Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata*(L.)Walp.)]

THESIS

Submitted to
Babasaheb Bhimrao Ambedkar University
(A Central University)
Lucknow

BABASAHEB
BHIMRAO
AMBEDKAR
UNIVERSITY
LUCKNOW
प्रज्ञा शील करुणा
ESTABLISHED 1996

For the Degree of

Doctor of Philosophy

In

HORTICULTURE

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DEPARTMENT OF APPLIED PLANT SCIENCE (HORTICULTURE)
SCHOOL FOR BIOSCIENCES AND BIOTECHNOLOGY
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2018

Enrollment No. -302/13

Dedicated To

My

Loving Parents

Who gave me a lot of moral support and encouragement which can not be expressed in words.

Pushkar Singh Patel

DECLARATION

I, **Pushkar Singh Patel**,, Enrollment No. 302/13, hereby declare that I am a candidate for the degree of **Doctor of Philosophy in Horticulture**, Department of Applied Plant Sciences (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidhya-Vihar, Rae Bareli Road, Lucknow-226025 (U.P.), India and have carried out my research work entitled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata*(L.)Walp.)]".**This submitted for the award of the degree of Doctor of Philosophy in Horticulture is my original research work.

(Pushkar Singh Patel)

Date: 11/10/2018
Place: Lucknow

CERTIFICATE

This is to certify that the thesis titled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata*(L.)Walp.)]"** Submitted by Mr. **Pushkar Singh Patel,** Enrollment No. 302/13 is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedker University, Lucknow satisfies all the requirements as stipulated in the Doctor of Philosophy (Ph.D.) regulations- 1999 as amended in 2008/2010/2013 and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

Date: 11/10/18

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11/10/18

Head of the Department

ACKNOWLEDGEMENT

It is the contribution of one or more persons towards the task, which makes it successful. It gives me immense pleasure in acknowledging all the help that I have received during the period of research.

In my opinion, it is the "Almighty" before whom I should please for providing me courage and zeal to complete this manuscript by showering the endless blessings, with a world full of cheer, calm and peace.

First and foremost I express my deep sense of gratitude to my supervisor Prof. Sanjay Kumar, Department of Applied Plant Science (Horticulture), Lucknow, who is not only a teacher and guide to me, but my mentor and well-wisher too. His persistent encouragement, perpetual motivation, everlasting patience, constructive criticism and valuable technical inputs in research have benefitted me to an extent which is beyond expression. She not only trained me in science but in all aspects of life.

I wish to acknowledge in a deep sense of gratitude for Prof. R.B Ram, Professor and Head of Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University,

Lucknow, for providing me invaluable help, advice, encouragement and necessary lab facilities during the course of my research programme.

It is my deep sense to express my heartiest gratitude to Prof. Deepa Hansraj Dwivedi and Dr. Rubee Lata Department of Applied Plant Science (Horticulture), for her encouragement and help during the course of study.

Dr. M.L Meena, Dr. Sutanu Maji and Dr. Ravi Shankar Verma Department of Applied Plant Science (Horticulture), for his encouragement and help during the course of study.

I would like to take this opportunity to extend my gratitude to my seniors, batchmates and my juniors, Dr. Devendara Kumar, Mr. Rakesh Kumar Meena, Mr. Shashank verma, Sandeep Kumar Rajvanshi, Mr. Manoj Kumar, Mr. Rakesh Kumar Meena,Mr. Jitenendra Kumar Meena, Mr. D.C. Meena, Mr. Madhvendra Singh, Mr. Trivbhuvan Rai, Mr Ram Vilas, Mr. Pradeep, Mr. Lalit, Mr. Aman Shankar and Mr. Rajeev Kumar for their timely advices, encouragement, guidance and good will which enabled me to start and successfully complete my work.

I am also grateful to IIVR, Varanasi for providing Cowpea seeds for my research.

I express my unbound gratitude to my parents Mr. Raj Kumar and Smt. Phula Devi,brother Mr.Shashi Kant Singh, and sisters Smt. Shweta Singh, Smt. Kanak Lata, Smt. Digambareshwari. they always enlightened me to follow a righteous path in my life. They have been a constant source of inspiration and this work is especially dedicated to them.

Who directly or indirectly, gave encouragement and humorous company at BBAU, Lucknow. I am also thankful to all departmental staff members, especially Mr. Vinay Kumar, Office Assistant, Department of Applied Plant Science (Horticulture), BBAU, Mrs. Anita Tiwari, Laboratory Assistant, Mrs. Munni Devi, MTS, Mr. Anilesh Kumar Singh and finally,

I thank the Almighty for leading me all the ways towards successful completion of this work.I am also thankful to library section for the providing the facility of library during my research period and plagiarism.

Date: 11/10/18

Place: *Lucknow*

(Pushkar Singh Patel)

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LIST OF ABBEREVITIONS

ANOVA	:	Analysis of variance
CD	:	Critical Difference
cm	:	Centimeter
CV	:	Coefficient of variation
per se	:	As such with mean
et al.	:	and others
Fig	:	Figure
g	:	Gram
kg	:	Kilogram
m	:	Meter
ha	:	Hectare
mg	:	Milligram
SE (d)	:	Standard error difference
S.Em	:	Standard error mean
df	:	Degrees of freedom
RBD	:	Randomized Block Design
Vit-C	:	Ascorbic Acid
viz.,	:	Namely
vs.	:	Against
No.	:	Number

HD	:	Half dialed
FD	:	Full dialed
GCA	:	General combining ability
SCA	:	Specific combining ability
gca	:	General combining ability
sca	:	Specific combining ability
$\sigma^2 GCA$	:	Variance due to General combining ability
$\sigma^2 SCA$	:	Variance due to Specific combining ability
Cov. (F.S)	:	Covariance of Full sib
Cov. (H.S)	:	Covariance of Half sib
F_1	:	First Filial Generation
i.e.	:	That is
@	:	at the rate of
SS	:	Sum of Squares
MSS	:	Mean Sum of Squares
%	:	per cent
@	:	at the rate of
&	:	And
^0C	:	degree Celsius
A.P	:	Andhra Pradesh
VRS		Vegetable Research Station

CHAPTER-1

INTRODUCTION

CHAPTER-1 *INTRODUCTION*

Cowpea [*(Vigna unguiculata* (L.) Walp.)] chromosome No. (2n=22) belongs to the family Leguminosae also known as southern pea and black eye pea, is one of the most important vegetables. It is cultivated for its long, green or purplish pods to be cooked as vegetable or for dry seeds used as pulse. Its foliage is also used as fodder or green manure, producing 20-30 cm long pod and elongated kidney shaped, 8-12 mm long seeds. It is important as a pulse and vegetable crop and enriches soil fertility by fixing atmospheric nitrogen. Cowpeas are of ancient cultivation in Asia and Africa where immense diversity in *V. unguiculata* occur.

The sub species *sesquipedalis*is widespread in the humid tropics of India **(Verdcourt, 1970; Purseglove, 1974).** Moreover it will have spill over benefits to their farmlands through, for example, *in situ* decay of root residues, use of animal manures, and ground cover. In addition, because the seed is widely traded out of the major production areas, it provides a cheap and nutritious food for relatively poor urban communities (Singh and Sharma, 1997). There is now a common view that cowpea can play a significant role in farming systems where low inputs including animal fertilizer application can be justified.

Cowpea is commonly cultivated as a nutritious and highly appetizing food source in Asia and throughout the tropics and sub-tropics. Green pod of cowpea contains 85 g moisture, 3.0 g protein, 1.0 g minerals, 2.0 g fiber, 8.0 g carbohydrates, 72 mg calcium, 59 mg phosphorus, 2.0 mg

iron, 0.09 mg riboflavin and 0.07 mg thiamin per 100 g of edible portion. **(Anonymous , 2011).**

India has emerged as the second largest producer of vegetables next to only China. Occupying around 3.0% of the total cropped area. The share of India in vegetable production in the world is about 13.60% with an annual productivity of 15 tonnes per ha. Total vegetable production in the country has been estimated to be about 175.01 million tonnes from an area 10.29 million hectare **(NHB, 2017).** According to ICMR about 300 g vegetables (125g leafy, 100g root and 75g other vegetables) per capita per day is required. But the availability of vegetables in India is only 180g per capita per day, which is very low as compared to the recommended intake.

The climatic requirements of cowpea crop are similar to grain sorghum. On as little as 300 mm rain spread over the growing season, cowpea can produce a yield of up to one-ton seed and six tons of hay **(Claufurd*et al.*, 1996).** It is ideally suited to tropical lowlands, doing well in hot, dry and humid ecosystems **(Nwokolo and Smart, 1996).** Cowpea is thus an important seed crop grown throughout Africa and it is popular among the resource-poor farmers in the Limpopo Province of South Africa. Despite the importance of cowpea in sustaining livelihood of the rural communities, seed yield of the crop has always remained low and variable. Poor production practices including choice of cultivar, adaptability as well as lack of information on the right plant planting date has contributed to low cowpea productivity. There are diverse cowpea genotypes demanding a site specific directed management approach that include, among others, choice of proper planting date and a selection of best adapted genotypes. With all its different uses and its different advantages, cowpea is a viable and high potential alternative crop. Due to

its versatility in yielding high protein and fodder, there is a need to expand production that could be met by growing high yielding varieties **(Delacy *et al.*, 1990).**

Different varieties of cowpea have been bred recently, however, there is no detailed information yet on their specific planting date requirements and site specific adaptations **(Coetzee, 1990).** Research on cowpea production, improvement and utilization has been limited in South Africa as cowpea was regarded a rural crop with no industrial use. The lack of high yielding cultivars, which are drought tolerant and resistant to pests and diseases, as well as the unavailability of guaranteed market to dispose excess produce slowly relegated this nutritious pulse. Low seed yields can be attributed to unfavourable agronomic practices by farmers e.g. selection of suitable planting date.

These challenge researchers to find the most appropriate planting date using high yielding and early maturing varieties of cowpea **(Rachie, 1985).** Improved varieties of cowpea with resistance or tolerance to biotic and a biotic stresses can provide a powerful stimulus for rural development because they enhance the productivity, product quality, profitability and sustainability of farming systems with minimal input. Such varieties especially benefit resource poor farmers that cannot afford inputs such as insecticides and fertilizer **(Coetzee, 1990).**

There is therefore, strong need for genetic improvement and development of cowpea varieties with acceptable traits for exploiting different markets in South Africa. Varietal requirements of cowpea in terms of plant type, seed colour, maturity date and usage patterns are extremely diverse from region to region, making breeding programs for cowpea more complex than for other crops. No single variety cans be

suitable for all conditions **(Becker, 1988).** There is also a need to develop resistance to biotic and a biotic constraint in South Africa. The International Institute of Tropical Agriculture (IITA) has been able to breed cowpea varieties that yield close to four tons/ha. This level of production may be possible in South Africa by improving the overall productivity of cowpea through use of improved varieties and cultural practices.

Vegetables are rich and comparatively cheaper source of vitamins. The importance of vegetable crops in India can be judged from the fact that the majority of Indian population is vegetarian. India produces the largest variety of vegetables. Consumption of vegetable provides taste, palatability, increases appetite and provides fiber for digestion and prevents constipation. They also play key role in neutralizing the acids produced during digestion of pretentious and fatty foods and also provide valuable roughages which help in movement of food in intestine.

However, they are all species of [*Vigna unguiculata* (L.) Walp.], which in older reference may be identified as [*Vigna sinensis* (L.)Walp.] **Quinn, (1999).** There are mainly two types of cowpeas growing in India for grain and vegetable purposes. Generally grain type cowpea varieties produce short pods with more number of seeds and mature early whereas vegetable type varieties produce long pods with less number of seeds and mature late and the pods remain tender and soft for longer period. Cowpea is generally grown in marginal land with little or no inputs and therefore the yield is very low.

It is an annual herb with a strong principal root and many spreading lateral roots in surface soil. The root system having largest nodules is more extensive than those of soyabean. *Brady rhizobiuim* spp are the

specific symbiotic nodular bacteria. Growth forms vary and may be erect, trailing, climbing or bushy, usually indeterminate under favourable conditions. Leaves are alternate and trifoliate usually dark green. The first pair of them is simple and opposite. Stems are striate, smooth or slightly hairy, sometimes tinged with purple. Generally, cowpea grows in areas of low rainfall as high rainfall lead to crop failure. Many of the cowpea phenotype exhibit heat induced suppression of floral bud development, which result in two weeks delay in flowering when plant are found in very hot field environment under long days **(Ehlers and Hall, 1997).** A mean temperature of 27^0C is optimum for pod formation and seed yield, though; it performs better in region with rainfall of 250-100mm per annum. Loamy soil is considered the best for the cultivation of cowpea with a pH value of 6-7 for optimum growth. Varieties with shorter maturity dates are available for gardeners with a less lengthy summary. Cowpea is called as vegetable meat due to high amount of protein in grain with better biological value on dry weight basis. On dry weight basis, cowpea grain contains 23.4 per cent protein, 1.8 per cent fat and 60.3 percent carbohydrates and it is rich source of calcium and iron **(Gupta, 1988).** Apart from this, cowpea forms excellent forage and it gives a heavy vegetative growth and covers the ground so well that it checks the soil erosion. As a leguminous crop, it fixes about 70-240kg/ha of nitrogen per annum. Cowpea is mainly grown in tropical and subtropical regions in the world for vegetable and seed purpose and to lesser extent as a fodder crop **(Rangel *et al*., 2004).**

The essentiality of increase in productivity is the present challenge to the crop improvement field. The present day cultivars exhibit lower productivity, non synchronous flowering and fruiting, unresponsive to high doses of inputs like fertilizers, irrigation, and tillage *etc*., no

suitability of the various cropping systems, lodging and shattering susceptible, long duration, complete or partial absence of genetic resistance to major insect pest and diseases like mosaic virus, rust, powdery mildew and bacterial blight which cause considerable damage and very poor harvest indices. Development of cultivars with early maturity, acceptable grain quality, resistance to some important diseases and pests has significantly increased the yield and cultivated area **(Ehlers and Hall, 2007).** Understanding of the genetic variability of cowpea is important to design and accelerate conventional breeding programmes.

Collection, characterization and evaluation of available cowpea germplasm, quantification of the magnitude of diversity and classification into groups facilitate identification of genetic variability that enables breeders to select traits of interest for an improvement programme. Information on the nature and degree of genetic diversity would assist plant breeders in choosing the best genotypes as parents for hybridization **(Souza and Sorrells, 2005).**Yield being a complex trait, is influenced by many other important yield contribute environmental factors could help to maintain genetic diversity and sustain long term selection gain. On evaluation and genetic improvement on components of grain yield such as pods/plant, pod length, seed low improving cowpea yield potential (descriptors in sequential fashion is useful and convenient to discriminate the different varieties **(Joshi *et al.*, 2003).** Among the different pulses grown in the world, cowpea is grown in14.13 million hectare with production of 4.51 (‘000 MT) and the productivity of387.45 kg ha-1. In India, the cowpea is grown in an area of about 3.91 million hectare with a production of 2.22 (‘000 MT) having a productivity of 564.15 kg seed ha-1 and in Madhya Pradesh its covering area and production is very minor **(Shivnanda, 2005).**

The development of cultivars with early maturity, acceptable grain quality, resistance to some important diseases and pests has significantly increased the yield and cultivars area **(Ehlers and Hall 1997)** yield being a complex trait, is influenced by many other important yield contributing characters controlled by polygene and also environment factors. So, in these characters, observed variability is the sum total of hereditary effects ofconcerned 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 programme for genetic improvement of cowpea. To give a better insight of ancillary characters under selection, correlation coefficient analysis are the tools, which are being effectively used for determining the rate of various yield components in different crops, leading to the selection of superior genotypes. The phenotypic correlations of yield with growth attributes and path coefficient analysis become useful technique for crop improvement programmes to select the desirable traits **(Ahmed and Kamaluddin, 2013).**

Direct selection for the yield is not much effective as quantitative characters are controlled by polygenes. Hence, knowledge about association of character which will directly or indirectly contribute to yield is crucial.

Correlation coefficients explain the degree of association among the characters. However, it is difficult to explain a system of correlation when the indirect association between the characters increases. The method of path coefficient analysis development by **Wright (1921)** is

helpful in partitioning correlation into direct and indirect effects and in the assessment of relative contributions of each component to the yield.

There is great scope for genetic improvement in cowpea with regards to yield and quality. The success of most crop improvement programme largely depends upon the genetic variability and heritability of desirable traits. The magnitude and type of genetic variability help the breeder to determine the selection criteria and breeding scheme to be used for improvement purpose.

Keeping in view of the above facts, the present investigation entitled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata* (L.) Walp.)]"** has been undertaken to generate information about general and specific combining ability effects, genetic variability, heritability, genetic advance, correlation coefficient and path analysis with the following objectives:

1. To find out the genetic variability, heritability and genetic advance of cowpea.
2. To determine genotypic and phenotypic coefficient of variation for different yield and yield attributing traits of cowpea.
3. To assess the correlation coefficient and path coefficient analysis among the various traits of cowpea.
4. To ascertain the quality attributing traits of cowpea.

CHAPTER-2

REVIEW OF LITERATURE

CHAPTER-2 *REVIEW OF LITERATURE*

Cowpea [*(Vigna unguiculata* (L.) Walp.)] is one of the most Important leguminous vegetable crops of India. The morpho types grown in the state mainly belongs to three groups *viz*, grain type *(V. unguiculata*ssp. *Catjang* Wall), vegetable type (yard long bean) *(V. unguiculata* ssp. *Sesquipedalis* (L.) Verdcourt) and dual purpose type *(V. unguiculata* ssp. *cylindrica)* **Gopala krishnan, (2004).** Even though a lot of work has been done on grain cowpea, very little attention has been paid to the improvement of vegetable types. The review of literature is presented under following sub headings.

2.1 Analysis of variance for the design of experiments

2.2 Mean performance of genotypes

2.3 Estimates of variability, heritability and genetic advance in percent of mean

2.4 Genotypic and Phenotypic Correlation coefficient

2.5 path coefficient analysis

2.1 Analysis of variance for the design of experiments

Meena *et al.*, (2015) evaluated 72 genotypes of cowpea to estimate genetic variability, of ten quantitative characters. Analysis of variance revealed highly significant difference among genotypes for all the characters indicated that considerable amount of genetic variability was present in the experimental material which can be exploited for improvement of seed yield in cowpea. Genotypic and phenotypic variance were recorded highest for length of plant (358.69, 378.69)

followed by pod wall proportion (38.30, 41.27) and lowest for primary branches perplant (0.30, 0.50).

Mehta *et al*., (2014) studied the genetic variability in M_2 and M_3 generation. Analysis of variance in M_2 and M_3 population showed significant differences among the treatments for all the twelve genotype for their yield and its attributing characters under study except protein per cent. For all the characters under study in both the generations, phenotypic coefficient of variation was higher in magnitude than genotypic coefficient of variation. High GCV as well as PCV was obtained in M_2 and M_3 generation for traits number of primary branches per plant, protein percent, yield per plant and hundred seed weight.

Rana *et al*., (2014) were collected cowpea genotypes from different places in the country and evaluated for different horticultural traits for genetic variation, character association. Genetic diversity was measured among the genotypes through D^2 statistics. All the eight characters under study differed significantly among the genotypes. Association studies revealed that genotypic correlation coefficients were higher than their phenotypic correlation coefficients in most of the cases. From the correlation and path analysis, it can be concluded that emphasis should be given on number of pods per plant and pod weight for selecting high yielding genotypes. Based on the degree of mean performance the genotypes were grouped into seven clusters. The top three characters which contributed most towards the mean performance were number of seeds per pod, pod yield per plant and pod weight.

Girish *et al*., (2006) evaluatedone hundred genotypes of cowpea for variability, for eleven quantitative characters. Wide range of variability was observed for most quantitative characters. Length of plant and seed yield showed highest phenotypic and genotypic variance, while primary and secondary branches showed lowest variances. The magnitude of Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), (h_2) and (GA) was high for seed yield per plant, number of pods per plant and length of plant. Days to first flower opening, days to 50% flowering and days to maturity were recorded low.

Zargar *et al*., (2005) evaluated thirty-two genotypes of cowpea for variability, for seven traits (days to 50% flowering, length of plant (cm), number of pods/plant, pod length (cm), number of seeds/pod, seed yield (g)/plot and 100-seed weight). Significant variation among the genotypes was evident for all the traits. A good variation was recorded for seed yield/plot, 100-seed weight, length of plant, number of pods per plant, number of seeds per pod and pod length. The magnitude of the phenotypic coefficient of variation (PCV) was higher than that of the genotypic coefficient of variation (GCV) for all the traits studied. High GCV and PCV were recorded for length of plant, number of pods per plant, seed yield per plot and 100 seed weight. High coupled with high genetic gain was observed for length of plant (96.39 and 90.78%), number of pods per plant (67.84 and 38.39%), seed yield per plot (175.02 and 122.83%) and 100 seed weight (37.40 and 39.34%).

Nkouannessi *et al*., (2005) found that the magnitude of the phenotypic coefficient of variation (PCV) was higher than that of the genotypic coefficient of variation (GCV). High GCV, PCV were recorded for length of plant and dry matter production. Length of plant,

number of pods per plant, pod length, 100 seed weight, seed yield, and dry matter production were characterized by very high.

Nigude *et al*., (2004) studied the variability, correlation and path coefficients in 45 cowpea genotypes. The genotypic (GCV) and phenotypic coefficients of variation (PCV) were higher for length of plant, grain yield per plant and number of pods per plant. The magnitude of PCV was higher than GCV for all the characters studied. In broad sense was higher for all the characters except number of seeds per pod.

Venkatesan *et al*., (2003) evaluated twenty genotypes of cowpea for variability, for 12 traits (number of days to first flower, length of plant, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod yield per plant, pod length, number of seeds per pod, 100 seed weight, seed yield per plant, and dry matter production). Significant variation among the genotypes was evident for all the traits. The greatest variation was recorded for length of plant.

Arora *et al*., (2003) evaluated ten diverse genotypes of cowpea for 8 morphological characters (hypocotyl length, epicotyl length, seedling height, length and diameter of first pair of true leaves, petiole length of first trifoliate leaf and fresh and dry weight of seedlings) at seedling stage.

Ushakumari *et al*., (2000) employed D^2 analysis in fifty genotypes of cowpea and grouped all into 13 clusters. IT-86-F-310-6 gave the highest values for number of branches, pod length, and seeds per pod, while IT-87-D-272 gave the highest values for plant height, clusters per plant, pods per cluster, and single plant yield. The highest

contributions towards divergence were recorded for plant height (22.69%), seeds per pod (17.63%), number of branches (16.82%), number of pods per cluster (15.27%) and pod length (13.47%).

2.2 Mean performance of genotypes

Aswathi *et al.*, (2015) carried out an investigation with seeds of ten cowpea varieties to study the mean performance of the varieties with respect to storability and seed quality parameters. The seeds were evaluated for four seed quality parameters *viz*., germination, speed of germination, seedling vigour index I and seedling vigour index II and diversity was assessed using Mahalanob is D_2 analysis after ten months of storage under ambient conditions. There was significant variation for the quality aspects related to storage. Variety Kashi Kanchan had a germination of 61.67 per cent after ten months of storage. On the basis of D_2 values the genotypes were grouped into four clusters. Cluster I was the largest containing four varieties **(Lola, Vellayani Jyothika, Vyjayanthi and Anaswara).** The maximum inter-cluster distance was recorded between clusters I and IV (Hridya and Bhagyalakshmi). The maximum intra-cluster distance was found in cluster IV followed by I. Varieties Kana kamony and Kashi Kanchan grouped in cluster II and Kairali and Sreya in cluster III.

Badhe *et al.*, (2015) concludedbased on D_2 statistic, the forty genotypes of cowpea from different geographical origin was grouped into six clusters indicating wider genetic diversity. The clustering pattern indicated the absence of relationship between genetic diversity and geographical origin of genotypes. Intercrossing among them would lead to upgrade genetic base in the base population and opportunities to obtain

high heterotic effects. It will helpful to recover desirable transgressive segregants and wide spectrum of variability in subsequent generations Estimation of the degree of the mean performance between biological populations and computation of relevant contributions of different components to the total mean performance is donecompletely by Mohalanobis's generalized distance estimated by D_2 statistic (**Nair and Mukharjee, 1960 and Mourya and Singh, 1977). (Nair and Mukharjee (1960)** were the pioneers to use D_2 statistic as measure of mean performance in the field of plant breeding for classification ofteak plants.

Aswathi *et al*., (2015) studied the mean performance of the ten cowpea varieties with respect to storability and seed quality parameters. The seeds were evaluated for seed quality parameters,*viz*., germination and speed of germination. There was significant variation for the quality aspects related to storage. Variety Kashi Kanchan had a germination of 61.67 per cent after ten months of storage.

In yard long bean, significant differences among genotypes were observed for petiole length and length and breadth of terminal as well as lateral leaflets **(Resmi, 1998). (Borah and Khan 2000)** reported low pev and GeV for leaflet length.

Bhardwaj *et al*., (2014) were conducted field experiment in the *Kharif* 2012 to estimate genetic variability, correlation and path co-efficient studies in sixty genotypes of cowpea were evaluated for eleven morphological traits *viz*., length of plant, leaf length, leaf diameter, number of branches, stem girth, number of leaves, number of pods, seeds per pod, pod weight, 100 seed weight and seed yield per plant. The high range of variability was observed for length of plant (117.2-261.5),

number of leaves (194-568), pod weight (10-105) and seed yield per plant (3.12-225.05) while rest of the traits showed medium range of variability. The highest value of PCV (Phenotypic coefficient of variation) and GCV (Genotypic coefficient of variation) were recorded for seed yield per plant (108.91, 108.86) followed by number of pods (66.12, 65.05), pod weight (49.1, 48.37) and 100 seed weight (28.88, 27.92). In general, the genotypic correlation coefficients were higher in magnitude than the phenotypic correlation coefficients. Seed yield per plant was highly significant and positively correlated with number of pods per plant (0.92, 0.90), pod weight (0.90),

Adewale *et al*., (2010) studied the grain yield components of eleven cowpea genotypes to understand the sensitivity of the quantitative traits to heterogeneous environments. Significant genotypic variation in pod length was only in 2007. 100 seed weight and pod yield were significantly influenced by the effect of genotype, year and their interactions. Seeds per pod, 100 seed weight and pod length had fairly high relative genetic gain resulting from high GCV, PCV and repeatability; indicating their low sensitivity to G x E.

Ogbonnaya *et al.*, (2003) evaluated cowpea genotypes varying in drought tolerance for collar diameter and root: shoot ratio in hydroponics. Based on the results, selection of cowpea for vigorous growth under well watered conditions could be conducted by means of hydroponics.

Narayanan kutty *et al*. (2003b) observed that number of pods per plant, followed by average weight of pods and number of pickings, had the greatest positive direct effects on pod yield. The direct effects of pod length and days to first picking were low mainly due to high indirect effects via average weight of pods and number of pickings.

Subbaiah *et al*. (2003) revealed that the number of pods per plant had strong positive direct effect as well as indirect effects through various traits on green pod yield. The other traits namely number of branches per plant, pod length, pod weight, and number of seeds per pod also had strong positive influence on green pod yield.

Venkatesan *et al*. (2003a) evaluated 20 genotypes of diverse origin and path analysis showed positive direct effect on number of pods per plant, pod length, clusters per plant, seeds per pod and hundred seed weight on yield.

Yadav *et al*. (2003) recorded dry matter in pod, pods per plant, seeds per pod and plant height are main components of green pod yield per plant in path analysis studies.

Ushakumari *et al.*, (2002) reported that contribution towards mean performance was recordedfor length of plant (22.69%), seeds per pod (17.63%), number of branches (16.82%), number of pods per cluster (15.27%) and pod length (13.47%) in cowpea.

Kapoor *et al.*, (2000) revealed that the number of seeds per pod and 100 seed weight were the main contributing characters towards the seed yield. Pod length contributed indirectly towards seed yield via the number of seeds per pod and 100 seed weight in the study involved 160 genotypes of cowpea. The direct effect of pod yields on grain yield and genotypic correlation between pod yield and grain yield were almost equal.

(Neema and Palanisamy, 2001) and they also reported that the highest positive direct effect on grain yield was recorded by pod yield and the lowest by pod length. The indirect effect was maximum for pod length via pod yield.

Most of the reports on genetic variability showed a wide range of variability for length of plant with moderate to high and high, based on studies varying number of genotypes and there were few reports based on the segregating material. A report showed moderate and moderate (**Patil and Patil, 1986). Rangaiah and Nehru (1998)** indicated low (5.61%) with 6%.However, **Selvi *et al., (*1994)** revealed that high (99.89%) with moderate GCV and PCV values.

Kumar *et al., (*2002) reported for green fodder yield per plant, number of days to 50% flowering, length of plant and dry fodder yield per plant in the study involved five cultivars. In general, genotypic coefficient of variation was found to be higher than the corresponding phenotypic coefficient of variation for this character.

2.3 Estimates of variability, heritability and genetic advance in percent of mean

Wide range of variability was reported for days to first flowering by **Pandita *et al.,* (1982),** while moderate and low PCVv and GCV were found by Singh and Verma (2002) and Philip (2004) respectively.

High genetic variability was observed for peduncle length by several workers **Trehan *et al.,* (1970).** The genomic relationship between subspecies *unguiculata* and *sesquipeda* is was studied by **Neema (1986)** and reported higher pollen fertility in subspecies *sesquipedalis.* Singh and **Dapaafi. (1998)** characterized a partial male sterile line of cowpea

(IT85D-3626) based on morphology, pollen viability and pod set. Partial male sterile plants were found to have 77.0 per cent pollen viability compared to 98.3 per cent in normal plants.

Genetic variability in the base population is a pre-requisite for effective crop improvement. Considerable variation for several characters in cowpea was reported by **Radhakrishnan and Jebaraj (1982), Sobha and Vahab (1998), Kumar and Sangwan (2000) and Venkatesan *et al.*, (2003).**

Wide range of variation for plant height was reported by **Pandita *et al.*, (1982), Anbuselvam *et al.*, (2000), Rangaiah and Mahadevu (2000) and Singh and Verma (2002). Pekoen and Artuk (2004)** compared some cowpea genotypes fromTurkey and reported significant differences for days to seedling emergence.

Effectiveness of selection depends upon the heritability and genetic advance of the character studied. High heritability coupled with high genetic advance for several characters was reported by several workers in cowpea **(Ajith, 2001 Philip, 2004).**

2.4 Genotypic and Phenotypic Correlation coefficient

Badhe *et al.*, (2015) concluded based on D2 statistic, the forty genotypes of cowpea from different geographical origin was grouped into six clusters indicating wider genetic diversity. The clustering pattern indicated the absence of relationship between genetic diversity and geographical origin of genotypes. Inter crossing among them would lead to upgrade genetic base in the base population and opportunities to obtain high heterotic effects. It will helpful to recover desirable trans gressive segregants and wide spectrum of variability in subsequent generations

Estimation of the degree of the mean performance between biological populations and computation of relevant contributions of different components to the total mean performance is done completely by Mohalanobis's generalized distance estimated by D2 statistic **(Nair andMukharjee, 1960 and Mourya and Singh, 1977).**

Aswathi *et al*., (2015) studied the mean performance of the ten cowpea varieties with respect to storability and seed quality parameters. The seeds were evaluated for seed quality parameters, *viz*., germination and speed of germination. There was significant variation for the quality aspects related to storage. Variety Kashi Kanchan had a germination of 61.67 per cent after ten months of storage.

The relationship between various plant characters gives the measurement of correlation coefficients, which will give an indication for breeders. The extent of observed relationship between two characters is known as simple, total phenotypic correlation. Environmental correlation is the measure of environmental influence on the covariance between the two characters in question. **Patil *et al.*, (1989**) reported that the grain yield was highly correlated with pods per plant, 100 seed weight, clusters per plant, pod length and days to 50% flowering based on diallele cross involving ten diverse indigenous lines and varieties of cowpea.

This character is highly variable and highly heritable. Most of the reports Indicated moderate to high with low. A moderately high with moderate value of was reported by **Mehta and Zaveri (1999),** while **Rangaiah and Nehru (1998)** reported low to moderate estimates for number of branches with very low in cowpea. **Madhusudhan (1994),** reported high heritable values of 96.21 per cent in F1 materials, while in Balraju 1997, reported that, low (14.2%) for this trait. Many reports

indicated that low to high rangingfrom 0.6 **Apte *et al.*, (1987)** to 13.43 **Balraju, (1997). Apte *et al.*, (1987)** reported moderate GCV (17.39%) and high PCV (79.18%) for the character while Rangaiah and Nehru (1998) reported high GCV and PCV.

The relationship between various plant characters gives the measurement of correlation coefficients, which will give an indication for breeders. The extent of observed relationship between two characters is known as simple, total phenotypic correlation. Environmental correlation is the measure of environmental influence on the covariance between the two characters in question. **Patil *et al.*, (1989)** reported that the grain yield was highly correlated with pods per plant, 100 seed weight, clusters per plant, pod length and days to 50% flowering based on diallele cross involving ten diverse indigenous lines and varieties of cowpea.

Bhardwaj *et al*., (2014) were conducted field experiment in the *Kharif* 2012 to estimate genetic variability, correlation and path co-efficient studies in sixty genotypes of cowpea were evaluated for eleven morphological traits *viz*., length of plant, leaf length, leaf diameter, number of branches, stem girth, number of leaves, number of pods, seeds per pod, pod weight, 100 seed weight and seed yield per plant. The high range of variability was observed for length of plant (117.2-261.5), number of leaves (194-568), pod weight (10-105) and seed yield per plant (3.12-225.05) whilerest of the traits showed medium range of variability. The highest value of PCV (Phenotypic coefficient of variation) and GCV (Genotypic coefficient of variation) were recorded for seed yield per plant (108.91, 108.86) followed by number of pods (66.12, 65.05), pod weight (49.1, 48.37) and 100 seed weight (28.88, 27.92). In general, the genotypic correlation coefficients were higher in magnitude than the

phenotypic correlation coefficients. Seed yield per plant was highly significant and positively correlated with number of pods per plant (0.92, 0.90), pod weight (0.90,0.89), 100 seed weight (0.57, 0.55), leaf length (0.56, 0.90), leaf diameter (0.27, 0.11)and seeds per pod (0.22, 0.14), respectively.

Diaga *et al.*, (2011) found that pod dry weight and grain yield was significantly correlated with root and shoot dry weights. If vegetative growth is profuse, it had negative effect on grain yield and resulting reduction of harvest index.

Ullah *et al.*, (2011) examined twenty genotypes of cowpea for path analysis. The maximum direct positive effect was observed by pod weight followed by number of pods per plant towards pod yield. Pod weight also exerted positive indirect effect through days to first flowering, pod length, pod diameter, days to marketable harvest and number of pods per plant. Likewise, number of pods per plant exerted positive indirect effect via days to first flowering, pod length, pod diameter, pod weight and days to marketable harvest. However, number of pods per plant depicted negative indirect effect via seeds per pod.

Adewale *et al.*, (2010) studied the grain yield components of eleven cowpea genotypes to understand the sensitivity of the quantitative traits to heterogeneous environments. Significant genotypic variation in pod length was only in 2007. 100 seed weight and pod yield were significantly influenced by the effect of genotype, year and their interactions. Seeds per pod, 100 seed weight and pod length had fairly high relative genetic gain resulting from high GCV, PCV and repeatability; indicating their low sensitivity to G x E.

Grish *et al*. (2006) evaluate done hundred genotypes of cowpea for variability, for eleven quantitative characters. Wide range of variability was observed for most quantitative characters. Length of plant and seed yield showed highest phenotypic and genotypic variance, while primary and secondary branches showed lowest variances.

The magnitude of Phenotypic Coefficient of Variation (PCV), Genotypic Coefficientof Variation (GCV), (h2) and (GA) was high for seed yield per plant, number of pods per plant and length of plant. Days to first flower opening, days to 50% flowering and days to maturity were recorded low.

Nkouannessi *et al*., (2005) found that the magnitude of the phenotypic coefficient of variation (PCV) was higher than that of the genotypic coefficient of variation (GCV). High GCV, PCV were recorded for length of plant and dry matter production. Length of plant, number of pods per plant, pod length, 100 seed weight, seed yield, and dry matter production were characterized by very high.

Nigude *et al*., (2004) studied the variability, correlation and path coefficients in45 cowpea genotypes. The genotypic (GCV) and phenotypic coefficients of variation (PCV) were higher for length of plant, grain yield per plant and number of pods per plant. The magnitude of PCV was higher than GCV for all the characters studied. In broad sense was higher for all the characters except number of seeds per pod.

Belhekar *et al*., (2003) revealed that by studying F_2 generation, the seed yield per plant exhibited positive and significant correlation with length of plant, number of flowers per plant, first pod maturity,

complete maturity, number of pods per plant and 100 seed weight both at the phenotypic and genotypic levels. However, it showed a negative and significant correlation with the number of pods per peduncle and seed index.

Venkatesan *et al.*, (2003) stated that the numbers of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant and pod yield were positively correlated with seed yield at the genetic and phenotypic levels by studying correlation and path analysis in 20 genotypes of cowpea. The magnitude of genetic correlation was higher than that of phenotypic correlation. The number of clusters per plant was positively associated with number of branches per plant, number of pods per cluster and number of pods per plant, but was negatively correlated with number of days to flowering, 100seed weight, and dry matter production. The number of branches per plant and number of pods per cluster exhibited few significant associations with the other traits. Based on the above reviews, it is clear that number of pods per plant, number of seeds per pod, 100 seed weight and pod length have positive significant association with yield. These characters can be considered during selection for yield improvement.

Kumari *et al.*, (2003) reported significant genetic variation for most of the traits by studying genetic variation and correlation analysis in 50 cowpea genotypes. The phenotypic coefficient of variation (PCV) was higher than the corresponding genetic coefficient of variation (GCV). GCV and PCV values were highest for days to flowering and maturity, number of clusters and pods per plant, 100 seed weight and seed yield per plant. High phenotypic and genotypic variances were observed for the length of main stem by **Vidya (2000)** in yard long bean and by **Ajith (2001)** in bush type vegetable cowpea. Moderate values of phenotypic

and genotypic coefficients of variation (PCV and Gev respectively) were recorded for plant height byKalaiyarasi and **Palanisamy (2000),** while **Philip (2004)** found low values. High PCV and GCV were recorded for pods per plant and yield by Lakshmi and Goud (1977), **Kumari *et al.*, (2003)** and **Kutty *et al.*, (2003)** Pod length was reported to have high genetic variability by **Bapna and Joshi (1973),** while moderate values of pev and Gev were also observed **(Kalaiyarasi and Palanisamy, 2000; Singh and Verma, 2002).**

Arora *et al*., (2003) evaluated ten diverse genotypes of cowpea for 8morphological characters (hypocotyl length, epicotyl length, seedling height, length and diameter of first pair of true leaves, petiole length of first trifoliate leaf and fresh and dry weight of seedlings) at seedling stage.

Belhekar *et al*., (2003) revealed that by studying F2 generation, the seed yield per plant exhibited positive and significant correlation with length of plant, number of flowers per plant, first pod maturity, complete maturity, number of pods per plant and 100 seed weight both at the phenotypic and genotypic levels. However, it showed a negative and significant correlation with the number of pods per peduncle and seed index.

Tyagi *et al*., (2000) studied genetic variability in twenty four cowpea genotypes. They observed the lowest value of PCV for number of seeds per pod and the highest for plant height. The results also revealed that the PCV was moderate for pod length, number of pods per plant and 100 seed weight, and it was high for days to 50% flowering, seed weight per pod, seed yield per plant, days to maturity and plant height. They were found the lowest GVC value for number

of seeds per pod followed by pod length. High heritability with moderate GCV and GA were recorded for number of pods per plant, seed weight per pod and 100 seed weight.

Rangaiah *et al.*, (1999) reported that total seed weight was positively and significantly associated with all the traits, except length of plant and pod weight made the greatest contribution towards yield per plant in both crosses. Length of plant, number of pods per plant and number of seeds per pod showed significant and positive association with hundred seed weight indicating that more number of pods gives more number of seeds and also observed a positive association of pod length with length of plant, number of branches per plant and number of pods per plant.

Birader *et al., (*1996) reported strong correlation between pod weight per plant and seed yield, pod length and number of seeds per pod, number of clusters and number of pods perplant and pod weight per plant. **Gowda (1996)** revealed a positive and significant association of seed yield with number of pods per plant, number of seeds per pod and 100seed weight and also found a significant and negative association with 100 seed weight andnumber of seeds per plant. **Singh and Singh (1977)** revealed that number of clusters perplant, number of seeds per pod and total biomass made greatest direct contribution to seed yield in 45 cowpea genotypes. **Vardhan and Savithramma (1998)** reported a very high positive association of green pod yield with pods per plant.

Fernandez and Miller (1985) studied four determinate and indeterminate cowpea cultivars and reported five cultivars differed significantly for yield, biomass and nitrogen fixation. The biomass and

seed yield were more in indeterminate cultivars with inoculation and harvest index was found to be more in determinate types.

2.5 Path coefficient analysis

Vardhan and Savithramma (2010) studied path coefficient analysis for green pod yield per plant in 29 accessions of cowpea and concluded that green pods per plant, pod length, pods per plant, pod length, pod diameter and number of primary branches were major traits contributing to yield.

Kumari *et al*.,(2003) revealed that high and genetic gain for seed yield per plant, number of pods and number of clusters per plant by studying 50 cowpea genotype.

The performance of different genotypes in varying environments might be vary over season, year and locations. Study of these aspects would be more important to select highly adaptable genotypes. **Viswanathan and Nadarajan (1996)** evaluated thirteen genotypes in three environments. Two of them showed average response to changes in environmental conditions with higher mean yields and one is specially suited for the unfavourable growing season.

Kumar *et al*., (2002) reported high for green fodder yield per plant, number of days to 50% flowering, length of plant and dry fodder yield per plant in the study involved five cultivars. In general, genotypic coefficient of variation was found to be higher than the corresponding phenotypic coefficient of variation for this character.

Kalaiyarasi and Palanisamy (2002) stated that number of seeds per pod, number of pods per plant, crude protein content and length of plant had high positive direct effects on seed yield while pod length, hundred seed weight, number of branches per plant and crude fibre content had negative direct effects on seed yield in the F3 population of cowpea. Pod length and hundred seed weight had positive indirect effects on seed yield through number of pods.

Cisse (2001) stated that the most productive genotypes could be identified through concomitant selection for yield in high productivity environments and for harvest index in low productivity conditions by evaluating ten genotypes.

Chattopadhyay *et al.*, (2001) evaluated twenty cowpea genotypes for stability in yield and its components such as number of pods per plant, pod length and pod weight and revealed that the significant genotype and environment interaction was observed for allcharacters except pod length.

Cisse (2001) stated that the most productive genotypes could be identified through concomitant selection for yield in high productivity environments and for harvest index in low productivity conditions by evaluating ten genotypes.

Lopes *et al.*, (2000) revealed that high genetic variation for most of the studied traits of cowpea and the presence of high genotype environment interaction for pod length and seed yield was detected.

Selvam *et al.*, (2000) concluded that number of seeds per pod is most contributing trait for the yield. The number of seeds per pod is highly variable character and moderately heritable in cowpea ranged from

31.3 percent based on studies of 24 and 50 cowpea genotypes and observed a high coupled with low.

Kulkarni and Birari (1999) studied six genotypes of asparagus bean and two hybrids of cowpea [*Vigna unguiculata* (L.) Walp.] for yield components and revealed that one variety performed best under different environments, while yields of the other genotypes were not very stable.

Birader *et al., (*1996) reported that strong correlation between pod weight per plant and seed yield, pod length and number of seeds per pod, number of clusters and number of pods per plant and pod weight per plant. association of pod length with length of plant, number of branches per plant and number of pods per plant.

Mehta and Zaveri *et al.*, (1999) reported moderate to high for number of clusters per plant in cowpea. **Sarvamangala (20**04) revealed moderate to high GCV and PCV with number of clusters. Many reports indicated high phenotypic and genotypic coefficient values with regard to number of clusters per plant. Most of the segregating populations showed high estimates for both.

Sawant (1994) found that the seed yield was significantly and positively correlated with branches per plant, inflorescence per plant, pods per plant, pod length, seeds per pod, 100 seed weight and harvest index.

Altinbas and Sepetoglu (1993) conducted an experiment and correlated with pods per plant, seeds per pod and number of branches per plant. Both days to flowering and maturity had no influence on seed yield, 100 seed weight was negatively and significantly associated with pods per plant and seeds per pod.

Altinbas (1993) revealed by path analysis study that the most important yield component was number of pods per plant affecting the yield through path analysis, whereas **Sawant (1994)** revealed by the path analysis that pods per plant had the highest positive direct effect on seed yield followed by 100 seed weight, seeds per pods, days to flowering, inflorescence per plant, harvest index per plant and pod length.

Oseni *et al.*, (1992) concluded through path analysis that the major components contributing to seed yield were days flowering, 100 seed weight, days to pod filling and pod length.

Siddique and Gupta (1991) observed a significant correlation of seed yield per plant with days to 50% flowering, days to maturity, number of clusters per plant and number pods per plant. **Oseni *et al.*, (1992)** revealed that there is a positive correlation between seed yield and pods per plant, between days to flowering and 100 seed weight. While, negative correlations were observed between days flowering and seed yield and between 100 seed weight, seed yield, days to flowering, 100 seed weight, days, days to pod filling and pod length were the major components contributing to yield.

Shiddique and Gupta (1991) reported that pods per plant, 100 seed weight and seeds per pod as the most important yield attributing characters.

Siddique and Gupta (1991) observed a significant correlation of seed yield per plant with days to 50% flowering, days to maturity, number of clusters per plant and number pods per plant.

Oseni *et al.*, (1992) revealed that there is a positive correlation between seed yield and pods per plant, between days to flowering and

100 seed weight. While, negative correlations were observed between days flowering and seed yield and between 100 seed weight, seed yield, days to flowering, 100 seed weight, days, days to pod filling and pod length were the major components contributing to yield.

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CHAPTER-3

MATERIALS AND METHODS

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The present investigation entitled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata* (L.) Walp.)]"** was carried out at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University),Vidya-Vihar, Rae Bareli Road, Lucknow 226025 (U.P.), India, during the summer season of 2014-15 and 2015-16. The details of materials used and methodology to execute the investigation have been described under chapter are given below:

3.1 LOCATIONANDSITEOFEXPERIMENT:

The Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, VidyaVihar, RaeBareliRoad, Lucknow is situated at anel evation of 111 meter above mean sea level in the subtropical tracts of central U.P. at 26°-56° Northlatitude.The climate of lucknow is charcterized by sub-tropical with hot, dry summer and cool winters. This region recived an averages annual rainfall of 650-750mm, which is distributed over a period of more than 100 days with peak period during July-Agust. It also received scattered showers during winter months. In general, the temperature ranges from 5.5^0 to 25^0. The coldest month is January, while the maximum temperature observed during May-June. The Horticulture Research Farm is located approximately 10 km away from the Lucknow Railway station towards South–East on Lucknow, RaeBareli Road, near Southcity.

3.2- TOPOGRAPHY, CLIMATE AND WEATHER CONDITIONS:

The climate of this regionis subtropical with maximum temperature ranging from 29.3^0C to 45^0C in summer and minimum temperature

ranging from 3.5 to 15^0C inwinter and relative humidity (RH) of 60-80% during different sea sons of the year. The Lucknow is characterized by sub tropical climate with hot summer and cold winter.The annual rainfall is about 750 mm, most of whichi sreceived from June to September with some irregulars howers in winters from the North – Eastmonsoon.

3.3 Experimental Materials

The experimenal materials of the present investigations were comprised sixteen cowpea genotypes of tropical and subtropical origin. The list of the genotypes (breeding lines) is given in Table (3.3) which were received from Indian Institute of Vegetable Research (IIVR), Varanasi, (U.P.) and evaluated at the Horticulture Research Farm first of the department of Applied Plant Science (Horticulture) Babasaheb Bhimrao Ambedkar University,Vidya-Vihar,RaeBareliRoad,Lucknow (U.P.). Experimental field was laid out in randomized block design with sixteen genotypes/lines and replicated thrice, each block into 16 unit plots. The sixteen genotypes were alloted to the 16 unit plots of each block. This were experimental total 48 plots having to size of each plot 1.80m X 0.90m, row to row and plant to plant spacing were 60cm and 15cm, respectively. The plots were raised by 15cm from the ground level to avoid water-logging, if occurred. The plot to plot (.90m) and block to block (1.80m) distance were continue. The each plot divide into three row and each row contained six plants this, each plot accommodates 18 plants and total plants maintained in cultivated area 864. Farm yard manure (FYM) 200 q/ha and nitrogen, phosphorus and potash were applied @ 55 kg, 80 kg and 36 kg per hectare, were respectively. Nitrogen was applied in to split doses; half at the time of sowing and remaining half at the time of vegetative growth and pod

formation of cowpea genotypes. All necessary cultural operations were done as and when required during the experimentation trial.

3.3: The experimental material in the form of seed of 16 genotypes/varieties brought from Indian Institute of Vegetables Research, Varanasi.

S. No.	Names of the genotypes/varieties	Source
1	KashiUnnati	IIVR, Varanasi
2	KashiShyamal	IIVR, Varanasi
3	KashiGauri	IIVR, Varanasi
4	KashiKanchan	IIVR, Varanasi
5	Kashi Nidhi	IIVR, Varanasi
6	IC – 559393	IIVR, Varanasi
7	IC – 259063	IIVR, Varanasi
8	IC – 559405	IIVR, Varanasi
9	IC – 202786	IIVR, Varanasi
10	IC – 559386	IIVR, Varanasi
11	IC – 202776	IIVR, Varanasi
12	IC – 242598	IIVR, Varanasi
13	EC- 9736	IIVR, Varanasi
14	EC – 1738	IIVR, Varanasi
15	EC- 30590	IIVR, Varanasi
16	EC – 15296	IIVR, Varanasi

3.4 Cultivation operation

3.4.1 Soil and field preparation

After deciding the experimental field, the field was irrigated to have optimum level of moisture condition. First, deep ploughing was done with disc plough and subsequent light ploughings were done with cultivator followed by planking. Then the required area was marked and 48 plots were prepared according to the layout plan.

3.4.2 Fertilizer application

Fertilizers was applied at the rate of 100 kg/ha nitrogen, 60 kg/ha phosphorus, 50 kg/ha potassium to the soil at the time of sowing. The complete dose of phosphorus and potassium fertilizer and one-third dose of nitrogenous fertilizers broadcasted in each plot in equal amount as basal dose before sowing. The remaining dose of nitrogenous fertilizers applied in two split doses.

3.4.3 Selection of seed and sowing time

Pure and healthy seeds of each genotype were collected before sowing. The seeds were soaked in water for 24 hours to get good germination. The distance between plants to plant was 20 cm and row to row 60 cm. The sowing was done on 15thJune 2015.

3.4.4 Intercultural operation

The experimental plot was irrigated during the cropping period depends upon the rain and field moisture. Weeding was done four times according to the requirement of maintain uninterrupted growth of the crop.

3.4.5 Selection of plant for observation

In a field experiment, detail study of the entire population is rather difficult. Since all the plants get identical environment, *i.e*. some plants

from the population were randomly selected for detailed investigation, then three plants were selected at random in each plot and tagged for identification.

3.5 Experimental design and layout

(A) Experimental design

The experiment was laid out in randomized block design with three replications. The experiment was conducted at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (ACentralUniversity),Vidya-Vihar, Rae Bareli Road, Lucknow-226025 (U.P.), India.

The plan of layout is given in Fig. No.1. the details of layout areas under.

(B) Details of the layout plan

(1) Number of genotypes : 16

(2) Number of replications : 3

(3) Total number of plots : 16 × 3 = 48

(4) Gross plot size : 1.80x0.90m

(5) Row to Row distance : 60 cm

(6) Plant to plant distance : 15 cm

(7) Number of plants per row : 06

(8) Number of row per plot- : 03

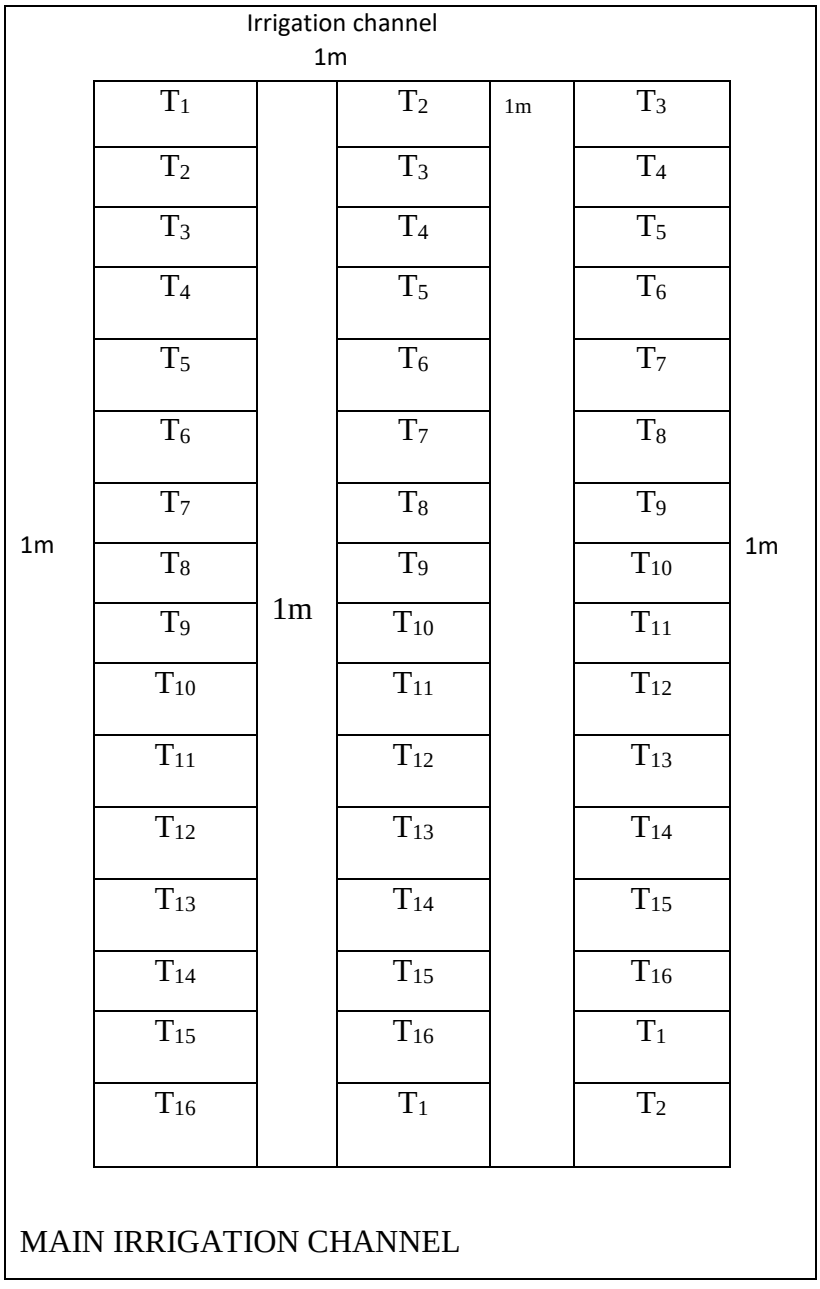
(9) Number of plants per plot- :18

(10) Total plants- : 864

(11) Design- :Randomized Block Design

(12) Recommended dose of fertilizers (RDF) : ($N:P_2O_5:K2O$) (20:60:60Kg/ha)

LAYOUT OF EXPERIMENT FIELD



T_1		T_2		T_3
T_2		T_3		T_4
T_3		T_4		T_5
T_4		T_5		T_6
T_5		T_6		T_7
T_6		T_7		T_8
T_7		T_8		T_9
T_8		T_9		T_{10}
T_9		T_{10}		T_{11}
T_{10}		T_{11}		T_{12}
T_{11}		T_{12}		T_{13}
T_{12}		T_{13}		T_{14}
T_{13}		T_{14}		T_{15}
T_{14}		T_{15}		T_{16}
T_{15}		T_{16}		T_1
T_{16}		T_1		T_2

Plate-1: A general view of lay-out plan of Experimental site

Plate- 2: A general view of sowing the cowpea seed in the field

Plate-3: A general view of cowpea at initial growth stage

3.6 Observations were recorded:

3.6.1 Plant height:

The height of ivetagged plants was measured in centimetres from the ground level to the tip of the main stem at final picking, with the help of meters scale and the average plan theight was worked out.

3.6.2: Number of primary branches per plant:

Number of branches per plant was counted at final harvest for five tagged plants and the average was calculated.

3.6.3 Number of branches per plant:

Number of days taken from date of transplanting to days on which 50% of the plants in a plot flowered was recorded.

3.6. 4 Days to first open flower:

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.

3.6.5 Number of pod per plant:

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

3.6.6 Days to first pod picking:

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

3.6.7 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.

3.6.8 Pod diameter (cm):

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

Plate-4: A general view of cowpea at pod developing stage

3.6.9 Number of pods per peduncle:

The total number of pods per peduncle from the five randomly selected plants was counted and their average value was counted at maturity.

3.6.10 Pod weight per plant:

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.

3.6.11 Pod yield per plot:

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 6.12Peduncle length (cm):

Randomly five peduncle were selected from each selected plants and their length was measured in cm.

3.6.13 Number of peduncle per plant:

The total number of peduncle from the five randomly selected plants was counted and their average value was counted.

3.6.14 Duration of reproductive phase:

Number of days were counted from the day of flower initiation to the date of pod maturity of the plants of a plot for each treatment in each of the replication and averaged.

3.6.15 Number of seeds per plant:

Weight of hundred seeds selected at random from each plant was expressed in grams.

3.6.16 Number of seeds per pod:

Total number of seeds per pod averaged over five randomly selected pods in each plant was recorded.

3.6. 17 100 seeds weight:

Weight of hundred seeds selected at random from each plant was expressed in grams.

3.6.18. Vitamin A (IU)

Take 5g of fresh sample and crush in 10-15 ml acetone, adding a few crystals of anhydrous Sodium sulphate of Pestal and Morter. Decent the supernatant into a beaker. Repeat the process twice and transfer the combined supernatant to a reparatory funnel, add to 10-15 ml petroleum Ether and mix thoroughly. Two layers will separate outstanding. Discard the lower layer and collect upper layer in a 100 ml with petroleum ethereal and record optical density at 452 mm using petroleum Ether as blank. The total Vitamin A was calculated in mg / 100g sample by using following formula.

3.6.19VitaminC(mg/100g):

The vitamin-C content was determined by 2,6-dichlorophenol indophenol visual titration method as described by Ranganna(1994). Aliquotes prepared by macerating freshly harvested fully ripe cowpea pods in the presence of 3% metaphosphoric acid and titrated against 2, 6-dichlorophenol indophenols dye to pink end point persisting at least for 15 seconds.

Plate- 5: A general view of at the time of chemical analysis

3.7 STATISTICAL AND GENETICAL ANALYSIS:

1. Analysis of variance for design of experiment:

The analysis of variance of the experimental design was carried out for each character separately as following (Panse and Sukhatme, 1967).

Source of Variation	**D.F.**	**S.S.**	**M.S.S.**	**F-calculated values**
Replications	(r-1)	RSS	MSR	MSR/MSE
Treatments	(t-1)	TSS	MST	MST/MSF
Parents	(p-1)	PSS	MSP	MSP/MSE
Lines	(f-1)	FSS	MSF	MSF/SME
Tester	(m-1)	MSS	MSM	MSM/MSE
Lines vs. tester	1	FSS vs. MSS	MSR vs. MSM	MSF s.MSM/MS
Hybrids/F_1 population	(F_1-1)	F_1SS	MSF_1	MSF_1/MSE
Parents vs. hybrids	1	PSS vs. F_1SS	MSP vs. MSF_1	MSP vs. SF_1/MS
F_2 population	(F_2-1)	F_2SS	MSF_2	MSF_2/MSE
Parents vs. F_2s	1	PSS vs. F_2SS	MSP vs. MSF_2	MSP vs. SF_2/MS
Error	(r-1) (t-1)	ESS	MSE	-

Whereas,

r = number of replications

t = total number of treatments

p = number of parents

f = number of lines

m = number of tester

F_1 = number of hybrids

F_2 = number of populations

CRITICAL DIFFERENCE:

In order to compare the means of variance critical difference (CD) was calculated by the following formula:

CD = SE x t at 5 percent and 1 percent

Where,

SE is the standard error of the difference of the treatment means to be compared and calculated by following formula:

$SE = \sqrt{2Ve/r}$

Where,

Ve = error mean sum of squares

r = number of replications

T (5% or1%) = tabulated value at 5 percent or 1 percent level of significance for error degree of freedom.

COMBINING ABILITY ANALYSIS:

The analysis of variance for combining ability was carried out according to the method outlined by Kempthorne (1957). The partitioning of treatments was done into males female and females x males for F_1 generation. The skeleton of analysis of variance for combining ability as follows:

Analysis of variance for combining ability:

Source of variation	**D.F.**	**M.S.**	**Expectation of M.S.**
Replications	(r-1)		-
Hybrids	(fm-1)		-
Lines	(f-1)	m_1	δ^2_e +r[Cov(F.S.) – 2Cov(H.S.)] + Mr Cov (H.S.)
Testers	(m-1)	m_2	δ^2_e +r[Cov(F.S.) – 2Cov(H.S.)] + fr Cov (H.S.)
Lines x Tester	(m-1) x (f-1)	m_3	δ^2_e +r[Cov(F.S.) – 2Cov(H.S.)]
Error	(r-1) x (mf-1)	m_4	δ^2_e
Total	(mf-1)		-

Kempthorne (1957) advocated general combining ability (GCA) and specific combining ability (SCA) in forms of covariance of half-sibs (H.S.) and covariance of full-sibs (F.S.) as below:

δ^2 gca = Cov (H.S.)

δ^2 sca = Cov (F.S.) – 2Cov. (H. S.)

Where,

Cov (H.S.) = $[(m_1-m_1+ (m_2-m_3)/r (1+m)]$

Cov (H.S.) = $[(m_1-m_4+ (m_2-m_4)/r (m_3, m_4) + 6r$ cov (H.S.) – r (f+m) Cov (H.S.)]3r

Estimation of general and specific combining ability effects:

The following mathematical models were applied to estimate the general and combining ability effects of i_{jk} observations.

X_{ijk} = $\mu + g_i + g_j + s_{ij} + e_{ijk}$

μ = general mean

g_i = general combining ability effect of i^{th} male parent.

g_j = general combining ability affect of j^{th} female parent.

s_{ij} = specific combining ability effect of ij^{th} combination

e_{ijk} = error associated with ij^{th} observation at X_{ijk}

I = number of male's parents, 1, 2……..n.

j = number of female parents, 1, 2 …….f.

k = number of replication, 1, 2 ……..r.

The individual effects of g.c.a. and s.c.a. was estimated as under

μ = (X./mfr) where, X… = Total of all hybrid combinations

g_i = $(X_i../f_r) – (X…/m_{rf})$, where, $X_i…$ = Total of i^{th} male parents over all the females and replications.

g_j = $(X_{ij}../m_r) – (X…/m_{fr})$, where, $X_{ij}…$ = total of j^{th} female parents over all the males and replications.

S_{ij} = $[X_{ij}/r\text{-}X_i../f_r – (X_{ij}/m_r + X./m_{rf})$, where,

X_{ij} = $(ij)^{th}$ combination total over all the replications.

The following restrictions apply on combining ability effects.

(i) Σgi = 0

(ii) Σgi = 0

(iii) Σgij = 0 (for each i and j)

Test of significance for general and specific combining ability effect:

Standard error effects were computed by taking the square foot variance of effects.

S.E. (gi) = √δ2e/fr

S.E. (gj) = √δ2e/mr

S.E. (gij) = √δ2e/r

Standard errors of difference between the value of two general and specific combining ability effects were calculated as follows:

S.E. (gi-gi) = √δ2e/fr

S.E. (gi - gj) = √δ2e/mr

S.E. (gij - gij) = √δ2e/r

Average Degree of Dominance:

The average degree of dominance was calculated using the formula given by Kempthorne and Curnow (1961):

Degree of dominance = (δ2s/δ2g) 0.5

Where,

δ2s = estimated variance due to s.c.a.

δ2g = estimated variance due to g.c.a.

HETEROSIS:

It was estimated in percent increase or decrease in the performance of F_1 hybrids over better parent and economic parent (Pusa Ashaudhi).

Heterosis over better parent (%) = $\frac{F_1 - BP}{BP} \times 100$

Heterosis over standard variety (%) = $\frac{F_1 - SV}{SV} \times 100$

Where,

F_1 = mean of the F_1 hybrids

BP = mean value of better parent, and

SV = mean value of SV (Pusa Meghdoot)

The significance of the estimates of heterosis was tested with the help of C.C. and p = 0.05 and 0.01 calculated on the basis of S.E. in the ANOVA for the design of experiment.

INBREEDING DEPRESSION:

The inbreeding depression was calculated from the deviation between F_1 and its corresponding F_2 for each character separately. Inbreeding depression (%) was calculated by formula.

$$\text{Inbreeding depression} = \frac{F_1 - F_2}{F_1} \times 100$$

Where,

F_1 and F_2 are the mean values of F_1 and F_2 populations respectively.

The test of significance was done on F_1 - F_2 values and indicated in percentage value of inbreeding depression. The value of C.D. was used for testing significance.

GENETIC COMPONENTS:

$$\textit{CovHS}\ (\textit{line}) = \frac{M_1 - M_{it}}{rt}$$

$$\textit{CovHS}\ (\textit{tester}) = \frac{M_1 - M_{it}}{rt}$$

$$\textit{CovHS}\ (\textit{tester}) = \frac{1}{1}$$

Where,

Ml = Mean squares due to lines

Mt = Mean squares due to testers

Mlt = Mean squares due to lines x testers

Me = Mean squares due to error

r = Number of replications

l = Number of lines

t = Number of testers

δ^2g (*testers*) = Cov. H.S. (testers)

δ^2 g (*lines*) = Cov. H.S. (average)

sca variance (δ^2s) = $\frac{M_{it} - M_e}{r}$

Degree of dominance:

It was calculated using the formula given by Kempthorne and Curnow (1961):

Degree of dominance =

δ^2_D = Dominance variance

δ^2_A = Additive variance

Gene action:

Gene action was worked out following Kempthorne (1957)

Additive genetic variance δ^2_A = 4 Cov. H.S. (average) with F = 0

Dominance variance (δ^2_D) = δ^2_{SCA} with F = 0

Where,

F = inbreeding co-efficient

Predictability ratio:

Predictability ratio =

Where,

δ^2_{SCA} = Estimated variance due to SCA

δ^2_{SCA} = Estimated variance due to GCA

Testing of inbreeding depression:

The test of significance was done on $F_1 - F_2$ values and indicated in percentage value of inbreeding depression. The value of C.D. was used for testing significance.

ESTIMATION OF VARIATIONS:

The mean sum of squares for error was subtracted from the mean sum of squares due to strains for obtaining the genetic variance which was calculated according to the method as suggested by Burton (1952) and phenotypic variance calculation method as suggested by Burton and De Vane (1953).

Environmental variance (σ^2e) = F

Genotypic variance (σ^2e) = V – E/r

Phenotypic variance (σ^2e) = ($\sigma^2g + \sigma^2e$)

Genotypic coefficient of variation = $\frac{\sqrt{\sigma^2g}}{} \times 100$

Phenotypic coefficient of variation = $\frac{\sqrt{\sigma^2e}}{} \times 10$

Where,

V = strain mean square

E = error mean square

r = number of replications and

X = general mean of the characters

PCV and GCV >30% - High

15-30% - Moderate

< 15% - Low

Heritability:

The heritability in broad sense (h^2b^2) was calculated as suggested by Hanson *et al.* (1956).

$$h^2\ (\%) = \frac{\delta^2 g \times 100}{\delta^2 p}$$

Where,

$\delta^2 g$ = Genotypic variance

$\delta^2 p$ = Phenotypic variance

Heritability (h^2)	>80%	-	High
	50-80%	-	Moderate
	< 50%	-	Low

Genetic advance:

It was calculated using the following formula suggested by Allard (1960).

$$Gs = (K)\ (\delta ph)\ (h^2)$$

Where,

G = the estimation of genetic advance under selection.

K = selection differential (2.06), constant at 5 percent selection intensity

δph = the phenotypic standard deviation.

h^2 = the estimation of heritability coefficient.

Genetic advance in percentage of mean: It was calculated as follows

$$Gs\ (\%) = [G_2/X] \times 100$$

Where,

Gs = expectation of genetic advance

X = mean of the character

Gs (%) = genetic advance in percent to mean of character.

Genetic gain

>80% - High

50-80% - Moderate

< 50% - Low

CORRELATION AND PATH COEFFICIENT:

The formula for calculation of the genotypic phenotypic coefficient of correlation was worked out as suggested by Robinson *et al*., (1951).

(a) Genotypic correlation r_{xy} (g) = $\frac{Cov._{xy}(g)}{[V_x(g).V_y(g)]^{0.5}}$

$Cov._{xy}$ (g) = Genotypic covariance between character x and y, and this was computed as

$Cov._{xy}$ (g) = [$Cov._{xy}$ (p) - $Cov._{xy}$ (e)]/r

V_x (g) and V_y (g) = Genotypic variance for the characters x and y respectively.

r = number of replication

(b) Phenotypic correlation r_{xy} (p) = $\frac{Cov._{xy}(p)}{[V_x(p).V_y(p)]^{0.5}}$

Where,

$Cov._{xy}$ (p) = Phenotypic covariance between characters x and y and this computed as

$Cov._{xy}$ (p) = [$Cov._{xy}$ (g) + $Cov._{xy}$ (e)]/r

V_x (p) and V_y (p) = Phenotypic variance for the characters x and y, respectively.

V^{xy} (e) = the error variance for character x and y, respectively.

Test of significance of correlation coefficient:

$$t = \frac{\sqrt{(n-2)}}{\sqrt{(1-2)}}$$

Where,

r = correlation coefficient

n = number of treatment

The significance of correlation coefficient was tested against 'r' values from r-table of Fisher and Yates (1938) for (n-2) degree of freedom where, 'n' is the number of treatments.

Path coefficient analysis:

Wright (1921a) defined the path coefficient as the ratio of standard deviation of the all causes is constant, except one in question the variability of which kept in changed. Path coefficient is simply a standardized partial regression coefficient and as such measures the direct influence on variable upon another and permits the correlation coefficient into component of direct and indirect effects (Wright 1921b). The concept of path analysis was later on elaborated by Dewey and Lu (1959).

CAUSAL SYSTEM:

The causal system indicates mutual association as measured by correlation coefficient and the direct influence as measured by path coefficients.

The path coefficient was obtained by the simultaneous equations which expressed between correlation and path coefficient as suggested by Dewey and Lu (1959).

a. Calculation of direct effect:

$r_{1.9}$ = $p_{1.9} + p_{2.9} + r_{1.3} + p_{3.9} + r_{1.4} + r_{1.5} + r_{1.6}\, p_{6.9} + r_{1.7}p_{7.9} + r_{1.8}p_{8.9}$ + $r_{1.9}p_{9.9}$

$r_{2.9}$ = $r_{2.9}p_{1.9} + p_{2.9} + r_{2.3}p_{3.9} + r_{2.4}p_{4.9} + r_{2.5}\, p_{5.9} + r_{2.6}p_{7.9} + r_{2.8}p_{8.9}$ + $r_{2.9}p_{9.9}$

$r_{3.9}$ = $r_{3.1}p_{1.9} + r_{3.2}p_{2.9} + p_{3.9} + r_{3.9}p_{4.10}$ …… $r_{38}p_{89}$

$r_{4.9}$ = $r_{42}p_{19} + r_{42}p_{29} + r_{43}p_{39}$ + …….. $r_{48}p_{89}$

$r_{5.9}$ = $r_{15}p_{19} + r_{42}p_{29} + r_{53}p_{39}$ + …….. $r_{58}p_{89}$

$r_{6.9}$ = $r_{62}p_{19} + r_{62}p_{29} + r_{63}p_{39}$ + …….. $r_{68}p_{89}$

$r_{7.9}$ = $r_{71}p_{19} + r_{72}p_{29} + r_{73}p_{39}$ + …….. $r_{78}p_{89}$

$r_{8.9}$ = $r_{81}p_{19} + r_{82}p_{29} + r_{83}p_{39}$ + …….. $r_{89}p$

Where ‘r’ represents the correlation coefficient between the characters and ‘p’ indicates the effects of various characters on the dependent variable (the yield in this case).

b. Calculation of indirect effect:

The indirect effect can be calculated by multiplying the value of coefficient to the correlation coefficient or respective rows and column as per the formula given below.

Indirect effect = rij x Pij

i = 1……n

j = 1……n

pij = $P_{1y}P_{2y}$ ……Pny

c. Calculation of residual effect:

The residual effects were calculated by the following formula:

Residual effects = $1 - R^2$

Where,

$R^2 = P_1y.r_1y + P_2y.r_2y$ + …… Pny. Rny

CHAPTER-4

EXPERIMENTAL FINDING

CHAPTER -4 EXPERIMENTAL FINDING

The present investigation entitled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata* (L.) Walp.)]"**was carried outat Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University),Vidya Vihar,RaeBareli Road, Lucknow 226025 (U.P.), India, during the summer season of 2014-15 and 2015-16. In this chapter the results obtained from various characters are being presented in tables and described under the following heads.

4.1 Analysis of variance for the design of experiments.

4.2 Mean performance of genotypes

4.3 Estimates of variability, heritability and genetic advance in percent of mean

4.4 Genotypic and Phenotypic Correlation coefficient

4.5 Path coefficient analysis

4.1 ANALYSIS OF VARIANCE:

Analysis of variance (ANOVA) for the nineteen characters is given in Table- 4.1.a. The variances for different characters were divided into replications, treatments and error. Observations were recorded like plant height (cm), number of primary branches/plant, number of branches per

plant, days to first open flower, number of pod per plant , days to first pod picking , pod length (cm), pod diameter (cm), number of pod per peduncle, pod weight per plant, pod yield per plot, peduncle length (cm), number of peduncle per plant, duration of reproductive phase, number of seeds per plant number of seeds per pod, 100 seeds weight, vitamin A (IU) and vitamin C (mg/100g) were recorded.

Table No -4.1.a: Analysis of variance for the 10 characters of cowpea

S. No	Source of variation	D. F.	Characters									
			Plant height(cm)	Number of primary branches per plant	Number of branches per plant	Days to first open flower	Number of pod per plant	Days to first pod picking	Pod length (cm)	Pod diameter (cm)	Number of pods per peduncle	Pod weight per plant (g)
1.	Replication I year	2	2.8269	1.7452	1.8700	2.9835	2.6905	2.7563	2.3621	6.0031	1.6225	2.6900
	II year		2.2277	1.4378	0.9478	1.9274	2.6692	1.7509	2.6006	3.0234	3.012	2.1266
	Pooled		2.6876	2.9954	1.4351	2.5242	1.1380	2.4724	0.7897	5.2982	0.6079	4.0910
2	Treatment I year	15	5.7192	1.5506	0.3244	5.9654	30.0519	2.9286	3.4385	1.1336	3.9090	272.4005
	II year		5.7547	1.6801	0.4708	26.4899	23.6521	50.4905	7.2258	1.4582	4.2280	1859.8863
	Pooled		3.0392	3.1928	0.5058	14.5245	5.4645	25.2819	3.8110	1.8977	3.7275	1571.9144
3	Erorrs I year	30	1.3134	0.0326	0.0240	2.6109	2.5567	1.9701	0.5141	0.1043	0.1339	94.4020
	II year		2.8010	0.0955	0.1906	5.8565	6.0584	9.2471	1.8169	0.3452	0.4532	434.9380
	Pooled		2.6866	0.0848	0.1943	5.6119	11.8019	8.8161	2.7280	0.4310	1.2208	467.9763

Table No -4.1.b: Analysis of variance for the 10 characters of cowpea

S. No	Source of variation	D.F.	Characters								
			Pod yield per plot (g)	**Peduncle length (cm)**	**Number of peduncle per plant**	**Duration of reproductive phase**	**Number of seeds per plant**	**Number of seeds per pod**	**100 seeds weight**	**Vitamin A(IU)**	**Vitamin C (mg/100g)**
1.	Replication I year		2.6976	1.4613	2.4419	2.8276	2.2865	5.4885	2.9907	2.5953	2.8788
	II year		1.8587	1.6161	1.4976	1.5564	3.2172	2.1283	0.9020	2.2868	2.2341
	Pooled		2.3710	1.1246	1.3071	2.2518	2.0624	1.0975	0.0467	5.1957	3.1615
2	Treatment I year		15453.7148	4.3768	2.7415	10.1685	1532.4103	4.1677	0.2259	1562.9871	1.9505
	II year		253857.1377	3.0160	6.4491	26.1064	2266.5120	5.7099	0.6038	1982.9230	2.3150
	Pooled		113603.9889	3.2285	2.4834	21.2731	3264.1809	4.3692	0.6209	1501.0639	2.2688
3	Erorrs I year		4890.9791	0.1792	0.2649	1.6271	116.1104	0.5161	0.0357	614.0173	0.3802
	II year		48453.7090	0.5031	1.9132	12.4948	654.3845	1.9372	0.2609	2872.8299	0.8665
	Pooled		47129.6644	1.2636	1.8025	6.1470	680.1677	2.6341	0.1077	1423.5688	0.7053

4.2 Mean performance of genotype:

Mean value of genotypes in respect to various characters are presented in (Table No.-4.2.a, 4.2.b, 4.2.c, 4.2.d and 4.2.e) respectively.

4.2.1 Plant Height (cm):

The height of plant represents the growth and vigor of a plant. So the plant height ranges from27.89 to 32.35 cm in 2014-15 in minimum genotype EC-15296 and maximum in genotype EC-1738 respectively with minimum plant height (cm) in genotype EC – 15296 and maximum plant height (cm) in genotype IC – 559405.

4.2.2 Number of primary branches per plant:

The number of primary branches per plant ranged from 2.22 to 4.53 with minimum number of primary branches per plant in genotype IC – 242598 and maximum number of primary branches per plant in genotype Kashi Kanchen.

4.2.3 Number of branches per plant:

The number of branches per plant ranged from 3.62 to 4.50 with minimum number of branches per plant in genotype IC – 242598 and maximum number of primary branches per plant in genotype Kashi Unnati.

4.2.4 Days to first open flower:

The maximum and minimum days to first open flower was observed in genotype IC-559405 and IC-202786.

4.2.5 Number of pod per plant:

The maximum and minimum number of pod per plant was recorded in genotype IC-202786 and EC -9736.

Table No-4.2.a: Mean performance of 16 genotypes of cowpea

S. No.	Genotypes	Characters											
		Plant height (cm)			Number of primary branches per plant			Number of branches per plant			Days to first open flower		
		2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	Pooled
1.	Kashi Unnati	30.73	28.75	29.74	3.42	3.74	3.58	4.16	4.83	4.50	43.87	42.37	43.12
2.	Kashi Shyamal	31.60	27.04	29.32	4.18	4.33	4.25	3.83	4.25	4.04	40.76	41.62	41.19
3.	Kashi Gauri	29.71	31.20	30.46	3.09	3.14	3.12	4.08	4.08	4.08	44.98	37.94	41.46
4.	Kashi Kanchan	31.91	28.04	29.98	4.50	4.56	4.53	3.91	4.67	4.29	43.76	42.30	43.03
5.	Kashi Nidhi	29.00	30.50	29.75	2.60	2.56	2.58	4.09	3.50	3.79	42.87	43.65	43.26
6.	IC – 559393	29.46	28.07	28.77	2.50	2.51	2.51	4.17	4.00	4.08	44.76	37.48	41.12
7.	IC – 259063	31.96	28.20	30.08	2.73	2.90	2.82	3.83	4.09	3.96	42.30	39.58	40.94
8.	IC – 559405	29.53	31.57	30.55	2.78	2.71	2.75	4.50	4.50	4.50	42.64	36.51	39.58
9.	IC – 202786	32.13	28.60	30.37	3.15	3.04	3.10	3.75	3.75	3.75	43.83	47.05	45.44
10.	IC – 559386	31.17	28.60	29.88	3.78	3.57	3.68	4.42	3.83	4.13	43.16	41.78	42.47
11.	IC – 202776	29.19	31.50	30.34	2.14	2.36	2.25	4.17	4.75	4.46	42.50	45.90	44.20
12.	IC – 242598	31.40	30.20	30.80	2.17	2.28	2.22	3.66	3.58	3.62	42.85	44.83	43.84
13.	EC- 9736	30.31	28.90	29.60	2.48	2.16	2.32	3.50	3.91	3.71	45.67	41.17	43.42
14.	EC – 1738	32.35	28.30	30.33	2.79	2.79	2.79	3.41	4.08	3.75	45.98	43.67	44.83
15.	EC- 30590	32.18	28.74	30.46	3.78	3.82	3.80	3.67	4.00	3.83	42.62	43.87	43.24
16.	EC – 15296	27.89	28.25	28.07	3.80	3.88	3.84	4.41	4.00	4.21	41.87	42.89	42.38
SEM ±		0.6617	0.9663	0.6692	0.1042	0.1784	0.1189	0.0894	0.2521	0.1800	0.9329	1.3972	0.9671
CD at 5%		1.9111	2.7908	1.8852	0.3011	0.5154	0.3350	0.2583	0.7281	0.5070	2.6944	4.0354	2.7247

Table No-4.2.b: Mean performance of 16 genotypes of cowpea

S. No.	Genotypes	Characters											
		Number of pod per plant			Days to first pod picking			Pod length (cm)			Pod diameter (cm)		
		2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	Pooled
1.	Kashi Unnati	45.33	42.90	44.12	54.90	51.97	53.44	11.80	14.48	13.14	5.65	5.65	5.65
2.	Kashi Shyamal	42.00	44.62	43.31	55.28	51.68	53.48	12.40	13.87	13.14	6.21	4.09	5.15
3.	Kashi Gauri	40.50	46.50	43.50	55.17	49.25	52.21	12.78	14.76	13.77	6.34	5.71	6.03
4.	Kashi Kanchan	43.17	44.35	43.76	54.34	50.76	52.55	11.87	11.97	11.92	4.56	4.92	4.74
5.	Kashi Nidhi	41.75	46.28	44.01	55.65	56.95	56.30	13.87	11.89	12.88	6.79	5.21	6.00
6.	IC – 559393	39.33	46.27	42.80	53.71	47.27	50.49	14.50	12.80	13.65	5.89	5.32	5.61
7.	IC – 259063	39.42	47.80	43.61	55.18	48.11	51.65	12.85	12.85	12.85	5.34	5.37	5.35
8.	IC – 559405	39.67	47.85	43.76	53.78	45.25	49.52	13.24	12.45	12.85	5.87	4.84	5.36
9.	IC – 202786	40.92	42.35	41.63	53.28	61.00	57.14	11.98	13.97	12.98	6.76	6.53	6.65
10.	IC – 559386	45.92	39.45	42.69	53.49	55.36	54.42	11.30	14.27	12.78	6.34	6.94	6.64
11.	IC – 202776	40.83	46.75	43.79	55.10	55.03	55.07	11.98	15.80	13.89	6.98	6.51	6.75
12.	IC – 242598	46.16	39.12	42.64	56.78	52.97	54.88	14.24	13.66	13.95	6.43	5.64	6.04
13.	EC- 9736	49.41	41.35	45.38	54.76	47.64	51.20	13.98	9.45	11.72	6.65	5.63	6.14
14.	EC – 1738	47.17	43.21	45.19	54.33	54.28	54.30	13.21	14.95	14.08	5.76	5.25	6.10
15.	EC- 30590	40.00	45.15	42.58	53.62	54.21	53.92	14.87	14.87	14.87	5.98	5.44	5.71
16.	EC – 15296	44.92	41.35	43.13	53.25	54.32	53.78	12.98	13.43	13.21	5.83	5.25	5.54
SEM ±		0.9232	1.4211	1.4025	0.8104	1.7557	1.2122	0.4140	0.7782	0.6243	0.1865	0.3392	0.2680
CD at 5%		2.6663	4.1044	3.9512	2.3405	5.0707	3.4150	1.1957	2.2477	1.8997	0.5386	0.9798	0.7551

Table No-4.2.c: Mean performance of 16 genotypes of cowpea

S. No.	Genotypes	Characters											
		Number of pods per peduncle			Pod weight per plant (g)			Pod yield per plot (g)			Peduncle length (cm)		
		2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	Pooled
1.	Kashi Unnati	6.47	7.58	7.03	372.56	334.47	353.51	3659.00	4058.81	3858.91	4.50	6.11	5.31
2.	Kashi Shyamal	5.56	5.68	5.62	376.87	363.27	370.07	3758.00	3808.36	3783.18	8.14	6.84	7.49
3.	Kashi Gauri	7.46	4.85	6.16	388.54	381.01	384.77	3856.00	3583.93	3719.97	8.06	5.57	6.82
4.	Kashi Kanchan	6.84	4.62	5.73	390.25	384.12	387.18	3693.00	3628.50	3660.75	6.43	8.01	7.22
5.	Kashi Nidhi	6.87	4.49	5.68	385.75	385.09	385.42	3581.00	4006.68	3793.84	7.73	5.36	6.54
6.	IC – 559393	7.54	7.98	7.76	383.76	380.79	382.27	3658.00	3915.04	3786.52	5.89	8.95	7.42
7.	IC – 259063	5.35	7.69	6.52	360.74	337.29	349.01	3754.00	3477.31	3615.65	7.76	6.51	7.14
8.	IC – 559405	4.98	6.56	5.77	363.34	321.72	342.53	3781.00	3366.67	3573.83	6.09	8.36	7.22
9.	IC – 202786	4.78	7.53	6.16	370.54	366.24	368.39	3692.00	3889.35	3790.67	9.91	7.59	8.75
10.	IC – 559386	4.75	6.39	5.57	375.87	375.98	375.93	3688.00	3966.53	3827.27	7.69	6.74	7.22
11.	IC – 202776	7.23	7.27	7.25	374.89	387.49	381.19	3728.00	4048.57	3888.28	7.55	7.39	7.47
12.	IC – 242598	7.89	6.61	7.25	389.56	389.50	389.53	3685.00	4359.99	4022.50	7.78	7.31	7.55
13.	EC- 9736	5.83	7.98	6.91	369.34	380.08	374.71	3691.00	3211.17	3451.09	6.71	6.19	6.45
14.	EC – 1738	7.34	7.69	7.52	376.98	382.69	379.83	3725.00	3721.27	3723.14	7.58	8.16	7.87
15.	EC- 30590	6.84	6.56	6.70	385.67	358.20	371.93	3821.00	3863.03	3842.01	7.58	7.13	7.36
16.	EC – 15296	8.24	7.24	7.74	365.98	313.68	339.83	3825.00	3901.50	3863.25	6.63	6.96	6.80
SEM ±		0.21	0.38	0.45	5.60	12.04	8.83	40.37	127.08	88.62	0.24	0.40	0.45
CD at 5%		0.61	1.12	1.27	16.20	34.77	24.88	116.61	367.05	249.69	0.70	1.18	1.29

Table No-4.2.d: Mean performance of 16 genotypes of cowpea

S. No.	Genotypes	Characters											
		Number of peduncle per plant			Duration of reproductive phase			Number of seeds per plant			Number of seeds per pod		
		2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	Pooled
1.	Kashi Unnati	13.56	12.98	13.27	33.75	35.90	34.82	309.07	264.25	286.66	11.52	13.35	12.44
2.	Kashi Shyamal	14.34	11.31	12.82	34.32	35.30	34.81	312.73	295.54	304.14	13.56	13.55	13.55
3.	Kashi Gauri	13.78	11.20	12.49	32.16	38.55	35.36	283.95	267.48	275.72	12.56	12.65	12.60
4.	Kashi Kanchan	11.89	13.76	12.82	30.15	34.73	32.44	309.95	294.76	302.36	12.87	13.34	13.11
5.	Kashi Nidhi	12.65	15.21	13.93	35.76	36.41	36.09	303.69	268.76	286.22	13.28	15.36	14.32
6.	IC – 559393	14.56	12.29	13.42	34.64	33.79	34.21	268.58	253.81	261.20	12.80	16.29	14.54
7.	IC – 259063	14.74	11.71	13.23	36.78	36.74	36.76	273.02	281.76	277.39	14.08	15.23	14.65
8.	IC – 559405	13.98	10.61	12.30	35.45	29.98	32.72	247.15	217.24	232.20	12.45	16.24	14.34
9.	IC – 202786	12.97	13.26	13.12	35.49	39.44	37.47	236.97	213.99	225.48	12.98	13.63	13.31
10.	IC – 559386	12.54	14.30	13.42	36.67	34.88	35.77	275.16	232.79	253.98	14.27	12.43	13.35
11.	IC – 202776	11.98	13.74	12.86	34.45	35.73	35.09	277.63	307.34	292.48	16.18	14.21	15.19
12.	IC – 242598	14.67	14.31	14.49	32.54	37.57	35.06	266.11	259.47	262.79	13.45	13.39	13.42
13.	EC- 9736	13.67	15.02	14.35	31.76	27.63	29.70	284.53	285.95	285.24	15.23	12.55	
14.	EC – 1738	14.67	11.89	13.28	34.87	34.83	34.85	274.67	267.81	271.24	14.87	12.87	13.87
15.	EC- 30590	13.87	14.66	14.26	32.68	33.04	32.86	301.03	290.79	295.91	13.45	13.28	13.37
16.	EC – 15296	12.89	14.02	13.46	33.78	34.46	34.12	304.43	284.04	294.24	12.65	11.50	12.07
SEM ±		0.297	0.798	0.548	1.736	2.040	1.012	6.221	14.765	10.647	0.414	0.803	0.662
CD at 5%		0.858	2.306	1.5442	2.127	5.894	2.851	17.96	42.655	29.995	1.198	2.320	1.866

Table No-4.2.e: Mean performance of 16 genotypes of cowpea

S. No.	Genotypes	Characters								
		100 seeds weight (g)			Vitamin A(IU)			Vitamin C (mg/100g)		
		2014-15	2015-16	pooled	2014-15	2015-16	pooled	2014-15	2015-16	pooled
1.	Kashi Unnati	4.94	5.19	5.06	928.26	983.39	955.82	17.46	15.80	16.63
2.	Kashi Shyamal	5.27	5.37	5.32	970.28	985.58	977.93	15.48	16.18	15.83
3.	Kashi Gauri	5.63	5.86	5.74	923.38	978.67	951.03	16.32	16.23	16.28
4.	Kashi Kanchan	5.13	5.31	5.22	926.54	944.54	935.54	17.48	17.90	17.69
5.	Kashi Nidhi	5.38	4.77	5.07	936.52	923.42	929.97	17.89	17.34	17.61
6.	IC – 559393	4.71	4.45	4.58	947.18	963.75	955.47	15.29	17.28	16.28
7.	IC – 259063	4.64	4.79	4.72	938.52	966.78	952.65	15.39	16.95	16.17
8.	IC – 559405	5.03	4.42	4.72	956.14	958.18	957.16	16.81	16.43	16.62
9.	IC – 202786	4.94	4.45	4.70	963.77	940.58	952.17	16.42	16.86	16.64
10.	IC – 559386	5.30	4.48	4.89	962.70	913.28	937.99	16.98	15.38	16.18
11.	IC – 202776	5.04	5.58	5.31	924.41	946.23	935.32	17.11	15.26	16.18
12.	IC – 242598	4.98	4.86	4.92	972.51	985.42	978.97	17.14	17.87	17.50
13.	EC- 9736	4.92	4.95	4.94	978.89	927.53	953.21	17.18	17.43	17.31
14.	EC – 1738	5.02	4.89	4.95	972.56	922.39	947.48	16.10	16.38	16.24
15.	EC- 30590	4.57	4.41	4.49	989.56	980.43	984.99	16.13	15.43	15.78
16.	EC – 15296	4.94	4.61	4.78	985.49	924.26	954.88	15.90	17.45	16.67
SEM ±		0.109	0.294	0.134	14.306	30.945	15.403	0.356	0.537	0.342
CD at 5%		0.315	0.851	0.377	41.319	89.375	43.395	1.028	1.552	0.966

4.2.6 Days to first pod picking:

The minimum days to first pod picking was observed in genotype IC-559405 and maximum days to first pod picking was recorded in genotype in IC-202786

4.2.7 Pod length (cm):

The minimum pod length was found in genotype Kashi Kanchan (11.92 cm) and maximum pod length was recorded in genotype EC-30590 (14.87 cm)

4.2.8 Pod diameter (cm):

The minimum pod diameter was recorded in genotype Kashi Kanchan (4.74 cm) and maximum pod diameter was recorded in genotype IC-202776

4.2.9 Number of Pods per peduncle:

The minimum number of pods per peduncle was observed in genotype Kashi Shyamal and maximum number of pods per peduncle was observed in genotype EC-1738

4.2.10 Pod weight per plant (g):

The minimum pod weight per plant was recorded in genotype EC-15296 (313.68 g) and maximum pod weight per plant was recorded in genotype Kashi Nidhi (385.42 g)

4.2.11 Pod yield per plot (g):

The Minimum pod yield per plot was recorded in genotype EC- 9736 and maximum pod yield per plot was recorded in genotype IC-242598

4.2.12 Peduncle length (cm):

The minimum peduncle length was observed in genotype Kashi Unnati and maximum peduncle length was observed in genotype IC -202786.

4.2.13: Number of peduncle per plant:

The minimum number of peduncle per plant was recorded in genotype Kashi Kanchan and maximum number of peduncle was observed in IC-259063.

4.2.14 Duration of reproductive phase:

The Minimum duration of reproductive phase was observed in genotype EC-9736 and maximum duration of reproductive phase was observed in genotype IC-259063.

4.2.15 Number of seeds per plant:

The Minimum number of seeds per plant was observed in genotype IC-202786 and maximum number of seeds per plant was recorded in genotype Kashi Shyamal.

4.2.16 Number of seeds per pod:

The Minimum number of seeds per pod was observed in genotype EC-15296 and maximum number of seeds per pod was observed in IC-202776.

4.2.17 100 seed weight (g):

The Minimum and maximum 100-seed weight was recorded in genotype EC-30590 and maximum in genotype Kashi Gauri.

4.2.18 Vitamin A (IU):

The minimum Vitamin A was found in genotype Kshi Nidhi and maximum Vitamin A is found in genotype EC-30590.

4.2.19 Vitamin C (mg/100g):

The minimum Vitamin C was observed in genotype EC-30590 and maximum Vitamin C was observed in genotype Kashi Kanchan

4.3 Estimates of variability, heritability and genetic advance in percent of mean

4.3.1 Genetic variability:

The coefficient of variation value is presented in (Table No. 4.5.). The phenotypic coefficient of variation (PCV) was higher than their respective genotypic coefficient of variation (GCV) for all the traits under study.

The coefficient variation value is presented table 4.5. The phenotypic coefficient variation (PCV) was higher than their respective genotypic coefficient variation (GCV) for all the traits under study. The widest range was recorded for pod yield per plot g (3451.09-3663.25) followed by number of seeds per plant (232.20-304.14), Vitamin A (929.97-984.99),pod weight per plant g (339.83-389.53), days to first pod picking (49.52-57.14),and duration reproductive phase (29.07-36.76) while lowest range were recorded in number of branches per plant (3.71).

Plate-6: A general view of genotypes in cowpea

Plate-7: A general view of genotypes in cowpea

Plate-8: A general view of genotypes in cowpea

Plate-9: A general view of genotypes in cowpea

Plate-10: A general view of 16 genotypes of cowpea

Phenotypic coefficient variance was higher for number of primary branches per plant (24.78%) followed by number of pods per peduncle (19.44%), peduncle length (17.61%) where as it was moderate for pod diameter (14.16%) followed by pod length (12.89%), number of seeds per pod (12.55%) and low was recorded 100 seeds weight (8.86%) followed by number of pods per plant (7.45%), days to first pod picking and it was lowest recorded for vitamin A (3.97%).

Highest genotypic coefficient of variation (GCV) was observed for number of primary branches per plant (22.97%) followed by number of pods per peduncle (9.82%) and it was moderate for pod diameter (8.52%) followed by number of seeds per plant (7.53%) and low was recorded for 100 seeds weight (5.89%) followed by number of branches per plant (5.68%) and lowest was recorded vitamin A (0.38%).

Table No- 4.3.a: Estimates of variability, heritability and genetic advance as per cent of mean for nineteen characters in cowpea 2014-15

S. No.	Character	Range		Mean	Variance		PCV (%)	GCV (%)	h2 (%)	Genetic Advance	GA % of mean
		Min.	Max.		Phenotypic	Genotypic					
1.	Plant height(cm)	27.89	32.35	30.66	2.78	1.47	5.44	3.95	0.53	1.81	5.92
2.	Number of primary branches per plant	2.14	4.50	3.12	0.54	0.51	23.54	22.81	0.94	1.42	45.55
3.	Number of branches per plant	3.41	4.50	3.97	0.12	0.10	8.87	7.96	0.81	0.59	14.73
4.	Days to first open flower	40.76	45.98	43.40	3.73	1.12	4.45	2.44	0.30	1.19	2.75
5.	Number of pod per plant	39.33	49.41	42.91	11.72	9.17	7.98	7.06	0.78	5.51	12.85
6.	Days to first pod picking	53.25	56.78	54.54	2.29	0.32	2.77	1.04	0.14	0.44	1.02
7.	Pod length (cm)	11.30	14.87	12.99	1.49	0.97	9.39	7.60	0.65	1.65	12.67
8.	Pod diameter (cm)	5.34	6.98	6.09	0.45	0.34	10.99	9.62	0.77	1.06	17.36
9.	Number of pods per peduncle	4.75	8.24	6.50	1.39	1.26	18.16	17.26	0.90	2.20	33.80
10.	Pod weight per plant (g)	360.74	390.25	376.92	153.73	59.33	3.29	2.04	0.39	9.86	2.62
11.	Pod yield per plot (g)	3581.00	3825.00	3724.69	8411.89	3520.91	2.46	1.59	0.42	79.08	2.12
12.	Peduncle length (cm)	4.50	9.91	7.25	1.58	1.40	17.32	16.31	0.89	2.29	31.64
13.	Number of peduncle per plant	11.89	14.74	13.55	1.09	0.83	7.71	6.71	0.76	1.63	12.02
14.	Duration of reproductive phase	30.15	36.78	34.08	4.47	2.85	6.21	4.95	0.64	2.77	8.14
15.	Number of seeds per plant	236.97	312.73	283.04	588.21	472.10	8.57	7.68	0.80	40.10	14.17
16.	Number of seeds per pod	11.5	16.18	13.51	1.73	1.22	9.74	8.17	0.70	1.90	14.10
17.	100 seeds weight	4.57	5.63	5.03	0.10	0.06	6.26	5.01	0.64	0.41	8.25
18.	Vitamin A(IU)	923.38	989.56	954.79	930.34	316.32	3.19	1.86	0.34	21.36	2.24
19.	Vitamin C (mg/100g)	15.29	17.89	16.57	0.90	0.52	5.74	4.37	0.58	1.13	6.85

Table No. 4.3.b: Estimates of variability, heritability and genetic advance as per cent of mean for nineteen characters in cowpea 2015-16

S. No.	Character	Range		Mean	Variance		PCV (%)	GCV (%)	h2 (%)	Genetic Advance	GA % of mean
		Min.	Max.		Phenotypic	Genotypic					
1.	Plant height(cm)	27.89	31.57	29.15	3.79	0.98	6.67	3.40	0.26	1.04	3.58
2.	Number of primary branches per plant	2.16	4.33	3.15	0.62	0.53	25.09	23.09	0.85	1.38	43.77
3.	Number of branches per plant	3.50	4.83	4.11	0.28	0.09	12.95	7.43	0.33	0.36	8.77
4.	Days to first open flower	36.51	47.05	42.04	12.73	6.88	8.49	6.24	0.54	3.97	9.44
5.	Number of pod per plant	39.12	47.85	44.08	11.92	5.86	7.83	5.49	0.49	3.50	7.94
6.	Days to first pod picking	47.27	61.00	52.25	22.99	13.75	9.18	7.10	9.18	5.91	11.30
7.	Pod length (cm)	9.45	15.80	13.47	3.62	1.80	14.13	9.97	0.50	1.95	14.50
8.	Pod diameter (cm)	4.09	6.94	5.52	5.52	0.37	15.33	11.03	0.52	0.90	16.36
9.	Number of pods per peduncle	4.49	7.98	6.67	1.71	1.26	19.61	16.82	0.74	1.98	29.70
10.	Pod weight per plant (g)	313.68	389.50	365.10	909.92	474.98	8.26	5.97	0.52	32.44	8.88
11.	Pod yield per plot (g)	3211.17	4359.99	3800.42	116921.52	68467.81	9.00	6.89	0.59	412.48	10.85
12.	Peduncle length (cm)	5.36	8.95	7.07	1.34	0.84	16.37	12.94	0.62	1.49	21.07
13.	Number of peduncle per plant	10.61	15.02	13.14	3.43	1.51	14.08	9.36	0.44	1.68	12.81
14.	Duration of reproductive phase	27.63	39.44	34.94	0.62	0.53	25.09	23.09	0.85	1.38	43.77
15.	Number of seeds per plant	213.99	295.54	267.86	1191.76	537.38	12.89	8.65	0.45	32.07	11.97
16.	Number of seeds per pod	11.50	16.29	13.74	3.19	1.26	13.01	8.16	0.39	1.45	10.55
17.	100 seeds weight	4.41	5.86	4.90	0.38	0.11	12.50	6.90	0.30	0.38	7.84
18.	Vitamin A(IU)	913.28	985.42	952.78	2576.19	-296.64	5.33	1.81	-0.12	-12.04	-1.26
19.	Vitamin C (mg/100g)	15.26	17.90	16.64	1.35	0.48	6.98	4.18	0.36	0.86	5.15

Table No.4.3.c: Estimates of variability, heritability and genetic advance as per cent of mean for nineteen characters in cowpea pooled

S. No.	Character	Range		Mean	Variance		PCV (%)	GCV (%)	h2 (%)	Genetic Advance	GA % of mean
		Min.	Max.		Phenotypic	Genotypic					
1.	Plant height(cm)	28.07	30.55	29.91	2.75	0.06	5.54	0.81	0.02	0.07	0.24
2.	Number of primary branches per plant	2.2	4.53	3.13	0.60	0.52	24.78	22.97	0.86	1.37	43.87
3.	Number of branches per plant	3.71	4.83	4.04	0.25	0.05	12.27	5.63	0.21	0.22	5.33
4.	Days to first open flower	41.12	45.44	42.72	7.10	1.49	6.24	2.85	0.21	1.15	2.69
5.	Number of pod per plant	41.63	45.38	43.49	10.75	-1.06	7.54	2.36	-0.10	-0.66	-1.53
6.	Days to first pod picking	49.52	57.14	53.40	11.56	2.74	6.37	3.10	0.24	1.66	3.11
7.	Pod length (cm)	11.72	14.87	13.23	2.91	0.18	12.89	3.21	0.06	0.22	1.65
8.	Pod diameter (cm)	4.74	6.65	5.80	0.68	0.24	14.16	8.52	0.36	0.61	10.56
9.	Number of pods per peduncle	5.62	7.76	6.58	1.64	0.42	19.44	9.82	0.25	0.67	10.21
10.	Pod weight per plant (g)	339.83	389.53	371.01	651.97	183.99	6.88	3.66	0.28	14.84	4.00
11.	Pod yield per plot (g)	3451.09	3663.25	3762.55	58208.72	11079.05	6.41	2.80	0.19	94.60	2.51
12.	Peduncle length (cm)	5.31	8.75	7.16	1.59	0.33	17.61	7.99	0.21	0.53	7.47
13.	Number of peduncle per plant	12.12	14.49	13.34	1.92	0.11	10.37	2.52	0.06	0.17	1.27
14.	Duration of reproductive phase	29.07	36.76	34.51	8.67	2.52	8.53	4.60	0.29	1.76	5.11
15.	Number of seeds per plant	232.20	304.14	275.45	1110.84	430.67	12.10	7.53	0.39	26.62	9.66
16.	Number of seeds per pod	12.07	15.19	13.63	2.92	0.29	12.55	3.95	0.10	0.35	2.56
17.	100 seeds weight	4.49	5.74	4.96	0.19	0.09	8.86	5.89	0.44	0.40	8.07
18.	Vitamin A(IU)	929.97	984.99	953.79	3.97	12.92	3.97	0.38	0.01	0.70	0.07
19.	Vitamin C (mg/100g)	15.78	17.69	16.60	0.97	0.26	5.92	3.07	0.27	0.55	3.29

4.3.2 Heritability:

Heritability value in broad sense is presented in table-4.5 The highest heritability was recorded for number of primary branches per plant (0.86%) and 100- seeds weight (0.44%) and followed by number of seeds per plant (0.39%) , pod diameter (0.36%), duration of reproductive phase (0.29%), pod weight per plant (0.28%), number of pods per peduncle (0.25%), days to first pod picking (0.24%), number of branches per plant (0.21%), days to first open flower (0.21%) and peduncle length (0.21%) whereas, minimum was recorded for Vitamin A (0.01%).

4.3.3 Genetic gain:

The maximum genetic gain (%) was recorded for number of primary branches per plant (43.87%) followed by pod diameter (10.56%), number of pods per peduncle (10.21%), number of seeds per plant (9.66%), 100- seeds weight (8.07%), peduncle length (7.47%), number of branches per plant (5.33%), duration of reproductive phase (5.11%), pod weight per plant (4.00%), vitamin- c (3.29), days to first pod picking (3.11%), days to first open flower (2.69%), number of seeds per pod (2.56%), pod yield per plot (2.51%), number of peduncle per plant (1.27%), whereas, minimum was recorded for number of pod per plant (-1.53%).

4.4 Genotypic and Phenotypic Correlation coefficient:

The correlation coefficient at genotypic level are presented in (Table-5.2) that pod yield per plant had positive and significant genotypic correlation coefficient with pod yield per plant (1.000) followed by number of peduncle per plant (0.0269). However, negative and significant correlations were recorded for pod yield per plant with days to first pod picking (-1.4504). Days to first pod picking (0.9483) showed positive and

significant correlation followed by number of seeds per pod (-0.1115) and negative and significant correlations were recorded for plant height (-0.6427). Number of pods per peduncle (0.5861) fallowed by number of peduncle per plant (0.0096) showed positive and significant correlation and negative and significant correlations were recorded for plant height (-0.4931). Number of primary branches per plant (0.5380) showed positive and significant correlation followed by days to first pod picking (0.0365) and negative and significant correlations were recorded for primary branches per plant (-0.9256). Positive and significant genotypic correlation coefficient with vitamin-C (0.2426) followed by number of seeds per plant (0.05380). However, negative and significant correlations were recorded for number of peduncle per plant (-0.8543). Number of peduncle per plant (0.4851) followed by days to first pod picking (0.0043) showed positive and significant correlation and negative and significant correlations were recorded for number of branches per plant t (-0.5223), peduncle length (cm) (0.4751) followed by plant height (0.02997) showed positive and significant correlation and negative and significant correlations were recorded for number of branches per plant (-0.4498), and positive and significant genotypic correlation coefficient with number of seeds per plant (0.3597) followed by 100 seed weight (0.0835). However, negative and significant correlations were recorded for number of peduncle per plant (-0.6540).

At the phenotypic level are presented in (Table-5.3) that pod yield per plant had positive and significant genotypic correlation coefficient (1.000) followed by number of seeds per pod (0.0731). However, negative and significant correlations were recorded for vitamin-C (-0.0182). Vitamin-A had positive and significant correlation with pods per peduncle (0.0461) except negative and significant correlation with number of branches per plant (-0.0114), number of primary branches per plant (0.5696) showed

positive and significant correlation followed by vitamin-C (0.0103) and negative and significant correlations were recorded for pod diameter (-0.4396**).**Vitamin –C (0.5363) followed by peduncle length (0.0216) showed positive and significant correlation and negative and significant correlations were recorded for number of peduncle per plant (-0.2555),days to first open flower (0.5155) fallowed by number of pods per plant (0.01919) showed positive and significant correlation and negative and significant correlations were recorded for number of branches per plant (-0.0166), and positive and significant genotypic correlation coefficient with 100 seeds weight (0.5092) followed by number of seeds per pod (0.0348). However, negative and significant correlations were recorded for number of peduncle per plant (-0.0828).

The path coefficient analysis was obtained for clear, understanding of association of the genotypic correlation coefficient of yield with contributing components. The genotypic correlation coefficient was partitioned into direct and indirect effects through path coefficient analysis of parents. The results of path coefficient for parent are presented in Table-3. At genotypic level, highest positive direct effect towards pod yield per plant was showed by plant height (2.0266) followed by number of seeds per plant (2.0180), pod length (cm) (1.3435), days to first pod picking (1.3398), number of pods per peduncle (1.2163), vitamin-A (1.2087), number of primary branches per plant (1.0063), pod diameter (cm) (0.8480) and days to first open flower (0.3174).highest negative effect towards pod yield per plant was showed by number of peduncle per plant (-3.8261) followed by vitamin-C (-2.5669), number of seeds per plant (-1.8234), pod weight per plant (-1.8234), number of pod per plant (-1.2892), number of branches per plant (-0.4917) and number of seeds per pod (-0.4038).

4.5 Path coefficient analysis:

Highest positive direct effect on pod yield per plot (g) was exhibited by number of peduncle per plant (51.324) pod length (20.684), pod diameter (17.183), number of seeds per pod (6.083), peduncle length (4.912),hundred seeds weight (3.162), and vitamin C (1.150), Whereas, highest negative and direct effect towards pod yield per plot was exhibited pod weight per plant (-3.163) followed by number of branches per plant (-4.741), days to first open flower (-5.313), number of seeds per plant (-5.938), vitamin A (10.747), pods per peduncle (-11.249), and duration of reproductive phase (-18.599).

Table No.4.4.a -Genotypic Correlation coefficient for different pairs of characters in 16 parents of cowpea 2014-15

GENOTYPICAL Correlation Matrix																			
S. No.	**Character**	**Pods Per Plant**	**Branches Per Plant**	**Pod Length**	**Seeds Per Pod**	**Days to First Open Flower**	**Days to Pod First Picking**	**Peduncle Per Plant**	**Pod Weight Per Plant**	**Pod Diameter (cm)**	**Pods Per Peduncle**	**Peduncle Length**	**100 Seeds Weight**	**Seeds Per Plant**	**Vitamin A (IU)**	**Vitamin C**	**Primary Branches Per Plant**	**Duration of Reproduc**	**Pod Yield Per Plot (g)**
1.	Plant Height (cm)	-0.052	-0.945	-0.359	0.055	-0.312	-0.642	0.173	-0.189	-0.433	-0.493	0.299	-0.544	-0.279	-0.136	-0.439	0.246	-0.298	-0.421
2.	Pods Per Plant		-0.434	-0.208	0.240	0.259	-0.152	-0.132	-0.239	0.0248	0.095	-0.255	-0.001	0.126	0.278	0.294	-0.034	-0.448	-0.525
3.	Branches Per Plant			-0.501	-0.467	-0.758	-0.948	-0.522	-0.473	-0.071	-0.093	-0.449	0.175	-0.079	-0.657	-0.020	0.107	0.242	-0.079
4.	Pod Length				-0.077	-0.133	-0.287	0.485	0.058	0.069	0.413	-0.166	-0.654	-0.151	0.281	-0.440	-0.509	-0.393	-0.218
5.	Seeds Per Pod					0.010	0.111	-0.176	-0.254	0.329	-0.113	0.333	-0.145	-0.197	0.085	-0.050	-0.445	0.075	-0.196
6.	Days to Frist Open Flower						-1.417	-0.098	-0.282	-0.134	0.136	-0.363	-0.322	-0.581	-0.842	-0.216	-0.535	-0.778	-0.904
7.	Days to Frist pod Picking							0.004	-0.311	0.203	0.348	-0.170	-0.033	-0.028	-1.846	-0.077	-0.925	-0.935	-1.450
8.	Peduncle Per Plant								-0.360	-0.165	0.009	-0.095	-0.535	-0.341	0.206	-0.854	-0.364	0.024	0.026
9.	Pod Weight Per Plant (g)									-0.079	0.586	-0.027	0.164	0.201	-0.871	0.016	0.036	-1.016	-0.730
10	Pod Diameter (cm)										-0.120	0.475	0.251	-0.371	0.117	0.161	-0.581	0.245	-0.292
11.	Pods Per Peduncle											-0.274	-0.031	0.359	-0.113	-0.056	-0.187	-0.565	0.078
12.	Peduncle Length												0.158	-0.441	0.129	-0.317	-0.080	0.184	0.040
13	100 Seeds Weight													0.083	-0.839	0.244	0.104	-0.275	-0.310
14	Seeds Per Plant														-0.321	0.022	0.538	-0.596	-0.162
15	Vitamin A(IU)															-0.820	0.058	-0.323	-0.129
16	Vitamin – C (mg/gm)																-0.1880	-0.530	-1.014
17	Primery Branches Per Plant																	-0.338	0.251
18	Duration of Reproductive Phase																		0.544
19	Pod Yield Per Plot (g)																		1.000

Table No.4.4.b. - Phynotypical Correlation coefficient for different pairs of characters in 16 parents of cowpea 2014-15

PHYNOTYPICAL Correlation Matrix																			
S.No.	**Character**	**Pods Per Plant**	**Branches Per Plant**	**Pod Length**	**Seeds Per Pod**	**Days to First Open Flower**	**Days to Pod First Picking**	**Peduncle Per Plant**	**Pod Weight Per Plant**	**Pod Diameter (cm)**	**Pods Per Peduncle**	**Peduncle Length**	**100 Seeds Weight**	**Seeds Per Plant**	**Vitamin A(IU)**	**Vitamin C**	**Primary Branches Per Plant**	**Duration of Reproductive Phase**	**Pod Yield Per Plot (g)**
1.	Plant Height (cm)	0.286*	-0.323**	0.166*	0.188	0.449**	0.420**	0.437**	0.418**	-0.139*	-0.244**	0.420	0.095	0.116	0.461	0.201	0.329**	0.240	0.311**
2.	Pods Per Plant		-0.146	0.111	0.288**	0.515**	0.356	0.121*	0.212	0.115	0.146	-0.065*	0.278	0.302	0.498	0.500**	0.077	-0.036*	0.046**
3.	Branches Per Plant			-0.119*	-0.244**	-0.016*	0.063	-0.198*	0.058	0.039*	-0.017*	-0.237**	0.383**	0.130	-0.011*	0.263	0.195	0.431**	0.277
4.	Pod Length				0.107*	0.404**	0.434	0.611**	0.468**	0.189	0.408	0.067*	-0.091	0.133	0.587**	0.091*	-0.260	0.081	0.296
5.	Seeds Per Pod					0.191*	0.214	-0.013*	0.015*	0.504**	0.040	0.363	0.034*	-0.041*	0.198	0.116	-0.300**	0.189	0.073
6.	Days to First Open Flower						0.437**	0.351	0.520	0.099	0.186	0.075	0.360	0.075*	0.365	0.451	-0.094	0.163	0.298
7.	Days to Pod First Picking							0.430	0.654**	0.222	0.247	0.228	0.509**	0.377**	0.350	0.544	-0.124*	0.244	0.310
8.	Peduncle Per Plant								0.167	-0.025**	0.082	0.075	-0.082*	-0.053	0.479	-0.255**	-0.195	0.304	0.379
9.	Pod Weight Per Plant									0.086	0.448**	0.226	0.521	0.439	0.320	0.486	0.199	-0.061	0.264
10.	Pod Diameter cm										0.012*	0.480**	0.291	-0.196	0.196	0.238	-0.439	0.293	-0.009*
11.	Pods Per Peduncle											-0.190	0.056	0.370	0.046*	0.049	-0.139	-0.343**	0.166
12.	Peduncle Length (cm)												0.308	-0.230**	0.322	-0.021*	0.006*	0.329**	0.260
13.	100 Seeds Weight													0.320	0.061	0.536**	0.218	0.184	0.284
14.	Seeds Per Plant														0.169	0.296	0.569**	-0.166	0.234
15.	Vitamin A(IU)															0.129	0.217	0.306**	0.526**
16.	Vitamin C																0.010*	0.067*	-0.018
17.	Primary Branches Per Plant																	-0.123	0.327
18.	Duration of Reproductive Phase																		0.164
19.	Pod Yield Per Plot (g)																		1.000

Table No.4.4.c -Genotypic path coefficient analysis (direct and indirect effect) of yield contributing characters of Cowpea 2014-15

S.No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant	Pod Diameter cm	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A(IU)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	**2.0266**	-0.1060	-1.9159	-0.7278	0.1124	-0.6324	-1.3025	0.3506	-0.3837	-0.8792	-0.9993	0.6073	-1.1032	-0.5661	-0.2756	-0.8909	0.4989	-0.6040
2.	Pods Per Plant	0.0674	**-1.2892**	0.5603	0.2684	-0.3105	-0.3345	0.1966	0.1711	0.3093	-0.0319	-0.1225	0.3291	0.0016	-0.1632	-0.3591	-0.3792	0.0442	0.5784
3	Branches Per Plant	0.4648	0.2137	**-0.4917**	0.2464	0.2297	0.3730	0.4663	0.2568	0.2330	0.0349	0.0458	0.2212	-0.0865	0.0389	0.3232	0.0103	-0.0527	-0.1193
4	Pod Length	-0.4825	-0.2797	-0.6733	**1.3435**	-0.1047	-0.1787	-0.3862	0.6517	0.0789	0.0937	0.5558	-0.2236	-0.8787	-0.2029	0.3776	-0.5918	-0.6845	-0.5291
5	Seeds Per Pod	-0.0224	-0.0972	0.1885	0.0314	**-0.4036**	-0.0042	-0.0450	0.0714	0.1025	-0.1329	0.0458	-0.1345	0.0587	0.0796	-0.0343	0.0203	0.1798	-0.0303
6	Days to First Open Flower	-0.0990	0.0824	-0.2408	-0.0422	0.0033	**0.3174**	-0.4500	-0.0312	-0.0897	-0.0427	0.0432	-0.1153	-0.1023	-0.1845	-0.2674	-0.0686	-0.1699	-0.2471
7	Days to Pod First Picking	-0.8611	-0.2043	-1.2705	-0.3851	0.1494	-1.8995	**1.3398**	0.0058	-0.4169	0.2730	0.4674	-0.2283	-0.0443	0.0386	-2.4744	-0.1033	-1.2401	-1.2532
8	Peduncle Per Plant	-0.6619	0.5077	1.9984	-1.8560	0.6767	0.3758	-0.0165	**-3.8261**	1.3781	0.6325	-0.0366	0.3632	2.0380	1.3078	-0.7897	3.2687	1.3959	-0.0933
9	Pod Weight Per Plant	0.3209	0.4067	0.8032	-0.0995	0.4306	0.4791	0.5274	0.6106	**-1.6951**	0.1340	-0.9935	0.0470	-0.2793	-0.3419	1.4775	-0.0274	-0.0618	1.7235
10	Pod Diameter (cm)	-0.3679	0.0210	-0.0602	0.0592	0.2793	-0.1140	0.1728	-0.1402	-0.0670	**0.8480**	0.1024	0.4029	0.2128	0.3153	0.0994	0.1371	-0.4932	0.2080
11	Pods Per Peduncle	-0.5998	0.1155	-0.1134	0.5031	-0.1379	0.1656	0.4243	0.0116	0.7129	-0.1469	**1.2163**	-0.3336	-0.0388	0.4375	-0.1385	-0.0692	-0.2274	-0.6874
12	Peduncle Length	-0.8650	0.7368	1.2983	0.4803	-0.9617	1.0482	0.4918	0.2740	0.0800	-1.3714	0.7916	**-2.8865**	-0.4574	1.2729	-0.3725	0.9160	0.2319	-0.5329
13	100 Seeds Weight	-1.0986	-0.0026	0.3549	-1.3198	-0.2936	-0.6504	-0.0667	-1.0749	0.3325	0.5065	-0.0643	0.3198	**2.0180**	0.1686	-1.6942	0.4896	0.2117	-0.5562
14	Seeds Per Plant	-0.5093	-0.2308	0.1443	0.2754	0.3598	1.0602	0.0525	0.6233	-0.3678	0.6781	-0.6558	0.8041	-0.1523	**-1.8234**	0.5856	-0.0403	-0.9809	1.0874
15	Vitamin A(IU)	-0.1644	0.3367	-0.7944	0.3397	0.1028	-1.0184	-2.2324	0.2495	-1.0536	0.1416	-0.1376	0.1560	-1.0148	-0.3882	**1.2087**	-0.9920	0.0707	-0.3910
16	Vitamin C	-1.1285	-0.7551	0.0537	1.1307	0.1291	0.5548	0.1979	2.1929	-0.0415	-0.4149	0.1460	0.8146	-0.6228	-0.0567	2.1067	**-2.5669**	0.4825	1.3608
17	Primary Branches Per Plant	-0.2477	-0.0345	0.1079	-0.5127	-0.4482	-0.5388	-0.9314	-0.3671	0.0367	-0.5853	-0.1882	-0.0808	0.1056	0.5414	0.0589	-0.1891	**1.0063**	-0.3402
18	Duration of Reproductive Phase	0.0353	0.0532	-0.0288	0.0467	-0.0089	0.0923	0.1109	-0.0029	0.1205	-0.0291	0.0670	-0.0219	0.0327	0.0707	0.0383	0.0628	0.0401	**-0.1185**
19	Pod Yield Per Plot (g)	**-0.4218**	**-0.5257**	**-0.0795**	**-0.2182**	**-0.1961**	**-0.9044**	**-1.4504**	**0.0269**	**-0.7308**	**-0.2920**	**-0.0788**	**-0.0408**	**-0.3129**	**-0.1635**	**-0.1299**	**-1.0141**	**0.2514**	**-0.5443**

Table No-4.4.d. - Genotypic Correlation coefficient for different pairs of characters in 16 parents of cowpea 2015-16

S. No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant	Pod Diameter cm	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A (IU)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	-0.0673*	-0.3213	-0.0535*	-0.2153*	-0.6491	-0.5839**	-0.6419**	-0.3482*	0.1316	-0.5341	-0.6893	-0.0483*	-0.5980	-1.6577	-1.0468	-1.0177**	-0.8571**	-0.4271*
2.	Pods Per Plant		0.2914**	-0.0941*	0.5931	-0.9129	-0.7845	-1.0805	-0.5081	-0.6569	-0.3395**	-0.1667*	0.0227*	0.0501*	-0.5709**	-0.7032**	-0.2417**	-0.5739	-0.7645**
3	Branches Per Plant			0.0146*	-0.2009**	-0.5038***	-0.6994	-0.9100	-0.6713	-0.5989	-0.1438*	0.1044*	0.0802	0.0425*	-0.2880**	-0.9357	0.3677**	-0.7596	-0.4818**
4	Pod Length				-0.4816**	0.2790**	0.4247**	-0.5419**	-0.1427*	0.1073	-0.1459*	-0.0226*	-0.0216*	-0.3251**	0.0172*	-1.1954	0.1727*	0.6223**	0.5716**
5	Seeds Per Pod					-0.9232	-0.8111	-0.9642	-0.4228	-0.5748	-0.1073*	0.1261*	-0.7708	-0.6168	-0.8184	-0.3841**	-0.6695	-0.8130	-0.4501
6	Days to First Open Flower						0.8419	0.4811**	0.0747*	0.3349	-0.0209*	-0.3328**	-0.2671**	0.0641*	-1.3381	-0.5044	-0.0868	0.1165	0.4636
7	Days to Pod First Picking							0.3544**	0.0185*	0.4485	-0.1873**	-0.3968	-0.4231**	-0.2759**	-1.4272	-0.6153	0.0319*	0.4124**	0.5178**
8	Peduncle Per Plant								0.0843*	0.3008	-0.2015**	-0.6629	-0.6881	0.0906*	-1.8315	-0.2105	-0.2541	-0.7909	0.1822
9	Pod Weight Per Plant (g)									0.1633	-0.4365	-0.2364**	0.2246**	0.0465*	-1.2046	-0.3016	-0.4945	-0.2027**	0.0173*
10	Pod Diameter cm										0.1566**	-0.3013**	-0.5441**	-0.7833	-1.1392	-0.7480	-0.4530	0.0930	0.2252
11	Pods Per Peduncle											0.3172**	-0.7748	-0.3905**	-0.4321	-0.2666	-0.4739	-0.5732	-0.1485*
12	Peduncle Length												-0.7814	-0.4703	-0.7986	-0.1711*	-0.1410	-0.7367	-0.1977
13	100 Seeds Weight													0.4326**	-0.2802**	-0.5930**	0.0754*	0.0183*	-0.3011**
14	Seeds Per Plant														-0.2893**	-0.2348**	0.2087**	-0.4954	-0.1745
15	Vitamin A (IU)															-1.6339	-0.1849	-1.1843	-0.6123
16	Vitamin C																-0.3795	-0.7699	-0.5296
17	Primary Branches Per Plant																	-0.0365*	-0.0778*
18	Duration of Reproductive Phase																		0.4431
19	Pod Yield Per Plot (g)																		1.0000**

Table N0-4.4.e. -Phenotypic Correlation coefficient for different pairs of characters in 16 parents of cowpea 2015-16

S No	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant	Pod Diameter ((cm	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A(IU)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	0.5884	0.2878**	0.2522**	0.5739	0.3382**	0.3132**	0.3968	0.4644	0.3818**	-0.0001*	0.2302**	0.3848**	0.1035**	0.6201	0.3673	-0.1564	0.4846	0.3850**
2.	Pods Per Plant		0.4291	0.1740**	0.7922	0.0109**	0.0246**	0.0020**	0.2331**	-0.0605*	-0.0142*	0.3274**	0.3342**	0.2738**	0.6157	0.2740**	0.1093**	0.3787**	0.0465*
3	Branches Per Plant			0.4136	0.2740**	0.1008**	-0.0228*	0.0203**	0.0389*	0.1998	0.2536	0.3343**	0.7059	0.4887	0.4054**	0.0244*	0.3602	0.1757**	0.0724*
4	Pod Length				0.0652*	0.3703	0.4383	0.0380*	0.1590**	0.5275***	0.2560**	0.2180	0.4127	0.3441**	0.3319**	-0.2686**	0.2465**	0.5552	0.5137
5	Seeds Per Pod					0.0787	0.0782**	0.1720**	0.3202	0.0601*	0.1649	0.5360***	0.0965*	0.0356	0.6082	0.4461	-0.0916*	0.3982	0.2600**
6	Days to First Open Flower						0.9081	0.7208	0.5071	0.4514*	0.1804**	0.2054**	0.2176	0.2859	0.3803**	0.3190**	0.1950**	0.6055	0.6963
7	Days to Pod First Picking							0.6363	0.4474**	0.5021	0.0531*	0.1299	0.1179**	0.0877*	0.2929**	0.2209**	0.2610**	0.6902	0.7138
8	Peduncle Per Plant								0.5342	0.4800	0.1228	0.0994*	0.1302**	0.3536	0.3356**	0.4822	0.1283	0.3630**	0.5502
9	Pod Weight Per Plant									0.3634**	-0.0748*	0.2697**	0.4193	0.2792**	0.4323	0.4210**	-0.0718**	0.4931	0.4530
10	Pod Diameter cm										0.4481**	0.0941*	0.2464**	0.1267*	0.1269**	-0.0228*	-0.1404*	0.4087**	0.3748**
11	Pods Per Peduncle											0.3971**	-0.0316*	0.1496**	0.1575**	0.0746*	-0.2657	0.0079*	0.0771*
12	Peduncle Length												-0.0389*	-0.0020*	0.4050	0.3856	0.1294**	0.2163	0.2566**
13	100 Seeds Weight													0.6504	0.4294**	0.1650**	0.2119	0.4224	0.1681**
14	Seeds Per Plant														0.3069**	0.1800**	0.2707	0.1726	0.1401**
15	Vitamin A (IU)															0.5128	0.3369**	0.6594	0.5190
16	Vitamin C																0.0879**	0.4151	0.2704**
17	Primary Branches Per Plant																	0.3112**	0.1861**
18	Duration of Reproductive Phase																		0.7053
19	Pod Yield Per Plot (g)																		1.0000

Table No.4.4.f-Genotypic path coefficient analysis (direct and indirect effect) of yield contributing characters of Cowpea 2015-16

S. No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant	Pod Diameter (cm)	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A(IU)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	**1.1882**	-0.0800	-0.3817	-0.0636	-0.2558	-0.7712	-0.6938	-0.7627	-0.4137	0.1564	-0.6346	-0.8190	-0.0574	-0.7105	1.9698	-1.2438	-1.2092	-1.0184
2.	Pods Per Plant	0.1695	**-2.5176**	-0.7336	0.2370	-1.4933	2.2983	1.9750	2.7203	1.2791	1.6539	0.8546	0.4197	-0.0572	-0.1260	-1.4372	1.7705	0.6084	1.4448
3	Branches Per Plant	0.0108	-0.0098	**-0.0335**	-0.0005	0.0067	0.0169	0.0234	0.0305	0.0225	0.0201	0.0048	-0.0035	-0.0027	-0.0014	-0.0096	0.0313	-0.0123	0.0254
4	Pod Length	0.0611	0.1074	-0.0167	**-1.1411**	0.5495	-0.3184	-0.4847	0.6184	0.1628	-0.1225	0.1665	0.0258	0.0247	0.3710	0.0196	1.3641	-0.1971	-0.7102
5	Seeds Per Pod	-0.2412	0.6646	-0.2251	-0.5396	**1.1204**	-1.0344	-0.9088	-1.0803	-0.4737	-0.6440	-0.1202	0.1413	-0.8636	-0.6910	0.9169	-0.4304	-0.7501	-0.9109
6	Days to First Open Flower	0.7031	0.9888	0.5457	-0.3022	1.0000	**-1.0832**	-0.9120	-0.5211	-0.0809	-0.3628	0.0226	0.3605	0.2893	-0.0694	-1.4495	0.5464	0.0940	-0.1262
7	Days to Pod First Picking	-0.3481	-0.4676	-0.4170	0.2532	-0.4835	0.5019	**0.5961**	0.2113	0.0111	0.2674	-0.1116	-0.2365	-0.2522	-0.1645	0.8508	-0.3668	0.0190	0.2459
8	Peduncle Per Plant	0.3571	0.6012	0.5064	0.3015	0.5365	-0.2677	-0.1972	**-0.5564**	-0.0469	-0.1674	0.1121	0.3688	0.3828	-0.0504	-1.0190	0.1171	0.1414	0.4401
9	Pod Weight Per Plant	-0.0254	-0.0371	-0.0490	-0.0104	-0.0308	0.0054	0.0014	0.0061	**0.0729**	0.0119	-0.0318	-0.0172	0.0164	0.0034	0.0879	-0.0220	-0.0361	-0.0148
10	Pod Diameter (cm)	-0.0449	0.2243	0.2045	-0.0366	0.1963	-0.1144	-0.1532	-0.1027	-0.0558	**-0.3415**	-0.0535	0.1029	0.1858	0.2674	-0.3890	0.2554	0.1547	-0.0318
11	Pods Per Peduncle	-0.1496	-0.0951	-0.0403	-0.0409	-0.0300	-0.0058	-0.0524	-0.0564	-0.1222	0.0438	**0.2800**	0.0888	-0.2170	-0.1094	0.1210	-0.0747	-0.1327	-0.1605
12	Peduncle Length	-0.3709	-0.0897	0.0562	-0.0122	0.0679	-0.1790	-0.2135	-0.3567	-0.1272	-0.1621	0.1707	**0.5380**	-0.4204	-0.2530	0.4297	-0.0920	-0.0759	-0.3964
13	100 Seeds Weight	0.0560	-0.0263	-0.0929	0.0251	0.8930	0.3095	0.4902	0.7972	-0.2603	0.6304	0.8977	0.9054	**-1.1586**	-0.5013	-0.3247	0.6871	-0.0874	-0.0212
14	Seeds Per Plant	-1.3567	0.1136	0.0965	-0.7376	-1.3993	0.1454	-0.6259	0.2056	0.1054	-1.7771	-0.8861	-1.0670	0.9816	**2.2688**	0.6563	-0.5328	0.4735	-1.1240
15	Vitamin AIU)	0.2145	0.0739	0.0373	-0.0022	0.1059	0.1732	0.1847	0.2370	0.1559	0.1474	0.0559	0.1034	0.0363	0.0374	**0.1294**	0.2115	0.0239	0.1533
16	Vitamin C	1.3112	0.8809	1.1721	1.4973	0.4812	0.6319	0.7708	0.2636	0.3778	0.9369	0.3340	0.2143	0.7428	0.2941	-2.0467	**-1.2526**	0.4754	0.9644
17	Primary Branches Per Plant	-0.5034	-0.1195	0.1819	0.0854	-0.3311	-0.0429	0.0158	-0.1257	-0.2446	-0.2240	-0.2344	-0.0697	0.0373	0.1032	0.0915	-0.1877	**0.4946**	-0.0181
18	Duration of Reproductive Phase	-1.4585	-0.9766	-1.2926	1.0590	-1.3835	0.1983	0.7018	-1.3459	-0.3449	0.1583	-0.9753	-1.2536	0.0311	-0.8430	2.0152	-1.3102	-0.0621	**1.7016**
19	Pod Yield Per Plot (g)	**-0.4271**	**-0.7645**	**-0.4818**	**0.5716**	**-0.4501**	**0.4636**	**0.5178**	**0.1822**	**0.0173**	**0.2252**	**-0.1485**	**-0.1977**	**-0.3011**	**-0.1745**	**0.6123**	**-0.5296**	**-0.0778**	**0.4431**

Table No.4.4.h -Genotypic Correlation coefficient for different pairs of characters in 16 parents of cowpea pooled data

S.No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant (g)	Pod Diameter (cm)	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A (IU)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	-1.7050	-0.9520	0.4419	-0.1518	0.3415	0.0905	-2.0851	0.2645	0.6610	-0.9497	0.4131	0.0973	-1.6260	-5.7078	-0.3369	-1.0645	-0.1046	-0.8450
2.	Pods Per Plant		-0.1790	-1.0245	-0.6719	-0.0955	-0.4668	0.2008	-0.2143	-0.3229	0.1309	-0.8408	0.1151	0.1674	-4.9378	-0.0573	-0.3145	-0.7891	-0.7518
3.	Branches Per Plant			-1.1297	-0.3426	-0.9170	-0.6921	-1.9341	-0.9223	-0.5220	-0.3503	-0.9335	0.0300	-0.2000	-3.3358	-0.4289	0.2934	-0.3723	-0.1530
4.	Pod Length				-0.2985	-0.2164	-0.0194	-0.0798	-0.0914	-0.1702	0.6585	0.3250	-0.6073	-0.4509	0.8235	-1.2614	-0.4241	0.0914	0.9448
5.	Seeds Per Pod					-0.3026	-0.4010	-0.2116	0.0683	-0.0225	-0.2121	0.0492	-0.4296	-0.4507	-4.6163	-0.5279	-1.1177	-0.2146	-0.8081
6.	Days to First Open Flower						0.7446	0.1852	0.3769	0.6156	0.3558	0.4254	-0.1309	-0.1273	-2.3379	0.2523	-0.2487	-0.0661	0.0884
7.	Days to Pod First Picking							-0.1159	0.2024	0.6130	-0.1753	0.4651	0.0625	-0.0872	-1.7629	0.0454	-0.0044	0.5797	0.5965
8.	Peduncle Per Plant								0.0255	0.2059	0.8351	-0.4815	-1.0735	0.0929	1.0246	0.6751	-0.6337	-0.9243	-0.1393
9.	Pod Weight Per Plant (g)									0.2137	-0.2016	0.1732	0.3412	-0.0360	-2.7353	0.1710	-0.3114	-0.2669	0.0333
10.	Pod Diameter (cm)										-0.0904	0.0988	-0.0620	-0.6424	-1.8655	-0.1555	-0.6014	0.2963	0.3360
11.	Pods Per Peduncle											-0.2189	-0.4397	0.0230	0.7633	-0.2065	-0.5068	-0.1269	0.4630
12.	Peduncle Length												-0.4788	-0.8157	-0.8203	-0.5567	-0.1840	0.3798	0.0175
13.	100 Seeds Weight													0.2940	-2.7262	0.0240	0.0858	-0.0759	-0.0942
14.	Seeds Per Plant														-0.8433	-0.1297	0.3941	-0.5688	-0.0160
15.	Vitamin A (IU)															-3.2273	0.0329	-2.9105	-0.5386
16.	Vitamin C																-0.2714	-0.5657	-0.3038
17.	Primary Branches Per Plant																	-0.1460	0.0021
18.	Duration of Reproductive Phase																		0.4454
19	Pod Yield Per Plot (g)																		1.0000

Table No.4.4.i: Phenotypical correlation matrix for different pairs of chracters of 16 parents of cowpea pooled data

S.No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to First Open Flower	Days to Pod First Picking	Peduncle Per Plant	Pod Weight Per Plant (g)	Pod Diameter (cm)	Pods Per Peduncle	Peduncle Length	100 Seeds Weight	Seeds Per Plant	Vitamin A (I U)	Vitamin C	Primary Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height (cm)	0.3718**	0.0606*	0.2203**	0.3482**	0.2536**	0.2283**	0.3029**	0.4169**	0.1460*	-0.1357*	0.2973**	0.2404**	0.1317*	0.4808	0.1731*	0.0363*	0.2794**	0.2686**
2.	Pods Per Plant		0.1947**	0.1501*	0.4978	0.0745*	0.0083*	-0.0759*	0.1964**	0.0028*	0.0509*	0.1028*	0.2786	0.2942**	0.4994	0.2914**	0.0807*	0.1180*	-0.0375*
3	Branches Per Plant			0.4259	0.1754**	0.0601*	0.0062*	-0.0328*	0.1967	0.2477	0.2160**	0.1980**	0.5437	0.5391	0.3130**	0.1041*	0.3418**	0.2658**	0.1232**
4	Pod Length				0.1486*	0.3736	0.4308	0.1945**	0.3323**	0.4315***	0.3258	0.2344**	0.2834**	0.3956**	0.4476	-0.1455**	0.1159**	0.4656	0.4848
5	Seeds Per Pod					0.0389*	0.0395*	0.0420*	0.2974	0.3375**	0.1765**	0.4701	0.0659*	0.1180*	0.4018	0.2484	-0.1158*	0.2627**	0.1522**
6	Days to First Open Flower						0.8132	0.5836	0.4840	0.3126	0.1636	0.1195*	0.1938**	0.2385**	0.2708**	0.2486**	0.0756*	0.4239**	0.6001
7	Days to Pod First Picking							0.5400	0.4534	0.3912	0.0767*	0.1209*	0.1288*	0.1676**	0.1965**	0.1846	0.1492	0.5670	0.6572
8	Peduncle Per Plant								0.4492	0.2911**	0.0867*	0.0688*	-0.0024*	0.2622**	0.2426**	0.1287*	0.0014*	0.2191**	0.4537
9	Pod Weight Per Plant (g)									0.3271	0.1116**	0.3204	0.4867	0.4337	0.4224	0.4021	0.0822*	0.4019	0.4263**
10	Pod Diameter (cm)										0.3086**	0.3063	0.2139**	0.1094*	0.1333**	0.0560*	-0.2038**	0.3527	0.2681**
11	Pods Per Peduncle											0.1386*	-0.0424*	0.2638**	0.1080*	0.0478*	-0.1771**	-0.1315*	0.0835*
12	Peduncle Length												0.1065*	0.045*4	0.3570	0.1658**	0.1155	0.2389**	0.2133**
13	100 Seeds Weight													0.5699	0.3168**	0.2255**	0.2402**	0.3527**	0.1577
14	Seeds Per Plant														0.3317	0.2433**	0.4249	0.1334**	0.1950**
15	Vitamin A(IU)															0.2760	0.2945**	0.4705	0.4469
16	Vitamin C																0.0332*	0.1807**	0.1196*
17	Primary Branches Per Plant																	0.1648**	0.1889**
18	Duration of Reproductive Phase																		0.5775
19	Pod Yield Per Plot (g)																		1.0000

Table No.4.4.j-Genotypic path coefficient analysis (direct and indirect effect) of yield contributing characters of Cowpea pooled data

S. No.	Character	Pods Per Plant	Branches Per Plant	Pod Length	Seeds Per Pod	Days to Frist Open Flower	Daysto Pod Frist Picking	Pedencile Per Plant	Pod Weight Per Plant	Pod Diameter cm	Pods Per Pedincile	Peduncile Length	100 Seeds Weight	Seeds Per Plant	Vitamin A(iu)	Vitamin C	Primery Branches Per Plant	Duration of Reproductive Phase	Pod Yield Per Plot (g)
1.	Plant Height cm	**-5.4503**	-9.2926	5.1889	-2.4085	0.8275	-1.8613	-0.4930	11.3645	-1.4414	-3.6025	5.1761	-2.2516	-0.5305	8.8619	31.1094	1.8361	5.8018	0.5701
2.	Pods Per Plant	-8.0837	**-4.7413**	-0.8489	-4.8572	-3.1858	-0.4529	-2.2132	0.9521	-1.0162	-1.5309	0.6207	-3.9866	0.5456	0.7938	-23.4112	-0.2718	-1.4910	-3.7411
3.	Branches Per Plant	-19.6928	3.7036	**20.6849**	-23.3667	-7.0870	-18.9672	-14.3156	-40.0061	-19.0787	-10.7968	-7.2461	-19.3092	0.6206	-4.1365	-69.0001	-8.8725	6.0685	-7.7005
4.	Pod Length	2.6884	6.2323	-6.8722	**6.0835**	-1.8160	-1.3167	-0.1182	-0.4852	-0.5563	-1.0354	4.0059	1.9771	-3.6948	-2.7432	5.0095	-7.6735	-2.5798	0.5559
5.	Seeds Per Pod	0.8068	-3.5705	1.8206	1.5862	**-5.3138**	1.6078	2.1311	1.1245	-0.3627	0.1194	1.1272	-0.2612	2.2830	2.3950	24.5300	2.8053	5.9391	1.1403
6.	Days to Frist Open Flower	-8.5073	-2.3798	22.8423	5.3919	7.5374	**-24.9110**	-18.5496	-4.6134	-9.3899	-15.3352	-8.8642	-10.5969	3.2605	3.1703	58.2396	-6.2851	6.1956	1.6465
7.	Daysto Pod Frist Picking	4.6425	23.9580	-35.5208	-0.9975	-20.5837	38.2182	**51.3246**	-5.9489	10.3900	31.4611	-8.9988	23.8725	3.2091	-4.4762	-90.4788	2.3311	-0.2270	29.7546
8.	Pedencile Per Plant	6.5964	0.6353	6.1186	0.2523	0.6695	-0.5859	0.3667	**-3.1636**	-0.0805	-0.6514	-2.6420	1.5234	3.3960	-0.2940	-3.2413	-2.1358	2.0048	2.9239
9.	Pod Weight Per Plant	4.5443	3.6831	-15.8491	-1.5713	1.1730	6.4771	3.4786	0.4373	**17.1835**	3.6726	-3.4639	2.9763	5.8630	-0.6180	-47.0013	2.9388	-5.3509	-4.5856
10.	Pod Diameter cm	-7.4353	-3.6323	5.8717	1.9147	0.2527	-6.9250	-6.8956	-2.3161	-2.4043	**-11.2492**	1.0175	-1.1118	0.6979	7.2264	20.9857	1.7488	6.7656	-3.3331
11.	Pods Per Pedincile	-4.6651	-0.6431	-1.7208	3.2346	-1.0420	1.7479	-0.8613	4.1024	-0.9902	-0.4443	**4.9122**	-1.0755	-2.1601	0.1129	3.7494	-1.0143	-2.4898	-0.6235
12.	Peduncile Length	1.3066	2.6595	-2.9525	1.0279	0.1555	1.3455	1.4711	-1.5230	0.5478	0.3126	-0.6925	**3.1629**	-1.5144	-2.5799	-2.5946	-1.7609	-0.5821	1.2014
13.	100 Seeds Weight	-0.5780	0.6834	-0.1782	3.6069	2.5514	0.7773	-0.3713	6.3749	-2.0263	0.3684	2.6115	2.8435	**-5.9387**	-1.7460	16.1901	-0.1425	-0.5096	0.4506
14.	Seeds Per Plant	17.4747	1.7993	2.1492	4.8462	4.8441	1.3678	0.9373	-0.9989	0.3865	6.9040	-0.2470	8.7664	-3.1597	**-10.7474**	9.0636	1.3941	-4.2350	6.1136
15.	Vitamin A(iu)	-6.5639	5.6783	-3.8361	0.9470	-5.3086	-2.6885	-2.0273	1.1782	-3.1455	-2.1453	0.8778	-0.9434	-3.1351	-0.9698	**1.1500**	-3.7113	0.0379	-3.3470
16.	Vitamin C	-0.1403	0.0239	-0.1787	-0.5255	-0.2199	0.1051	0.0189	0.2812	0.0712	-0.0648	-0.0860	-0.2319	0.0100	-0.0540	-1.3444	**0.4166**	-0.1131	-0.2356
17.	Primery Branches Per Plant	19.7996	-5.8492	-5.4568	7.8877	20.7889	4.6260	0.0823	11.7868	5.7920	11.1866	9.4274	3.4231	-1.5962	-7.3294	-0.6123	5.0484	**-18.5999**	2.7158
18.	Duration of Reproductive Phase	2.4123	-18.1961	8.5850	-2.1072	4.9487	1.5242	-13.3691	21.3140	6.1541	-6.8329	2.9273	-8.7595	1.7497	13.1180	67.1181	13.0447	3.3671	**-23.0608**
19.	Pod Yield Per Plot (g)	**-0.8450**	**0.7518**	**-0.1530**	**0.9448**	**-0.8081**	**0.0884**	**0.5965**	**-0.1393**	**0.0333**	**0.3360**	**0.4630**	**0.0175**	**-0.0942**	**-0.0160**	**-0.5386**	**-0.3038**	**0.0021**	**0.4454**

CHAPTER-5

RESULTS AND DISCUSSION

CHAPTER -5 RESULT AND DISCUSSION

Pulses are consumed as dal, which is a cheap source of plant protein. These are consumed because of body building properties due to presence of various amino acids and they are also having medicinal properties. By products of pulses like, pod coats and bran are fed to animals in the farm of dry fodder. Some pulses crop like French bean, gram, cowpea, urd bean and moong bean are fed to animal as green fodder. Moong bean plants are also used as green manure which improves soil health and adds nutrient into the soil .Cowpea is popular legume and vegetable crop tropical and sub tropical region of the world. It is variously used different part of the world. Apart from its main use as cooked or boil soup and fried consume as well as salad. They can be boiled together with rice. Lives are occasionally use as vegetables but few cultivars have leaves of sufficient tenderness. Crop of residue are often used as fodder. In East and southern Africa the use of ripe seeds of cowpea as a pulse is more important than the use of unripe pods or seeds as vegetables. Cow pea is also rich in minerals and vitamins. Cowpea is an important component of agricultural and food systems throughout most of the world. Nutritionally dry beans is a nearly, perfect and rich food. It is an excellent source of protein, carbohydrates and fairly good source of minerals, vitamins, folic acid and dietary fiber (Rehman *et al.* 2000). The tender green pods and dry beans are used in canned, frozen foods, salads, pastas and purees. Cowpea is an extensively cultivated pulses and vegetable crop in India. It is important pulse and vegetable around the world and respect of area, production, productivity, availability and utility. In improvement programme, the breeding

objective to find out the genetic variability, heritability and genetic advance of cowpea, to determine genotypic and phenotypic coefficient of variation for different yield and yield attributing traits of cowpea and to assess the correlation coefficient and path coefficient analysis among the various traits of cowpea and to ascertain the quality attributing traits of cowpea. Before initiating any improvement programme one must wild up a germplasm pool that will serve as gene complex reservoir for different characters and consequently provide better source of variability, which forms the base for improvement. Since limited information is available on genetic diversity in cowpea with respect to morphological and quality characters.

Therefore, an attempt has been made in the present investigation to study the genetic variability in the available cowpea germplasm. Possibility of achieving improvement in any crop plants beans heavily on the magnitude of genetic variability. In cowpea pod yield a complex character is not only influenced by their associated characters which are governed by number of genes but also by environment. So to make selection effective, it is necessary to separate genetic variability from total variability. Since yield is associated with its component characters, it is essential to know the degree of mutual association as well as to expose the direct and indirect contribution of each component. Being a self pollinated crop, the variability available in cowpea needs evaluation which is helpful for breeders to adopt suitable breeding programme for further improvement. Leguminous vegetables have been cultivated for more than 6000 years in different part of the world. Legumes vegetables have consumption constitute about 5% of cultivated crop (Shanmugasundaram, 1990). Leguminous vegetable serves as a major source of protein in a diet. To meet the situation of increasing rate of

population there is a need to identify popularizes new crop species yielding multiple useful products having food, industrial, forage and nutritional value. Tender pods of cowpea are rich in minerals like calcium, phosphorus, iron and Vitamin A and C. Immature pods are dried and fried like potato chips and can be cocked like cowpea. Because of it's highly drought tolerating property, much of its area is concentrated in states like Madhya Pradesh, Uttar Pradesh, Karnataka, Rajasthan, Haryana and Bihar. In Karnataka, though large extent of area is under arid and semi- arid experiencing frequent drought, cowpea cultivation is revised in high especially for dry seed (Ram *et al.* 1988) and has not been rather for vegetable purpose. The present investigations were carried out with sixteen genotypes of cowpea. These genotype were evaluated for some important characters viz., plant height (cm), Number of primary branches per plant, number of branches per plant, days to first open flower, number of pod per plant, days to first pod picking, pod length (cm), pod diameter (cm), number of pods per peduncle, pod weight per plant, pod yield per plot, peduncle length (cm), number of peduncle per plant , duration of reproductive phase, number of seeds per plant, number of seeds per pod, 100 seeds weight, Vitamin A (IU) and Vitamin C (mg/100g). The parameters of variability such as coefficient of variation, heritability, correlation, path, genetic advance and genetic gain were computed so, as to help breeders to select desirable genotypes for different characters. Genotypic and phenotypic correlation were work out the degree of association of different component characters with green pod yield (q/ha) and path coefficient analysis was done to provide information on the case of this association (Wright, 1921and Dewey and Lu, 1959). The quantification of available variability was therefore, carried out for morphological and quality characters in order to identify desirable genotype based on

performance and to select promising donors for various characters that may be used for hybridization programme to obtain useful recombination and to create additional genetic variability. Success of crop improvement programmes depends largely on the extent of variability present in the germplasm stock for the traits for which the improvement is aimed. The knowledge of genetic variability and association of various characters are essential in planning the breeding programmes. With this respective, in the present investigation sixteen genotype of cowpea were evaluated for green vegetable pod yield along with its contributing characters. The proportion of variability, broad sense heritability and genetic advance over mean was estimated. The association among the characters and their direct and indirect effect on yield and genetic correlation were studied. To estimates of different statistical parameters such as variability, correlation coefficient, path analysis helps in deciding the best possible breeding approach to be employed for the improvement for yield and quality of cowpea.

Results and discussion

Analysis of variance revealed that the genotypes recorded highly significant variation for all the characters and it indicated the presence of sufficient variability for these characters (Table-1) thus there is a lot of scope for selection. One of the ways of assessing the variability is through examining the range of variation. The phenotypic variance and phenotypic coefficient of variation were slightly higher than corresponding genotypic variance and genotypic coefficient of variation for most of the characters indicated the presence of less environmental effect upon the concerned characters.

The knowledge of genetic variability, heritability and genetic advance are considered to be useful in predicting the response for selection of superior lines and selection of yield attributing components traits expressing a strong association with yield.

In order to generate additional information on the above facts following studies were made in the present investigation.

5.1 Analysis of variance for the design of experiments

5.2 Mean performance of genotypes

5.3 Estimates of variability, heritability and genetic advance in percent of mean

5.4 Genotypic and Phenotypic Correlation coefficient

5.5 Path coefficient analysis

5.1 ANALYSIS OF VARIANCE:

Analysis of variance (ANOVA) for the nineteen characters is given in Table-4.1. The variances for different characters were divided in to replications, treatments and error. Observations were recorded like plant height (cm), number of primary branches per plant, number of branches per plant, days to first open flower, number of pod per plant , days to first pod picking , pod length (cm), pod diameter (cm), number of pod per peduncle, pod weight per plant, pod yield per plot, peduncle length (cm), number of peduncle per plant, duration of reproductive phase, number of seeds per plant, number of seeds per pod, 100 seeds weight, vitamin A (IU) and Vitamin- C (mg/100g) were recorded. **Meena *et al*. (2015)** evaluated 72 genotypes of cowpea to estimate genetic variability

of ten quantitative characters. Analysis of variance revealed highly significant difference among genotypes for all the characters indicated that considerable amount of genetic variability was present in the experimental material which can be exploited for improvement of seed yield in cowpea. Genotypic and phenotypic variance were recorded highest for length of plant (358.69, 378.69) followed by pod wall proportion (38.30, 41.27) and lowest for primary branches per plant (0.30, 0.50).

5.2 MEAN PERFORMANCE OF GENOTYPE:

A comparison of the mean over parents (Table- 4.2) and the mean over the hybrids (Table-4.2.a and 4.2.b) for nineteen characters under study, revealed non- significant difference for the nineteen characters under study. The range of mean value of parents and range of mean value of genotype were more or less similar for most of the characters under study of cowpea.

Mean performance of cowpea germplasm for different characters are showed in (Table No.4.2.a & Table No.4.2.b.) the coefficient of variation, heritability and genetic gain value are presented. The phenotypic coefficient of variation (PCV) was higher than their respective genotypic coefficient of variation (GCV) for all the traits under study.

The widest range was recorded for pod yield per plot(3581.00-3825.00) followed by number of seed per plant(236.97-312.73), pod weight per plant (g) (360.74 -390.25), number of pod per plant (39.33-49.41), plant height (27.89-32.35), days to first open flower (40.76-45.98) and duration of reproductive phases (30.15-36.78). **Aswathi *et al.* (2015)** studied the mean performance of the ten cowpea varieties with

respect to storability and seed quality parameters. The seeds were evaluated for seed quality parameters *viz.* germination and speed of germination. There was significant variation for the quality aspects related to storage. Variety Kashi Kanchan had a germination of 61.67 per cent after ten months of storage. **Birader *et al.* (1996)** reported strong correlation between pod weight per plant and seed yield, pod length and number of seeds per pod, number of clusters and number of pods per plant and pod weight per plant. Gowda (1996) revealed a positive and significant association of seed yield with number of pods per plant, number of seeds per pod and 100 seed weight and also found a significant and negative association with 100 seed weight and number of seeds per plant. **Singh and Singh (1977)** revealed that number of clusters perplant, number of seeds per pod and total biomass made greatest direct contribution to seed yield in 45 cowpea genotypes. **Vardhan and Savithramma (1998)** reported a very high positive association of green pod yield with pods per plant.

5.3. Estimates of variability, heritability and genetic advance in percent of mean

Genetic variability:

The coefficient of variation value is presented in (Table No. 4.3.) The phenotypic coefficient of variation (PCV) was higher than their respective genotypic coefficient of variation (GCV) for all the traits under study.

The coefficient variation value is presented (Table No.4.3.). The phenotypic coefficient variation (PCV) was higher than their respective genotypic coefficient variation (GCV) for all the traits under study. The

widest range was recorded for pod yield per plot (g) (3451.09-3663.25) followed by number of seeds per plant (232.20-304.14), Vitamin A (929.97-984.99),pod weight per plant g(339.83-389.53), days to first pod picking (49.52-57.14) and duration reproductive phase (29.07-36.76) while lowest range were recorded in number of branches per plant (3.71-4.83) High genetic variability was observed for peduncle length by several workers **(Trehan *et al.*, 1970)**. The genomic relationship between subspecies *unguiculata* and *sesquipedalis* was studied by Neema (1986) and reported higher pollen fertility in subspecies *sesquipedalis.* Singh and Dapaafi (1998) characterized a partial male sterile line of cowpea (IT85D-3626) based on morphology, pollen viability and pod set. Partial male sterile plants were found to have 77.0 per cent pollen viability compared to 98.3 per cent in normal plants.

Phenotypic coefficient variance was higher for number of primary branches per plant (24.78%) followed by number of pods per peduncle (19.44%), peduncle length (17.61%) where as it was moderate for pod diameter (14.16%) followed by pod length (12.89%), number of seeds per pod (12.55%) and low was recorded 100 seeds weight (8.86%) followed by number of pods per plant (7.45%), days to first pod picking and it was lowest recorded for vitamin A (3.97%).

Highest genotypic coefficient of variation (GCV) was observed for number of primary branches per plant (22.97%) followed by number of pods per peduncle (9.82%) and it was moderate for pod diameter (8.52%) followed by number of seeds per plant (7.53%) and low was recorded for 100 seeds weight (5.89%) followed by number of branches per plant (5.68%) and lowest was recorded vitamin A (0.38%).

Heritability:

Heritability value in broad sense is presented in (Table No.-4.3). The highest heritability was recorded for number of primary branches per plant (0.86%) and 100- seeds weight (0.44%) and followed by number of seeds per plant (0.39%) , pod diameter (0.36%), duration of reproductive phase (0.29%), pod weight per plant (0.28%), number of pods per peduncle (0.25%), days to first pod picking (0.24%), number of branches per plant (0.21%), days to first open flower (0.21%) and peduncle length (0.21%) whereas, minimum was recorded for Vitamin A (0.01%).Effectiveness of selection depends upon the heritability and genetic advance of the character studied. High heritability coupled with high genetic advance for several characters was reported by several workers in cowpea **(Ajith, 2001 Philip, 2004).**

Genetic gain:

The maximum genetic gain (%) was recorded for number of primary branches per plant (43.87%) followed by pod diameter (10.56%), number of pods per peduncle (10.21%), number of seeds per plant (9.66%), 100-seeds weight (8.07%), peduncle length (7.47%), number of branches per plant (5.33%), duration of reproductive phase (5.11%), pod weight per plant (4.00%), vitamin- c (3.29), days to first pod picking (3.11%), days to first open flower (2.69%), number of seeds per pod (2.56%), pod yield per plot (2.51%), number of peduncle per plant (1.27%), whereas, minimum was recorded for number of pod per plant (-1.53%).

5.4 Genotypic and Phenotypic Correlation coefficient

The correlation coefficient at genotypic level are presented in (Table No-4.4) that pod yield per plant had positive and significant genotypic correlation coefficient with pod yield per plant (1.000) followed by number of peduncle per plant (0.0269). However, negative and significant correlations were recorded for pod yield per plant with days to first pod picking (-1.4504). Days to first pod picking (0.9483) showed positive and significant correlation followed by number of seeds per pod (-0.1115) and negative and significant correlations were recorded for plant height (-0.6427). Number of pods per peduncle (0.5961) fallowed by number of peduncle per plant (0.0096) showed positive and significant correlation and negative and significant correlations were recorded for plant height (-0.4931).

At the phenotypic level are presented in (Table-5.3) that pod yield per plant had positive and significant genotypic correlation coefficient (1.000) followed by number of seeds per pod (0.0731). However, negative and significant correlations were recorded for vitamin-C (-0.0182). Vitamin-A had positive and significant correlation with pods per peduncle (0.0461) except negative and significant correlation with number of branches per plant (-0.0114), number of primary branches per plant (0.5696) showed positive and significant correlation followed by vitamin-C (0.0103) and negative and significant correlations were recorded for pod diameter (-0.439**6).**Vitamin –C (0.5363) followed by peduncle length (0.0216) showed positive and significant correlation and negative and significant correlations were recorded for number of peduncle per plant (-0.2555).**Grish *et al*. (2006)** evaluated one hundred genotypes of cowpea for variability, for eleven quantitative characters. Wide range of variability was observed for most quantitative characters.

Length of plant and seed yield showed highest phenotypic and genotypic variance, while primary and secondary branches showed lowest variances.

The magnitude of Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), (h2) and (GA) was high for seed yield per plant, number of pods per plant and length of plant. Days to first flower opening, days to 50% flowering and days to maturity were recorded low. **Adewale *et al*. (2010)** studied the grain yield components of eleven cowpea genotypes to understand the sensitivity of the quantitative traits to heterogeneous environments. Significant genotypic variation in pod length was only in 2007. 100 seed weight and pod yield were significantly influenced by the effect of genotype, year and their interactions. Seeds per pod, 100 seed weight and pod length had fairly high relative genetic gain resulting from high GCV, PCV and repeatability; indicating their low sensitivity to G x E.

5.5 Path coefficient analysis:

Highest positive direct effect on pod yield per plot (g) was exhibited by number of peduncle per plant (51.324) pod length (20.684), pod diameter (17.183), number of seeds per pod (6.083), peduncle length (4.912),hundred seeds weight (3.162), and vitamin C (1.150), Whereas, highest negative and direct effect towards pod yield per plot was exhibited pod weight per plant (-3.163) followed by number of branches per plant (-4.741), days to first open flower (-5.313), number of seeds per plant (-5.938), vitamin A (10.747), pods per peduncle (-11.249) and duration of reproductive phase (-18.599). **Cisse (2001)** stated that the most productive genotypes could be identified through concomitant

selection for yield in high productivity environments and for harvest index in low productivity conditions by evaluating ten genotypes.

Siddique and Gupta (1991) observed a significant correlation of seed yield per plant with days to 50% flowering, days to maturity, number of clusters per plant and number pods per plant. **Oseni *et al*. (1992)** revealed that there is a positive correlation between seed yield and pods per plant, between days to flowering and 100 seed weight. While, negative correlations were observed between days flowering and seed yield and between 100 seed weight, seed yield, days to flowering, 100 seed weight, days, days to pod filling and pod length were the major components contributing to yield.

CHAPTER-6

SUMMARY AND CONCLUSION

CHAPTER-6 SUMMARY AND CONCLUSION

The present investigation entitled **"Genetic Variability, Heritability, Correlation and Path analysis in Cowpea [(*Vigna unguiculata*(L.) Walp.)] "**was carried out at Horticulture Research Farm, Department of Applied Plant Science(Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), VidyaVihar, RaeBareli Road, Lucknow-226025(U.P.) ,India,during the summer season of 2014-15 and 2015-16. In this chapter the results obtained from various characters are being presented in tables and described under the following heads.

4.1 Analysis of variance for the design of experiments.

4.2 Mean performance of genotypes

4.3 Estimates of variability, heritability and genetic advance in percent of mean

4.4 Genotypic and Phenotypic Correlation coefficient

4.5 Path coefficient analysis

The widest range was recorded for pod yield per plot followed by number of seed per plant, pod weight per plant (g) , number of pod per plant , plant height , days to first open flower and duration of reproductive phases.

Phenotypic coefficient of variation was higher for number of primary branches followed by number of pods per peduncle, peduncle length (cm), pod diameter (cm), pod length, number of branches per plant and number of pod per plant.

Highest genotypic coefficient of variation was observed in number of primary branched followed by number of pods per peduncle, peduncle length (cm), pod diameter (cm), number of branches per plant, number of seed per plant and pod length (cm).

The highest heritability was recorded for number of primary branches per plant followed number of pods per peduncle, peduncle length (cm), number of seeds per plant, number of branches per plant number of pods per plant, pod diameter (cm) and number of seed per pod .

The maximum genetic advance (%) was recorded for pod yield per plot fallowed by number of seeds per plant, pod weight per plant (g), number of pod per plant, duration of reproductive phase, peduncle length (cm) and number of pods per peduncle.

The correlation coefficient at genotypic level pod yield per plant had positive and significant genotypic correlation coefficient with pod yield per plant followed by number of peduncle per plant. However, negative and significant correlations were recorded for pod yield per plant with days to first pod picking. Days to first pod picking showed positive and significant correlation followed by number of seeds per pod and negative and significant correlations were recorded for plant height. Number of pods per peduncle followed by number of peduncle per plant showed positive and significant correlation and negative and significant correlations were recorded for plant height.

At the phenotypic level pod yield per plant had positive and significant genotypic correlation coefficient followed by number of seeds per pod. However, negative and significant correlations were recorded for vitamin-C .Vitamin-A had positive and significant correlation with Podes

per peduncle except negative and significant correlation with number of branches per plant , number of primary branches per plant showed positive and significant correlation followed by vitamin-C and negative and significant correlations were recorded for pod diameter**.** Vitamin –C followed by peduncle length showed positive and significant correlation and negative and significant correlations were recorded for number of peduncle per plant.

CONCLUSION

On the basis of above result obtained in the present investigation. The experimental materials consisting sixteen genotypes of cowpea i.e. Kashi Unnati, Kashi Shyamal, Kashi Gauri, Kashi Kanchan, Kashi Nidhi, IC-559393, IC-259063, IC-559405, IC-202786, IC-559386, IC-202776, IC-242598, EC-9736, EC-1738, EC-30590 and EC-15296. The maximum phenotypic and genotypic variance, genetic advance was observed for average pod yield per plot. The highest of PCV and GCV was recorded in number of primary branches was estimated. The maximum correlation coefficient at genotype level and phenotypic level was observed for average pod yield per plot. The results of path coefficient for parent are highest positive direct effect towards pod yield per plant was showed by plant height.

CHAPTER-7

BIBLIOGRAPHY

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CHAPTER-8

APPENDIX

MECHANICAL AND CHEMICAL ANALYSIS OF SOIL

Before sowimg soil sample were drawn out by random method from different places in the field and a composite sample was prepared and subjected to mechanical and chemical analysis the samples were sieved with 0.55 mm sieves. The mechanical, chemical and physical analysis of soils are given as under:

Analysis of the soil (Experimental field)

Constituents	Values (%)
Sand	58.21
Silt	21.26
Clay	20.53

Chemical Analysis

Contituents	Values (%)	Method
Total N_2	0.0380	Kjeldhal Method
Available P_2O_5 kg/ha	18.60	Olsen Method
Available K_2O	238.00	Morgan Mathod
Organic Carban	0.64	Black Method

Physical Characters

Items	Values(%)
pH	7.60
EC	0.30
Bulk Density	1.48
Particle Density	2.56
Pore Space	41.88
Permeability	5.06
M.E.	21.20

Appendix-1: ANOVA for Plant Height (cm) of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	14.4418	7.2209	2.6877	0.0746
Environments	1	54.2703	54.2703	11919.9600	0.0000
Interactions	2	0.0091	0.0046	0.0017	0.9983
Overall Sum	5	68.7212	13.7442	5.1157	0.0004
Treatments	15	45.5893	3.0393	1.1312	0.3446
Error	75	201.5013	2.6867		

Appendix-2: ANOVA for Pod Per Plant of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	26.8604	13.4302	1.1380	0.3259
Environments	1	33.1468	33.1468	247.9745	0.0000
Interactions	2	0.2673	0.1337	0.0113	0.9887
Overall Sum	5	60.2745	12.0549	1.0214	0.4112
Treatments	15	81.9685	5.4646	0.4630	0.9516
Error	75	885.1459	11.8019		

Appendix-3: ANOVA for Branches Per Plant of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	0.5578	0.2789	1.4351	0.2445
Environments	1	0.4774	0.4774	0.8396	0.3624
Interactions	2	1.1372	0.5686	2.9261	0.0598
Overall Sum	5	2.1724	0.4345	2.2358	0.0593
Treatments	15	7.5885	0.5059	2.6033	0.0034
Error	75	14.5746	0.1943		

Appendix-4: ANOVA for Pod Length (cm) of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	4.3085	2.1542	0.7897	0.4577
Environments	1	5.4531	5.4531	0.9385	0.3358
Interactions	2	11.6209	5.8104	2.1299	0.1260
Overall Sum	5	21.3824	4.2765	1.5676	0.1796
Treatments	15	57.1654	3.8110	1.3970	0.1709
Error	75	204.6054	2.7281		

Appendix-5: ANOVA for Seeds Per Pod of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	5.7823	2.8911	1.0975	0.3390
Environments	1	1.2788	1.2788	0.1928	0.6619
Interactions	2	13.2663	6.6332	2.5181	0.0874
Overall Sum	5	20.3274	4.0655	1.5434	0.1867
Treatments	15	65.5386	4.3692	1.6587	0.0784
Error	75	197.5632	2.6342		

Appendix-6: ANOVA for Day to Frist Open Flower of Cowpea

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	28.3319	14.1660	2.5242	0.0869
Environments	1	44.5538	44.5538	1040.9725	0.0000
Interactions	2	0.0856	0.0428	0.0076	0.9924
Overall Sum	5	72.9713	14.5943	2.6006	0.0318
Treatments	15	217.8686	14.5246	2.5881	0.0036
Error	75	420.8971	5.6120		

Appendix-7: ANOVA for Day to Pod Frist Picking of Cowpea

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	43.5947	21.7974	2.4724	0.0912
Environments	1	125.4010	125.4010	1141.2229	0.0000
Interactions	2	0.2198	0.1099	0.0125	0.9876
Overall Sum	5	169.2155	33.8431	3.8388	0.0038
Treatments	15	379.2297	25.2820	2.8677	0.0014
Error	75	661.2117	8.8162		

Appendix-8: ANOVA for Pedenciles Per Plant of Cowpea

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	4.7123	2.3562	1.3071	0.2767
Environments	1	3.9569	3.9569	510.3519	0.0000
Interactions	2	0.0155	0.0078	0.0043	0.9957
Overall Sum	5	8.6847	1.7369	0.9636	0.4457
Treatments	15	37.2514	2.4834	1.3777	0.1804
Error	75	135.1945	1.8026		

Appendix-9: ANOVA for Pod Weight Per Plant of Cowpea

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	3828.9697	1914.4849	4.0910	0.0206
Environments	1	3350.9761	3350.9761	5679.9419	0.0000
Interactions	2	1.1799	0.5900	0.0013	0.9987
Overall Sum	5	7181.1260	1436.2251	3.0690	0.0142
Treatments	15	23578.7168	1571.9144	3.3590	0.0003
Error	75	35098.2266	467.9763		

Appendix-10: ANOVA for Pod Diameter of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	4.5677	2.2838	5.2982	0.0070
Environments	1	7.7237	7.7237	1692.4458	0.0000
Interactions	2	0.0091	0.0046	0.0106	0.9895
Overall Sum	5	12.3005	2.4601	5.7071	0.0002
Treatments	15	28.4668	1.8978	4.4026	0.0000
Error	75	32.3294	0.4311		

Appendix-11: ANOVA for Pods Per Pedincile of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	1.4843	0.7422	0.6079	0.5471
Environments	1	0.7107	0.7107	0.6714	0.4152
Interactions	2	2.1172	1.0586	0.8671	0.4243
Overall Sum	5	4.3122	0.8624	0.7064	0.6204
Treatments	15	55.9138	3.7276	3.0533	0.0007
Error	75	91.5621	1.2208		

Appendix-12: ANOVA for Peduncile Length of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	2.8423	1.4212	1.1246	0.3302
Environments	1	0.7686	0.7686	79.5904	0.0000
Interactions	2	0.0193	0.0097	0.0076	0.9924
Overall Sum	5	3.6303	0.7261	0.5746	0.7193
Treatments	15	48.4290	3.2286	2.5549	0.0040
Error	75	94.7754	1.2637		

Appendix-13: ANOVA for 100 Seeds Weight of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	0.0101	0.0050	0.0467	0.9544
Environments	1	0.3889	0.3889	1.2594	0.2654
Interactions	2	0.6176	0.3088	2.8659	0.0632
Overall Sum	5	1.0165	0.2033	1.8869	0.1066
Treatments	15	9.3140	0.6209	5.7630	0.0000
Error	75	8.0808	0.1077		

Appendix-14: ANOVA for No. of Seeds Per Plant of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	2805.5525	1402.7762	2.0624	0.1343
Environments	1	5531.2876	5531.2876	2.3704	0.1279
Interactions	2	4666.8721	2333.4360	3.4307	0.0375
Overall Sum	5	13003.7119	2600.7424	3.8237	0.0039
Treatments	15	48962.7148	3264.1809	4.7991	0.0000
Error	75	51012.5820	680.1678		

Appendix-15: ANOVA for Vitamin A(iu) of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	14792.7930	7396.3965	5.1957	0.0077
Environments	1	97.6443	97.6443	23.9835	0.0000
Interactions	2	8.1426	4.0713	0.0029	0.9971
Overall Sum	5	14898.5801	2979.7161	2.0931	0.0755
Treatments	15	22515.9590	1501.0640	1.0544	0.4123
Error	75	106767.6641	1423.5688		

Appendix-16: ANOVA for Vitamin C of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	4.4602	2.2301	3.1615	0.0481
Environments	1	0.1107	0.1107	551.0032	0.0000
Interactions	2	0.0004	0.0002	0.0003	0.9997
Overall Sum	5	4.5713	0.9143	1.2961	0.2747
Treatments	15	34.0332	2.2689	3.2165	0.0004
Error	75	52.9037	0.7054		

Appendix-17: ANOVA for Primery Branches Per Plant of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	0.5081	0.2541	2.9954	0.0560
Environments	1	0.0210	0.0210	50.0348	0.0000
Interactions	2	0.0008	0.0004	0.0049	0.9951
Overall Sum	5	0.5300	0.1060	1.2497	0.2947
Treatments	15	47.8929	3.1929	37.6440	0.0000
Error	75	6.3613	0.0848		

Appendix-18: ANOVA for Duration of Reproductive Phase of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	31.0030	15.5015	2.5218	0.0871
Environments	1	17.6817	17.6817	62681.6719	0.0000
Interactions	2	0.0006	0.0003	0.0000	1.0000
Overall Sum	5	48.6852	9.7370	1.5840	0.1749
Treatments	15	319.0973	21.2732	3.4607	0.0002
Error	75	461.0260	6.1470		

Appendix-19: ANOVA for Pod Yield Per Plot (g) of Cowpea.

Source of Variations	D.F.	Sum of Squares	Mean Squares	F. Ratio	Probability
Replication	2	223489.3281	111744.6641	2.3710	0.1004
Environments	1	137640.4531	137640.4531	390.0747	0.0000
Interactions	2	705.7133	352.8566	0.0075	0.9925
Overall Sum	5	361835.5000	72367.1016	1.5355	0.1891
Treatments	15	1704059.8750	113603.9922	2.4105	0.0066
Error	75	3534724.7500	47129.6641		