to 50 per cent flowering.

5.2.2.2 Genotypic coefficient of variation

It is revealed from the Table 4.3 that genotypic coefficient of variation varied from 2.42% for days to 50 per cent flowering to 47.57% for number of cluster plant^{-1}.

High genotypic coefficient of variation was observed for number of flower cluster plant^{-1}, number of pods plant-^{1}, number of pods cluster^{-1}, pod weight and pod length. 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*. (2005) for plant height, Nigude *et al.* (2004), Prasanthi (2004) and Omoigui *et al.* (2005) 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.

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 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.

While, it was moderate for rest of the characters such as pod width, number of flower cluster^{-1}, number of branches at 30 DAS, pod yield plot^{-1}, pod yield ha^{-1}, pod yield plant^{-1}, number of branches at 60 DAS and number of seeds pod^{-1}.

5.2.3 Heritability

Heritability which denotes the proportion of genetically controlled variability expressed by a programme for a particular character or a set of character is very important biometrical tool for guiding plant breeders for adoption of appropriate breeding procedures. High heritability in broad sense is helpful in identifying appropriate character for selection and enables the breeder to select superior genotypes on the basis of phenotypic expression of quantitative characters. The estimated values of heritability in broad sense were classified as very high (more than 90%), high (more than 70- 90%), medium (50-70%) and low (less than 50%). Hanson *et al.* (1956).

Result indicated that the heritability estimates were observed very high for pod length, number of pods plant^{-1}, pod weight, number of flower cluster plant^{-1}, pod width. However, it was recorded to be high 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}. The results were in close proximate to that of Borah *et al.* (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) yield ha^{-1}. Om vir and singh (2014) for Number of seeds pod^{-1}, number of pod plant^{-1}, number of pods cluster^{-1}, and number of cluster plant^{-1}.

Low estimate of heritability was recorded for number of branches at 30 DAS. This is indicative of the fact that these characters are rather more influenced by the environment and may not respond much to selection.

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 which indicated that selection based on phenotypic performance would be rewarding. The results were in close 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) pod yield plant^{-1} and plant height.

5.2.4 Genetic advance

Heritability however indicates only the effectiveness with which selection of a genotype can be based on phenotypic performance, but fails to indicate the genetic progress. Heritability estimates along with genetic gains are more effective and reliable in predicting the improvement through selection (Johnson *et al.* (1955). Estimates of genetic advance helps to predict the extent of improvement that can be achieved for improving the different characters. The estimated values of genetic advance as percent of mean were classified as high (more than 20%), moderate (10-20%) and low (less than 10%).

Genetic advance as percentage of mean ranged between 3.88% for days to 50 per cent flowering and 93.63% for number of flower cluster plant^{-1}. The high estimate of genetic advance as percentage of mean was recorded for number of flower cluster plant^{-1}, number of pods plant^{-1}, pod length, number of pods cluster^{-1}, pod weight and 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}. 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) for all characters except number of seeds pod^{-1}.

Number of seeds pod^{-1}, number of branches at 60 DAS, plant height at 90 DAS, number of branches at 90 DAS 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 plant height at 60 DAS, plant height at 30 DAS, days to first picking, days to first flowering and days to 50 per cent flowering. The findings were in agreement to the finding of Pathak and Jamwal (2002) for days to first picking. Venkatesan *et al.* (2003), Girish *et al.* (2006), Eswaran *et al.* (2007) and Sharma *et al.* (2007) for plant height, Pathak and Jamwal (2002) for days to 50 per cent flowering. Borah *et al.* (2000) and Sheela *et al.* (2006) for number of branches plant^{-1}.

High heritability coupled with high genetic advance was reported for traits like number of flower cluster plant^{-1}, number of pods plant^{-1}, pod length, pod weight and number of pods cluster^{-1}. Suggested that the preponderance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions. The findings were in agreement to the findings of Anbumalarmathi *et al.* (2005) and Ramesh *et al.* (2002) for pod length, Om vir and Singh (2014) for number of pods cluster^{-1}, Bertini *et al.* (2009), Choudhary *et al.* (2010), Singh *et al.* (2012) for pods plant^{-1}.

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by number of branches at 60 DAS, plant height at 90 DAS, number of branches at 90 DAS which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about. The results were in consonance with 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}, Sheela *et al.* (2006) for plant height and number of branches.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by days to first picking, days to first flowering and days to 50 per cent flowering indicated that these characters were highly influenced by environmental effects and consequently, their selection would be ineffective. Similar results were reporting Pathak and Jamwal (2002) for days to 50 per cent flowering, om vir and Singh (2014) for 50 per cent flowering.

5.3 Correlation coefficient analysis

A wide range of variation in quantitative characters provides the basis for selection in plant breeding programme. The knowledge of association among the characters is useful to the 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) for number of pods plant^{-1}.

Plant height (cm)

Plant height at 30 DAS showed significant and positive correlation with plant height at 90 DAS, number of branches plant^{-1} at 30 DAS, plant height at 60 DAS and pod weight. Significant and negative association of this character was observed with number of flower cluster plant^{-1} and pods plant^{-1}.

Correlation coefficient of plant height at 60 DAS showed highly significant and positive with number of branches plant^{-1} at 60 DAS, number of branches plant^{-1} at 90 DAS, plant height at 90 DAS, number of branches plant^{-1} at 30 DAS.

Plant height at 90 DAS expressed a highly significant and positive correlation coefficient with number of branches plant^{-1} at 90 DAS, number of branches plant^{-1} at 60 DAS, number of branches plant^{-1} at 30 DAS, pods cluster^{-1} and pod length. But it was exhibited significant and negative with number of flower cluster plant^{-1} and pods plant^{-1}. 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.

Number of branches plant^{-1}

Number of branches plant^{-1} at 30 DAS expressed significant and positive correlation with number of branches plant^{-1} at 60 DAS, number of branches plant^{-1} at 90 DAS, pods cluster^{-1} and flower cluster^{-1}, while, it was found significant and negative correlation with other traits like days to first flowering and days to 50 per cent flowering.

Number of branches plant^{-1} at 60 DAS was significantly and positively associated with number of branches plant^{-1} at 90 DAS, pods cluster^{-1} and flower cluster^{-1}, while, it was found significantly and negatively associated with days to 50 per cent flowering and pod weight.

Number of branches plant^{-1} at 90 DAS expressed significantly and positive association with pod length and pods cluster^{-1}, while, it was found significant and negative with days to 50 per cent flowering. 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}.

Days to first flowering

Association of days to first flowering was recorded significant and positive with days to 50 per cent flowering, while, it was found significant and negative with number of flower cluster^{-1} and number of pods cluster^{-1}. 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

Days to 50 per cent flowering was recorded highly significant and positive association with pods yield plant^{-1} and pod width. It was observed significant and negative correlation with flower cluster^{-1}. These results are in close harmony with the findings of Singh *et al*. (2004) for pod yield plant^{-1}.

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}. Also, significant and negative association was exhibited with number of flower cluster plant^{-1} and pod length. These results are in close harmony with the findings of Patil *et al.* (2005), Venkatesan *et al.* (2003) and Lal *et al.* (2007).

Number of flower cluster plant^{-1}

The correlation coefficient of number of flower cluster plant^{1} was found significant and positive correlation with pods plant^{-1}, days to first picking, and pod yield plant^{-1}, while, it was exhibited significantly and negatively association with pod weight , pods cluster^{-1} and pod length. These results are in close harmony with the findings of Dahiya *et al.* (2007) Cholin *et al*. (2007) and Singh *et al.* (2011).

Days to first picking

Days to first picking were not recorded highly significant and positive association with any character, while, it was found significant and negative with pod length, pod weight and seeds pod^{-1}. These results are in close harmony with the findings of Pathak and Jamwal (2002) and Venkatesan *et al.* (2003) and kutty *et al.* (2003)

Number of pods cluster^{-1}

Days to first picking was recorded highly significant and positive association with pods plant^{-1}, while, it was found significant and negative with pod weight and pod length. These results are in close harmony with the findings of Venkatesan *et al*. (2003).

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}. Also, significant and negative association was exhibited with pod weight, pod length, seeds pod^{-1} and pod width. These results are in close harmony with the findings of Dahiya *et al.* (2007), Baghizadeh *et al.* (2010), Cholin *et al.* (2012).

Pod length (cm)

Pod length was recorded highly significant and positive association with pod weight and seeds pod^{-1}, pod yield plant^{-1} and pods width. 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 (cm)

Pod width showed significant and positive correlation with pod weight.

Pod weight (g)

Pod weight expressed highly significant and positive association with number of seeds pod^{-1}. 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) and Baghizadeh *et al.* (2010).

Number of seeds pod^{-1}

The correlation coefficient was found significant and positive correlation with pod yield plant^{-1}.These results are in close harmony with the findings of Pathak and Jamwal (2002) Alege *et al.* (2007) and Sharma *et al.* (2007).

5.4 Path coefficient analysis

Correlation coefficients are the indication of simple association between variables. In a biological system, however the relationship may exist in a very complex form. It is therefore, essential to study the relationship among variable in a comprehensive way. Path coefficient analysis is a powerful tool, which enable portioning of the given relationships in its further components. In other words, it takes into account not only the relationship of component characters with the dependent character, but simultaneously takes care of its relationship with other component also. Thus, it helps in understanding the causal system in a better way because it enables portioning the total correlations coefficient into direct and indirect effects of various characters. Wright (1921) and Dewey and Lu. (1959).

In the present investigation, path coefficient analysis was carried out for characters under study using genotypic and phenotypic correlation coefficient and taking pod yield plant^{-1} as dependable variables, in order to see the causal factor and so as to identify the components which are responsible for producing 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 the different characters revealed that pod yield plant^{-1} showed that number of pods plant^{-1} had highest positive direct effect on 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. 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) for number of pods plant^{-1} 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 flowering, number of seeds pod^{-1} and pods cluster^{-1}. The results corroborated the findings of Vinieta *et al*. (2003) Mittal and singh (2005) for days to first flowering.

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 further improvement of yield.

Path coefficient analysis revealed that number of pods plant^{-1}, pod weight, number of flower cluster^{-1}, pod width, number of branches at 90 DAS, number of cluster plant^{-1}, days to first picking, plant height at 90 DAS and pod length, days to first flowering days to 50 per cent flowering, number of seeds pod^{-1} and pods cluster^{-1} were the most important characters contributing towards pod yield plant^{-1} and hence purposeful and balanced selection based on these characters would be made rewarding for improvement of cowpea.

5.5 Quality parameters

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

Colour of flower

Colour of flower was observed to be white, purple, light purple. Genotypes 2011/COPBVAR-7, 2012/COPBVAR -1, 2012/COPBVAR-2, 2014/COPBVAR-3 and Arka Garima exhibited purple colour flower. While, white colour flowers were observed in genotype 2012/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-4 and Gomti. Whereas, genotypes 2012/COPBVAR-3, 2012/COPBVAR-5, 2014/COPBVAR-2, Kasha Kanchan, 2014/COPBVAR-5 and 2014/COPBVAR-6 were observed light purple flowers. The results corroborated the findings of Kehind (2001).

Colour of pod

Colour of pods was observed to be dark green, green and light green. genotypes 2012/COPBVAR-2 and 2014/COPBVAR-6 exhibited dark green pods. Whereas, genotypes 2011/COPBVAR-7, 2012/COPBVAR-1, 2012/COPBVAR-3, 2012/COPBVAR-5, 2012/COPBVAR-6, 2014/COPBVAR-2, 2014/COPBVAR-4 and Kashi Kanchan were observed green pods. Remaining genotypes exhibited light green pods. The results corroborated the findings of Kehind (2001).

Pod Shape

Significant 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 2012/COPBVAR-1, 2012/COPBVAR-2, 2014/COPBVAR-1, 2014/COPBVAR-2 and Arka Garima. Genotypes

2011/COPBVAR-7, 2014/COPBVAR-3, Gomti and 2014/COPBVAR-6 were produced curved pod. The remaining genotypes produced slightly curved pods.

Stringiness in pod

Significant variation was observed among the genotypes for stringiness in pods i.e. fiber present or absent (Table 4.7). Fiber was present in genotypes 2012/COPBVAR-2, 2012/COPBVAR-3, 2014/COPBVAR-3, 2014/COPBVAR-6, 2014/COPBVAR -5 and Arka Garima. Fiber was absent in the 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-3, 2012/COPBVAR-6 and 2014/COPBVAR-6.Whereas, genotype 2014/ COPBVAR -3, 2014/COPBVAR -4 and Arka Garima produced less fleshy pods. The remaining genotypes produced fleshy pods

Seed colour

Color of seeds was observed to be cream, dark maroon, maroon and light maroon. Genotypes 2012/COPBVAR-2 and 2014/COPBVAR-4 exhibited light maroon seeds. Whereas, genotypes 2012/COPBVAR-1, 2011/COPBVAR-6 was observed maroon seeds. Genotypes 2011/COPBVAR-7, 2012/COPBVAR-3, 2012/COPBVAR-5 and Kashi Kanchan were observed dark maroon colour. Genotype 2014/COPBVAR-6 observed black colour. Remaining genotypes exhibited creamish seeds.

Incidence of pod borer (%)

Pod borer incidence was observed maximum in genotypes 2014/COPBVAR-4 followed by 2014/COPBVAR-3, 2014/COPBVAR-5 and Gomti was found to highly susceptible to pod borer. The low incidence of pod borer was found in genotypes Kashi Kanchan and 2011/COPBVAR-7. The results corroborated the findings of Shukla *et al.* (2009) and Cheema *et al.* (2011).

Incidence of Alterneria blight (%)

The incidence of Alterneria 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 results corroborated the findings of Berg *et al.* (2003).

SUMMARY, CONCLUSIONS 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 (*Vigna unguiculata* L.)**" was conducted at Horticulture Complex, JNKVV, Jabalpur (M.P.) during the year 2014-15. The experimental material consisting of fifteen 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 60 × 30 cm respectively and each plot accommodated 40 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 fallows.

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

The mean performance of the genotypes revealed a wide range of variability for all the traits. 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. 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, 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 their limited scope 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 high 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 positive correlation of pod yield plant^{-1} was observed with number of pod plant^{-1}, followed by days to 50 per cent flowering, number of flower cluster plant^{-1} and number of seed pod^{-1}.

The phenotypic expression of correlation was lessened possibly due to multiple influences of environmental components. In view of their correspondence, selection on phenotypic basis would be effective.

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, Pod borer incidence was observed maximum in genotypes 2014/COPBVAR-4, 2014/COPBVAR-3, 2014/COPBVAR-5 and Gomti.

The incidence of Alterneria 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.

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 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 Conclusions

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 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 PCV was higher than GCV for all the traits. The wide 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, pod width. The heritability estimate were observed very high for pod length followed by number of pods plant^{-1}, number of cluster plant^{-1}, pod weight, number of flower cluster plant^{-1} and pod width $^{-1}$.

The high 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}.

Association analysis revealed high significant and positive correlation of pod yield plant^{-1} with number of pod plant^{-1}, days to 50 per cent flowering, number of flower cluster plant^{-1} and number of seed 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.

The highest production observed in genotype 2012/COPBVAR-6 (134.38 q ha^{-1}) and 2014/COPBVAR (130.93 q ha^{-1}). The low incidence of pod borer was found in genotypes Kashi Kanchan and 2011/COPBVAR-7 and low incidence of Alternaria blight was found in the genotypes 2014/COPBVAR-6, 2014/COPBVAR-2 and 2014/COPBVAR-5.

6.3 Suggestions for futher work

1) Evalution of identified promising genotypes ovar location and year. So that the can be recommended for commercial cultivation.
2) Identified 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) Character 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

Table 4.1: Analysis of variance for various character of cowpea (mean sum of square)

Source of variation	D.F	Plant height (cm)			Number of branches plant^{-1}		
		30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
Replication	2	0.195	0.523	7.589	0.011	0.074	0.086
Genotype	14	1.817**	10.528**	73.035**	0.386**	0.529**	0.801**
Error	28	0.448	2.172	3.066	0.121	0.081	0.148

Source of variation	D.F.	Days to first flowering	Days to 50% flowering	Number of flower cluster^{-1}	Number of cluster plant^{-1}	Days to first picking
Replication	2	2.155	1.622	0.067	22.427	5.403
Genotype	14	10.688**	9.612**	1.776**	343.897**	17.229**
Error	28	2.655	1.717	0.094	10.611	1.898

Source of variation	D.F.	No. of pods cluster^{-1}	No. of pods plant^{-1}	Pod length (cm)	Pod width (cm)	Pod weight (g)
Replication	2	0.206	28.466	1.931	0.003	27.755
Genotype	14	1.049**	770.133**	86.974**	0.071**	379.89**
Error	28	0.065	21.585	0.501	0.002	10.731

Source of variation	D.F.	No. of seeds pod^{-1}	Pod yield plant^{-1} (g)	Pod yield plot^{-1} (kg)	Pod yield ha^{-1} (q)
Replication	2	0.962	173.422	0.647	127.827
Genotype	14	5.165**	2118.927**	3.431**	660.987
Error	28	0.610	295.565	0.431	83.183

Source of variation	D.F.	Incidence of pod borer (%)	Incidence of Alternaria blight (%)
Replication	2	35.13	0.27
Genotype	14	55.26**	2.01*
Error	28	7.65	0.72

CURRICULUM VITAE

The author of this thesis **Ramnarayan Khandait** S/O Shri Gurudas khandait was born 26th September, 1990 at Betul (M.P.). He passed the High School Examination in the year 2005 with 43.46 percent marks from Govt. B. H. Sec. School Bhainsdehi Betul (M.P.).and Intermediate Public Examination in the year 2007 acquirng 80.66 percent marks from Govt. B. H. Sec. School Bhainsdehi Betul (M.P.).

He joined the Jawaharlal Nahru Krishi Vishwa Vidyalaya, Jabalpur campus Ganjbasoda (M.P.) in the year 2009 and successfully completed the degree of B.Sc. (Ag) from Jawaharlal Nahru Krishi Vishwa Vidyalaya, Jabalpur campus Ganjbasoda (M.P.) during the year June, 2013 with First Division (7.70) 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 7.69 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 (*Vigna unguiculata L.*)"** This is duly completed by him and presented in the form of this thesis.

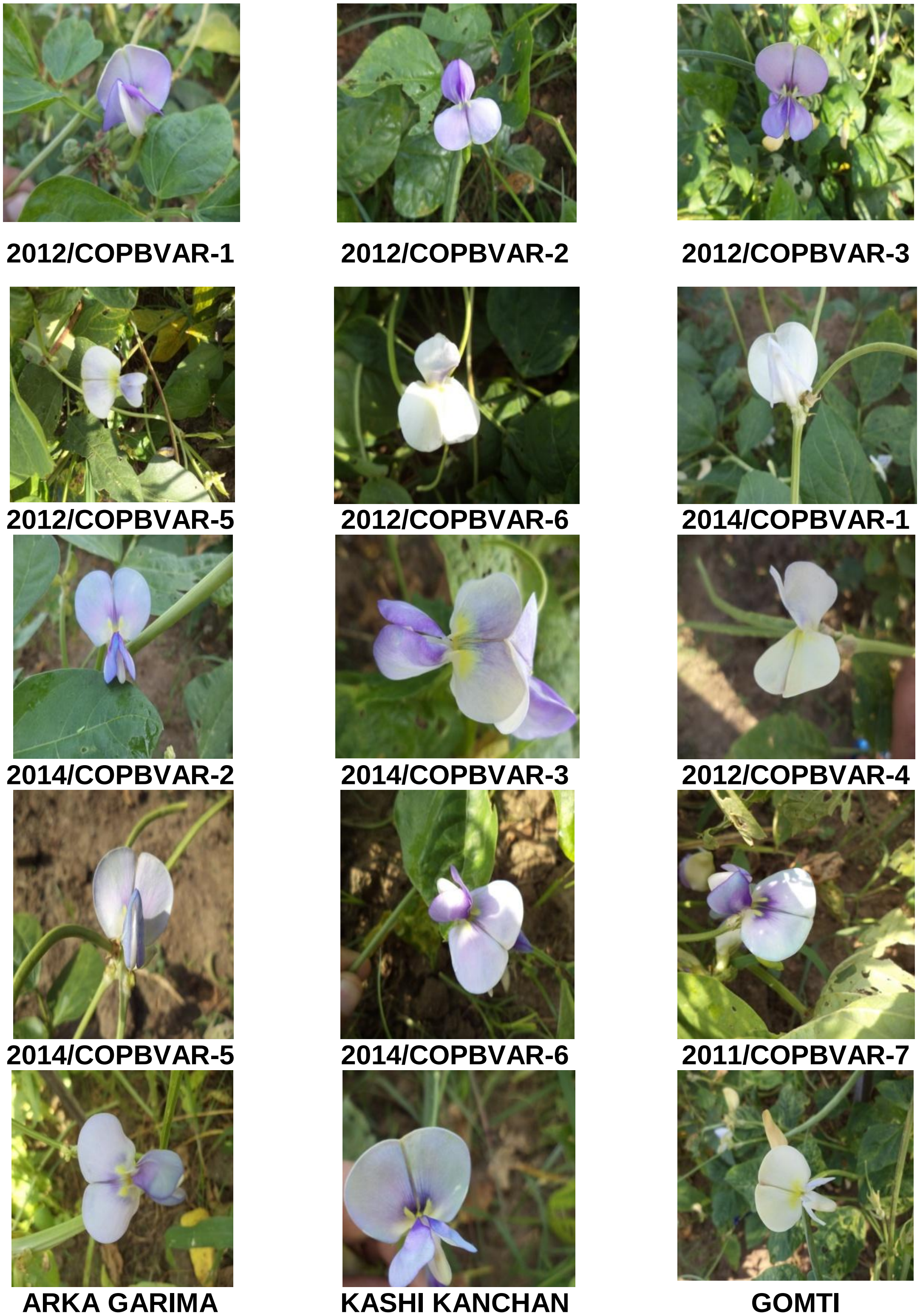

Plate 1. Sowing flower of different genotype under invitation

Plate 2. Sowing pods of different genotype under invitation

Plate 3. Sowing seed of different genotype under invitation