CHARACTERIZATION AND EVALUATION OF COWPEA (Vigna Unguiculata [L.] Walp). GERMPLASM

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I. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important pulse crops native to central Africa, belongs to family Fabaceae. 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 per cent 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 – 240 kg per ha of nitrogen per year.

Cowpea is mainly grown in tropical and sub tropical regions in the world for vegetable and seed purpose and to lesser extent as a fodder crop. It is a most versatile pulse crop because of its smothering nature, drought tolerant characters, soil restoring properties and multi-purpose uses. As a pulse crop, cowpea fits well into most of the cropping systems.

It has been estimated that the total pulse requirement for consumption by 2005 would be 23 million tones. Among the different pulses grown in the world, cowpea is grown in 10 million hectares with the productivity of 387 kg/ha (FAO, 2004). In India, the cowpea is grown in an area of about 3.9 million hectares with the productivity of 567 kg per ha. The productivity potential of the crop in Karnatake is low (420 kg/ha) as compared to the national productivity (Kalpana, 2000). The essentiality of increase the productivity, is the present challenge to the crop improvement field.

The present day cultivars exhibit lower productivity, non synchronous flowering and fruiting, non- response to high doses of inputs like fertilizers, irrigation, tillage *etc.*, non 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, 1997). Yield being a complex trait, is influenced by many other important yield contributing characters controlled by polygenes and also environmental factors. The overall effect of plant breeding on genetic diversity has been a long standing concern in the evolutionary biology of crop plants (Simmonds, 1962). The loss of genetic diversity has been dramatic for many cultivated species (Wikes, 1983). Better knowledge of the genetic similarity of breeding materials could help to maintain genetic diversity and sustain long term selection gain.

Hence, any breeding programme aiming at increasing yield should consider association between yield and its attributes through estimation of genotypic and phenotypic correlation, which help a great deal in formulating selection indices to aid in selection programmes. An understanding of the variability existing in a crop is necessary to formulate and accelerate conventional breeding programme. Collection and evaluation of germplasm, quantification of the magnitude of variability existing for different characters and classification into groups help in identifying, which would yield greater variability. This enables the breeder to operate selection efficiently.

Keeping these aspects in view, the present study was initiated for evaluating the extent of genetic variability existing for different characters in cowpea germplasm collected from different environments which will be of immense practical use for plant breeders to choose the plant of interest for different breeding programmes.

The study aims at following objectives,

1. To assess the extent of genetic variability for quantitative traits,
2. To study the nature and magnitude of association between seed yield and its component traits,

3. To assess the magnitude of genetic divergence and to classify the genotypes under different groups on genetic distance, and

4. To screen the germplasm for important diseases under field condition.

II. REVIEW OF LITERATURE

Cowpea (Vigna *unguiculata* (L) Walp.) is one of the important leguminous crops, which belongs to family Fabaceae and tribe Phaseolae. It is primarily originated in West Africa (Rawal, 1975). With the increased popular use of pulses in high fibre diets, the demand for cowpea can be expected to increase.

Since, limited availability of high productive varieties with good plant types and lack of short duration varieties with higher resistance to diseases, are the major hindrance to increase the production. The collection of information based on these factors will be useful to crop improvement activities. Therefore, literature available on the above aspects is reviewed under the following sub headings.

The review of literature is presented under following sub headings.

2.1 Genetic variability, heritability and genetic advance

2.2 Disease resistance

2.3 Character association

2.4 Path coefficient analysis

2.5 Genotype and environment effects

2.6 Genetic divergence

2.1 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The possibility of achieving improvement in any crop depends on the magnitude of genetic variability. The efforts taken by Johanssen (1909) and East (1916) have led to the partitioning of total variability into genetic and environmental components and both heritable and non-heritable factors contributed somatic variation in segregating populations and that variation in pure line was entirely due to environment (Johanssen, 1909).

Adaptability of genotypes varies due to their genetic differences. The environmental conditions have a significant effect as the expression of yield and other quantitative characters.

Comstock and Robinson (1952), Johnson *et al. (*1955b) Nei and Syakudo (1957), Athwal and Singh (1966) and Mital *et al. (*1969) revealed that the evaluation of genotypes under several environmental conditions to provide information on the relative magnitude of phenotypic and genotypic variability and the extent of genetic advance.

More contribution of the heritable component to the total variation of desirable characters becomes essential. Scientist paid more emphasis to improve the yield of a crop by studying the variability and heritability of yield and yield contributing components (Robinson *et al*., 1949, Grafius, 1959, and Nikell and Grafius, 1969). In 1964, Grafius stated that the major yield components in cowpea were pod numbers, seeds per pod and 100 seed weight. Any change in yield has to be brought from a change in one or more of these components.

The heritability value of a trait indicates the effectiveness of selection based on phenotypic expression. Quantitative characters are governed by more number of genes and further influenced by environment, of which a proportion observed value is heritable. Estimate of narrow sense heritability is not possible thus; by estimating broad sense heritability along with genetic gain is usually more useful in selecting the best individual (Johnson *et al*., 1955a).

A summary of review of literature related to heritability, genetic advance, genotypic coefficient of variation and phenotypic coefficient of variation in cowpea is listed in Table 2.1.

Table 2.1: Summary of review of literature on heritability, genetic advance, genotypic coefficient of variation and phenotypic coefficient of variation in cowpea (*Vigna unguiculata* (L.) Walp.)

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Plant height	7 parents and their F_1's	High	High	High	----	Thiyagarajan (1989)
	25 fodder cowpea genotypes	High	High	----	-----	Roquib and Patnaik (1990)
	80 genotypes	43.44	18.83	14.02	21.26	Thaware *et al.* (1991)
	4 F_1s	46.70	18.81	31.35	46.61	Savithramma (1992)
	10 varieties and 45 crosses	High	High	High	High	Sawant (1994)
	54 diverse genotypes	97.00	--	39.6	39.00	Selvi *et al.* (1994)
	70 genotypes	High	High	--	--	Rewale *et al.* (1995)
	34 genotypes	91.72	18.65	14.05	14.65	Backiyarani and Nadarajan (1996)
	34 genotypes	High	--	--	--	Ram and Singh (1997)
	29 accessions	High	High	High	High	Vardhan and Savithramma (1998)
	25 genotypes	High	--	--	--	Hasra *et al.* (1999)
	24 genotypes	98.80	--	42.55	42.80	Tyagi *et al.* (2000)
	42 diverse genotypes	High	High	High	--	Sharma (1999)
	50 genotypes	67.10	58.90	44.8	54.69	Selvam *et al.* (2000)
	F_2,F_2M_2, three crosses and double crosses F_2	31.69-58.44	2.86-8.81	4.97-14.52	7.34-22.45	Uma (2001)

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Number of branches/ plant	50 genotypes	34.94	0.60	17.39	29.43	Apte *et al.* (1987)
	80 genotypes	24.25	11.01	10.85	22.03	Tharware *et al.* (1991)
	54 diverse genotypes	86.00	--	29.8	27.60	Selvi *et al.* (1994)
	5 F_2's	91.72	3.02	32.08	33.50	Madhusudan (1994)
	F_2, F_3 and parents	18.20	13.43	15.12	35.06	Balaraju (1997)
	F_2 populations of 2 crosses	37.58-34.03	1.05-1.26	29.07-26.32	47.39-45.12	Rangaiah and Nehru (1998)
	F_2, F_3 generations of 4 crosses	82.88-88.33	32.00-40.7	17.57-21.68	19.3-23.79	Mehta and Zaveri (1999)
	50 genotypes	60.00	0.95	32.09	45.39	Selvam *et al.* (2000)
	F_2 population of 2 crosses	--	1.40-2.03	21.61-33.36	34.45-45.04	Hadapad (2001)
Days to 50% Flowering	42 F_1's	95.71	11.05	8.91	10.13	Marangappanavar (1984)
	4 F_1's	74.0-81.55	2.64-3.21	-	-	Patil and Patil (1986)
	50 genotypes	60.83	7.80	7.70	9.87	Apte *et al.* (1987)
	49 pure lines	65.30	3.91	4.91	6.07	Patil and Baviskar (1987)
	-	High	-	-	-	Ye and Zhang (1987)
	50 genotypes	--	--	High	High	Vineeta– kumari *et al.* (2003)
	50 genotypes	High	--	--	--	Sarvamangala (2004)

Table 2.1 condt....

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Days to maturity	42 F_1's	92.39	8.03	5.61	5.84	Marangappanavar (1984)
	4 F_1's	76.25-88.89	2.40-3.20	-	-	Patil and Patil (1986)
	50 genotypes	65.03	9.09	5.36	6.64	Apte *et al.* (1987)
	49 pure lines	82.88	9.28	6.72	7.38	Patil and Baviskar (1987)
	7 parents and F_1's	4.74	5.27	81.01	5.66	Thiyagarajan (1989)
	5 F_2's	4.86	4.86	99.84	8.47	Madhusudan (1994)
	50 genotypes	--	--	High	High	Vineeta – kumari *et al.* (2003)
	50 genotypes	High	--	--	--	Sarvamangala (2004)
Number of clusters per plant	54 diverse genotypes	90.00	--	43.3	41.10	Selvi *et al.* (1994)
	10 varieties & 45 crosses	High	High	High	High	Sawant (1994)
	34 genotypes	Low	--	High	High	Backiyarani and Nadarajan (1996)
	2 F2 crosses	Low	--	Low	--	Rangaiah (1997)
	F2 population of 2 crosses	23.54-39.32	2.17-3.88	28-28.4	57.70-45.40	Rangaiah and Nehru (1998)
	42 genotypes	High	Moderate	Moderate	--	Sharma (1999)
	50 genotypes	21.60	0.93	18.42	39.63	Selvam *et al.* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	22.46-58.73	2.33-7.82	38.15-55.46	18.85-41.14	Uma (2001)
	50 genotypes	High	High	High	High	Vineeta – kumari *et al.* (2003)
	50 genotypes	--	--	Moderate - High	Moderate - High	Sarwamangala (2004)

Table 2.1 condt…

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Number of pods per plant	49 pure lines	68.73	12.44	20.78	25.07	Patil & Baviskar (1987)
	35 genotypes	--	--	High	--	Sharma *et al.* (1988)
	25 fodder cowpea genotypes	High	High	--	--	Roquib and Patnaik (1990)
	F2 population	80.33	11.38	41.22	45.99	Gowda *et al.*(*1991*)
	4 F_1's	15.23	1.78	12.22	31.30	Savithramma (1992)
	15 genotypes	85.90	--	--	--	Damarany (1994)
	54 diverse genotypes	97.50	--	48.10	47.50	Selvi *et al.* (1994)
	10 varieties & 45 crosses	High	High	High	High	Savant (1994)
	34 genotypes	Low	Low	High	High	Backiyarani & Nadarajan (1996)
	F_2 population of 2 crosses	59.39-56.41	10.05-12.70	46.94-40.19	60.93-53.51	Rangaiah & Nehru (1998)
	29 accessions	High	High	High	High	Vardhan & Savithramma (1998)
	42 genotypes	High	Moderate	Moderate	--	Sharma (1999)
	24 genotypes	79.40	--	14.48	16.25	Tyagi *et al.* (1999)
	50 genotypes	26.10	2.22	26.85	52.51	Selvam *et al.* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	10.86-53.68	2.48-14.24	15.31-54.95	9.80-40.63	Uma (2001)
	50 genotypes	High	High	High	High	Vineeta – kumari *et al.* (2003)
	50 genotypes	--	--	Moderate-High	Moderate - High	Sarvamangala (2004)

Table 2.1 condt......

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Pod length	25 fodder cowpea genotypes	High	High	--	--	Roquib and Patnaik (1990)
	45 F_1's	52.79	1.97	10.29	14.16	Savithramma (1992)
	10 varieties and 45 crosses	High	High	High	High	Sawant (1994)
	54 diverse genotypes	78.40	--	17.0	15.10	Selvi *et al.* (1994)
	18 cultivars	High	High	High	High	Sreekumar *et al.* (1996)
	34 genotypes	87.45	4.57	16.02	17.82	Backiyarani and Nadarajan (1996)
	2 F_2 crosses	High	High	High	--	Rangaiah (1996)
	8 varieties, F_1 , F_2 crosses	High	High	High	High	Chattopadhyaya *et al.* (1997)
	F_2 populations of 2 crosses	68.53-96.67	3.17-16.03	14.13-58.23	16.95-59.50	Rangaiah and Nehru (1998)
	F_2, F_3 generation 4 crosses	48.56-69.34	8.99-18.92	6.26-11.03	8.99-13.24	Mehta and Zaveri (1999)
	42 diverse genotypes	High	Moderate	Moderate	--	Sharma (1999)
	24 genotypes	89.60	--	12.94	13.67	Tyagi *et al.* (2000)
	50 genotypes	69.20	2.60	12.60	15.15	Selvam *et al* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	57.10-74.24	1.14-2.30	5.33-10.13	6.73-12.51	Uma (2001)

Table 2.1 contd.....

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Number of seeds per pod	7 parents and their F_1's	High	High	High	--	Thiyagarajan (1989)
	25 fodder cowpea genotypes	High	High	--	--	Roquib and Patnaik (1990)
	3 F2 Population	70.16	3.18	19.24	22.92	Gowda *et al.* (1991)
	45 F_1's	50.90	High	7.93	15.16	Savithramma (1992)
	54 diverse genotypes	69.10	--	16.20	13.40	Selvi *et al.* (1994)
	34 genotypes	89.32	12.32	13.34	15.27	Backiyarani and Nadarajan (1996)
	18 cultivars	High	High	High	High	Sreekumar *et al.* (1996)
	34 genotypes	High	--	--	--	Ram and Singh (1997)
	F_2 populations of 2 crosses	31.62-48.89	1.39-2.94	11.01-20.08	19.59-20.70	Rangaiah and Nehru (1998)
	24 genotypes	98.80	--	42.55	42.80	Tyagi *et al.* (2000)
	50 genotypes	31.30	1.18	10.2	18.22	Selvam *et al.* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	58.11-75.79	2.06-3.33	10.27-17.26	12.18-19.83	Uma (2001)

Table 2.1 contd.....

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
100 seed weight	7 parents and their F_1's	High	High	High	--	Thiyagarajan (1989)
	3 F_2 populations	85.87	14.31	45.47	49.09	Gowda *et al.* (1991)
	45 F_1's	71.41	3.01	14.64	17.32	Savithramma (1992)
	54 diverse genotypes	98.50	--	5.54	55.40	Selvi *et al.* (1994)
	5 parents and 10 F_1's	83.3	--	--	--	Damarany (1994)
	70 genotypes	High	High	--	--	Rawale *et al.* (1995)
	34 genotypes	80.02	5.54	20.24	22.10	Backiyarani and Nadarajan (1996)
	24 genotypes	High	--	--	--	Ram and Singh (1997)
	2 F_2 crosses	High	--	--		Rangaiah (1997)
	F_2 populations of 2 crosses	70.56-75.28	8.77-14.86	54.93-53.12	65.38-61.22	Rangaiah and Nehru (1998)
	42 diverse genotypes	High	Moderate	Moderate	--	Sharma (1999)
	24 genotypes	99.80	--	25.71	--	Tyagi *et al.* (2000)
	50 genotypes	43.90	2.99	34.01	25.74	Selvam *et al.* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	69.17-87.88	1.19-3.18	7.61-19.60	9.15-20.93	Uma (2001)
	50 genotypes	--	--	High	High	Vineeta kumari *et al.* (2003)

Table 2.1 contd.....

Character	Material used for study	Heritability (%)	Genetic advance	GCV (%)	PCV (%)	References
Seed yield per plant	25 fodder cowpea genotypes	High	High	--	--	Roquib and Patnaik (1990)
	3 F2 populations	85.87	14.31	45.47	49.09	Gowda *et al.* (1991)
	50 genotypes	Low	--	--	--	Siddique and Gupta (1991)
	45 F_1's	18.34	6.32	22.54	52.64	Savithramma (1992)
	10 varieties and 45 crosses	High	High	High	High	Sawant (1994)
	54 diverse genotypes	98.50	--	5.54	55.40	Selvi *et al.* (1994)
	34 genotypes	80.02	5.44	20.24	22.10	Backiyarani and Nadarajan (1996)
	2 F_2 crosses	High	High	High	--	Rangaiah (1997)
	F_2 populations of 2 crosses	70.56-75.28	8.77-14.86	54.93-53.12	65.38-61.22	Rangaiah and Nehru (1998)
	24 genotypes	99.80	--	25.71	25.74	Tyagi *et al.* (2000)
	50 genotypes	43.90	2.99	34.01	51.32	Selvam *et al.* (2000)
	F_2, F_2M_2, three way crosses and double cross F_2	20.95-57.62	2.56-11.50	24.16-47.81	38.03-69.71	Uma (2001)
	50 genotypes	High	High	High	High	Vineeta kumari *et al.* (2003)

2.1.1 Plant height

Most of the reports on genetic variability showed a wide range of variability for plant height with moderate to high heritability and high genetic advance, based on studies varying number of genotypes and there were few reports based on the segregating material. A report showed moderate heritability and moderate genetic advance (Patil and Patil, 1986). Another report revealed that low heritability and low genetic advance for this trait (Apte *et al*., 1987) and Rangaiah and Nehru (1998) indicated low heritability (5.61%) with 6 % genetic advance. However, Selvi *et al. (*1994) revealed that high heritability (99.89%) with moderate GCV and PCV values.

Santoshkumar *et al. (*2002) reported high heritability for green fodder yield per plant, number of days to 50% flowering, plant height 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.

2.1.2 Number of main branches

This character is highly variable and highly heritable. Most of the reports indicated moderate to high heritability with low genetic advance. A moderately high heritability with moderate value of genetic advance was reported by Mehta and Zaveri (1999) while, Rangaiah and Nehru (1998) reported low to moderate heritability estimates for number of branches with very low genetic advance in cowpea. In 1994, Madhusudhan reported high heritable values of 96.21 per cent in F_1 materials, while in 1997 Balraju reported that, low heritability (14.2%) for this trait. Many reports indicating low to high genetic advance ranging from 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.

2.1.3 Number of clusters per plant

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 heritability and genetic advance. (Rangaiah *et al*., 1999, and Mehta and Zaveri, 1999). Mehta and Zaveri (1999) reported moderate to high heritability and genetic advance for number of clusters per plant in cowpea. Sarvamangala (2004) revealed moderate to high GCV and PCV with number of clusters.

2.1.4 Days to 50 % flowering

Most of the reports indicated higher heritability, lower genetic advance, lower values of genotypic and phenotypic coefficient of variation and three reports indicated lower heritability and genetic advance. The heritability ranged from 4.7 per cent (Thiyagarajan, 1989) to 92.39 per cent (Marangappanavar, 1984). Sarvamangala (2004) revealed that high heritability for this character.

2.1.5 Days to maturity

Reports on days to maturity indicated high heritability and genetic advance, two of them were based on F_1 generations (Marangappanavar, 1984 and Patil and Patil, 1986). One report based on 50 genotypes (Apte *et al*., 1987) another report based on 49 pure lines (Patil and Baviskar, 1987) and other three reports indicated low heritability and genetic advance. Sarvamangala (2004) showed high heritablitlity for this character by studying 50 genotypes. Apter *etal.,* (1987) reported low GCV, PCV and high heritability with low GAM for this character by studying 50 genotypes.

2.1.6 Number of pods per plant

Jagadishmurthy (1986) stated high phenotypic and genotypic variation, heritability and expected genetic advance by studying F_2 population and showed that number of pods per plant was the major yield contributing character. High heritability with high genetic advance has been reported for this character in cowpea (Mehta and Zaveri 1999; Mathur, 1995).

Reports based on segregating populations (Rangaiah and Nehru, 1998) and one study of limited genotypes indicated that, this trait is highly variable one. In 1999 Sharma showed moderate variability based on 42 genotypes. Mathur (1995) reported very high heritability (98.0%) with extremely high GCV and PCV (103.93%) values. Sarvamangala (2004) reported moderate to high GCV and PCV based on 50 genotypes.

2.1.7 Pod length

High heritability and genetic advance for this character is very much fruitful during selection programme. In 1989, Dharmalingam and Kadambavanasundaram reported high variability in pod length. Some reports indicated that high estimates of both heritability and genetic advance. The lowest being 7.84 (Mathur, 1995) and the highest being 58.23 (Rangaiah and Nehru, 1998) for GCV. Mathur (1995) found high heritability associated with low genetic advance.

2.1.8 Number of seeds per pod

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. Heritability ranged from 31.3 per cent (Selvam *et al*., 2000) to 98.8 per cent (Tyagi *et al.,* 2000) based on studies of 24 and 50 cowpea genotypes. Mathur (1995) observed a high heritability coupled with low genetic advance. Low to moderate heritability has been reported by Rangaiah and Nehru (1999) and Selvam *et al.* (2000). While Selvi *et al.* (1994), Backiyarani and Nadarajan (1996) and Selvam *et al.* (2000) reported moderate GCV and PCV for the character.

2.1.9 Hundred seed weight

This character is most related to yield which showed high estimates of GCV, heritability and genetic advance in all pulse crops. In general low to moderate variability was observed for this character. Heritability of hundred seed weight ranged from 14.47 % (Rangaiah and Nehru, 1999) to 99.2% (Selvi *et al.,* 1994). High heritability with low genetic advance was reported by Gowda *et al.* (1991) and Backiyarani and Nandarajan(1996). Analyzing diverse genotypes, Sharma (1999) reported moderate genetic advance. Low to moderate heritability coupled with relatively higher genetic advance was observed and it was supported by the findings of Gowda *et al.* (1991), Rangaiah and Nehru, (1998) Tyagi *et al.* (2000) and Selvam *et al.* (2000).

2.1.10 Seed yield per plant

Seed yield is an ultimate product of any selection or breeding programme. Most of reports indicated fairly higher estimates of heritability (Selvi *et al.,* 1994; Mathur, 1995 and Tyagi *et al.,* 2000). Mehta and Zaveri (1999) observed high genetic advance for the seed yield, based on their studies on segregating material while Mathur (1995) in a variability study, among F_2 population recorded high GCV and PCV for this character.

The heritability estimates of seed yield per plant varied from 18.34 (Savithramma, 1992) to 99.8 per cent (Tyagi *et al.,* 2000). Some reports indicated higher estimates of heritability (Biradar *et al.,* 1993; Selvi 1994; Mathur, 1995 and Tyagi *et al.,* 2000). High genetic advance for seed yield based on segregating material was observed by Mehta and Zaveri (1999), while Mathur (1995) recorded high GCV and PCV for seed yield by studying F_2 population. High genotypic and phenotypic coefficient of variability and heritability for seed yield per plant was reported by Dharmalingam and Kadambavansundaram (1989).

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

2.1.11 Yield attributing characters

Several workers have emphasized more for the characters having high heritability and genetic advance, which are more useful for effective selection for improvement of yield. Fernandez and Miller (1985) studied four determinate and indeterminate cowpea cultivars and reported that 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. Boe *et al.* (1992) reported that plant weight and forage yield were significantly higher in cowpea as compared to green gram. Tamilselven and Das (1994) concluded that the number of clusters, number of pods per plant and 100 seed weight should be used as a selection criteria in the development of high yielding genotypes of cowpea. Aravindan and Das (1996) reported that green fodder yield of cowpea was significantly and positively associated with leaf area and number of branches. Naidu *et al.* (1996) reported that number of pods per plant, seeds per pod, hundred seed weight and seed yield per plant were higher in determinate types, while the pod length was higher in indeterminate types. Flowering and maturity occurred earlier in determinate types than indeterminate types of cowpea. The dry matter production of determinants is a good indicator of grain yield in cowpea. 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.

Vineeta-Kumari *et al.* (2003) reported that 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.

2.2 DISEASE RESISTANCE

Diseases like mosaic virus, rust, powdery mildew and bacterial blight are the major biotic constraints in the production of cowpea. Developing high yielding varieties with resistance to these diseases would be a great achievement in crop improvement. Brief review of available literature related to these diseases are mentioned below.

2.2.1 Mosaic virus

Gumedzoe *et al.* (1990) observed some infected samples of cowpea in which yellow mosaic virus (cowpea mosaic comovirus) was found in 65% and cowpea mottle virus in 35% of the infected samples. Mixed infections were often observed including other cowpea viruses. A total of 23 cowpea cultivars were screened using an isolate of each virus, resistance was found to one of the two viruses tested but not to the mixed infection. No symptoms were found on cowpea cv. TV X 1850-01E on inoculation with both viruses.

Sohoo *et al.* (1991) derived a variety (Cowpea 88) from irradiated F_1 seed of the cross Cowpea 74 X virus resistant strain H2. Compared to Cowpea 74 Cowpea 88 was highly resistant to cowpea yellow mosaic virus and anthracnose [*Glomerella cingulata*].

Gubba (1994) observed that by analyzing 109 cowpea leaf samples, which were showing virus symptoms, cowpea aphid-borne mosaic virus (CAMV) was detected in 75 samples but none of the samples tested positive for blackeye cowpea mosaic virus (BICMV) where as seven samples were detected for cowpea yellow mosaic virus.

Rathore and Tiwari (1998) studied on spatial distribution of *Bemisia tabaci* (vector of yellow mosaic virus) during the summer and *kharif* seasons on mung bean (*Vigna radiata* (L.) Wilczek), urd bean (*Vigna mungo* (L.) Hepper) and cowpea (*Vigna unguiculata* (L.) Walp.). The results revealed that distribution on all the test crops was aggregated. Crops, cropping stage and seasons did not affect the aggregated behaviour. However, the degree of aggregation was greater when the population was high and showed a tendency towards randomness in the case of low density of *Bemisia tabaci.*

In a study conducted during summer and *kharif* by using ten genotypes of cowpea (*Vigna unguiculata*) differing in response to cowpea yellow mosaic virus (CYMV) and observed high significant linear component of the genotype x environment interaction. Stability analysis revealed that genotypes CS39, CS55, CS82, CS88 and CS94 had high and stable resistance to CYMV (Sangwan *et al.,* 2000).

Bashir *et al.* (2002) evaluated ninety four cowpea (*Vigna unguiculata*) germplasm accessions under field conditions for viral infection, the viral disease incidence was ranged from 0 to 66.6% and detected cucumber mosaic virus (CMV), bean common mosaic virus

(BCMV), black eye cowpea mosaic virus (BlCMV), cowpea aphid-borne mosaic virus (CABMV) and mungbean yellow mosaic virus (MYMV). The ten accessions such as 27005, 29154, 27181, 27196, 27197, IT97K-89235, IT94K-556-6, IT96K-113-6, IT85F-1380 and IT95K-1985 were found to be resistant to viral infection.

2.2.2 Rust

Chandrashekar *et al.* (1989) stated that C-152 was the most susceptible cultivar, whereas TVX 944 and KBC-1 were intermediates; V-37 was the least susceptible and exhibited slow rusting behaviour.

In a study by Heath (1989) on cowpea cultivars resistant or susceptible to the dikaryotic phase of *Uromyces vignae*, revealed that the monokaryotic and dikaryotic phases of the cowpea rust fungus activate the same genes for resistance in each cowpea cultivar.

Raju *et al.*(1991) studied the partial resistance to powdery mildew (*Erysiphe polygoni*) in 21 cowpea cultivars and stated that, mean response of V-105, V-269, V-276, V-282 and V-385 showed clear slow-mildewing, while RC-48, S-488, TVX-944-02E, V-27, V-36 and V-118 were rated as susceptible. Mildew resistance in some cultivars was negatively correlated with that of leaf rust.

Cao *et al.*(1991) studied 1000 accessions of *Phaseolus vulgaris* and *Vigna unguiculata* for resistance to *Uromyces appendiculatus*, out of 1000 accessions only seven were classed as highly resistant (e.g. B766, B767 and B774), six as resistant (e.g. B1484 and B1485) and ten as moderately resistant (e.g. B731 and B732).

Ryerson and Heath (1996) investigated the nature of the cowpea rust resistance genes present in resistant cultivars, and the progeny of a cross between a resistant and a susceptible cowpea cultivar. The results revealed that the different levels and inheritance of resistance patterns shown by the F_2 generation and subsequent progeny, suggested the presence of multiple genes and the presence of dominant and recessive resistance components.

Cherian *et al*. (1996a) evaluated nineteen genotypes of cowpea (*Vigna unguiculata*) for slow rusting (a resistance mechanism) of which C152 was highly susceptible to rust [*Uromyces appendiculatus*] as a control and several genotypes including V38, APC813, APC83 and V17 were identified as possessing favorable slow rusting behaviour.

Cherian *et al.* (1996b) evaluated 14 varieties of cowpea (*Vigna unguiculata*) for slow rusting (*Uromyces phaseoli* [*U. appendiculatus*]) resistance. The study revealed that the varieties IT84D-449, IT86D-364, IT86D-373, IT86D-498, IT86D-1038, IT87D-1827, IT87S-1390, IT87S-1393, IT87S-1459 and IT845-2246 possessed good slow rusting mechanism.

Rangaiah (1997) stated that a minimum of two genes control rust resistance by studying eight F_2 populations of cowpea (*V. unguiculata*).

Saber and Hussein (1998) studied some mutants and stated that some selected M_4 resistant plants gave higher seed yield, and several had diverse morphological characters such as plant height, early and late flowering, number of pods/plant, number of seeds/plant, weight of 100 seeds, thickness of stem, pod shape and resistance to rust. Zeng-Yong San *et al. (*1999a) stated that disease severity and duration of saturated humidity was positively correlated

Zeng-Yong San *et al.* (1999b) revealed that there were significant differences in resistance to rust among the 21 cowpea varieties tested. One of them, Yinonghongrentechangdoujiao was immune, while the other two Jinshanchangdou and Chenduzijiabailu were highly resistant.

Uma and Salimath (2003) studied on the inheritance of rust (*Uromyces vignae* resistance in cowpea, using the F_2 and F_2M_2 populations of three crosses (C-152 x C-11, C-152 x KM-1 and C-152 x C-10) and the M_2 population of C-152. Results revealed that C-152 was highly susceptible, whereas C-11, C-70 and KM-1 were highly resistant to rust. The frequency of resistant segregants was almost three-fold higher than that of the susceptible segregants in the F_2M_2 populations and in the M_2 population.

2.2.3 Powdery mildew

Quindere-MAW and Barreto (1988) evaluated 81 genotypes to study the reactions of diseases and observed that seven were resistant to cowpea severe mosaic comovirus and cowpea (aphid-borne) mosaic potyvirus, thirteen genotypes to smut, eleven genotypes to bacterial blight [*Xanthomonas campestris* pv. *vignicola*] and four genotypes to powdery mildew [*Erysiphe polygoni*].

A study was conducted using four cultivars of cowpea revealed that powdery mildew (*Erysiphe polygoni*) and rust (*Uromyces appendiculatus*) were the major diseases observed with significantly lower number of pods per plant and number of seeds per pod (Stoffella *et al*., 1990).

Raju and Anilkumar (1990) evaluated twenty lines under glasshouse conditions for resistance to powdery mildew and stated that some lines were showing partial resistance while some exhibited high resistance.

Raju *et al*. (1991) assessed 21 cowpea cultivars for partial resistance to powdery mildew (*Erysiphe polygoni*) and mean response of V-105, V-269, V-276, V-282 and V-385 showed clear slow-mildewing, while RC-48, S-488, TVX-944-02E, V-27, V-36 and V-118 were rated as susceptible. Mildew resistance in some cultivars was negatively correlated with that for leaf rust.

Raju and Anilkumar (1991) stated that evaluating twenty germplasm lines of cowpea under greenhouse conditions, some lines exhibited partial resistance and these genotypes never exceeded 10% of the leaf area at any time of plant growth compared with 62.6% on the susceptible line.

Pradeep-Saxena *et al.* (1992) studied the extent of damage caused by powdery mildew of cowpea (*Oidium* spp.) and results revealed that plant size, number of branches and yield of cowpea were adversely affected by increasing levels of infection. There was 18% reduction in the number of seeds/pod at the lowest level of infection and 46% at the highest level. The percentage reduction was observed in plant height (22%), number of pods per plant (35%), green fodder yield (27%) and seed yield (50%) respectively.

Wongpiyasatid *et al*. (1999) studied the ten mutants of mung bean lines for resistance to powdery mildew (*Erysiphe polygoni*), Cercospora leaf spot (*C. canescens*) and cowpea weevil (*Callosobruchus maculatus*) resistance. Some lines showed resistance to powdery mildew and some were resistant to Cercospora leaf spot and some were resistant to cowpea weevil.

2.2.4. Bacterial blight

Amusa and Okechukwu (1998) stated that nine out of 45 cowpea breeding lines evaluated have confirmed resistance to blight. Sixteen breeding lines were found to be resistant to canker induction while twelve were resistant to both blight and canker.

Bua *et al. (*1998) evaluated twenty six cowpea lines for resistance to *Xanthomonas campestris* pv. *vignicola* (*X. axonopodis* pv. *Vignicola*) reported that during the first rains, the highest disease incidences, 55.0 and 54.5%, were recorded in the lines IT82E-12 and SLA 59, respectively. During the second rains, the highest disease incidence (65.9%) was recorded in the line Ife Brown and the lines were grouped into four categories, i.e. resistant, moderately resistant, moderately susceptible and susceptible.

Adebitan and Olufajo (1998) evaluating twelve cowpea varieties for yield and fodder production traits and disease resistance revealed that only IAR7/180-4-5 showed multiple disease resistance to scab (*Elsinoe phaseoli*), anthracnose (*Colletotrichum lindemuthianum*) and bacterial blight (*Xanthomonas campestris* pv. phaseoli).

Gomez *et al.* (1998) evaluated 40 advanced (F_9) lines for bacterial leaf blight disease resistance. The results revealed that experimental lines A-4, M-28-6-6 and TC-9-6 were moderately resistant, while TVX-3871 was resistant.

Alla-HMA *et al*. (1999) stated that only one line BARC-RR-12 showed leaf and pod resistance to infection by isolate PB4 under artificial conditions among the eighty one cowpea genotypes; 22 cultivars, eight introductions and 51 germplasm lines studied.

Sushma-Nema *et al.* (2000) observed that cowpea bacterial blight disease during the rainy season. Fifty one cultivars/lines were screened for their reaction to *P. vignae* at Jabalpur during 1996-97. None of the entries were resistant to the disease and only IFC-9502 was moderately resistant.

Fery and Dukes (2002) stated that a significant variability in cowpea germplasm for resistance to southern blight. Two cultivars, Brown Crowder and Carolina Cream exhibited promising levels of resistance in two years of testing.

2.3 CHARACTER ASSOCIATION STUDIES

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 co- variance 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.

Siddique and Gupta (1991b) 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. In 1992, Oseni *et al.* 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. Altinbas and Sepetoglu (1993) concluded that 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. 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. Tamilselvan and Das (1994) reported that the number of clusters, number of pods per plant and 100 seed weight should be used as a selection criterion in the development of high yielding genotypes of cowpea. In a study involving three F_2 populations 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. Gowda (1996) revealed that 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. In 1997, Singh and Singh revealed that number of clusters per plant, number of seeds per pod and total biomass made greatest direct contribution to seed yield in 45 cowpea genotypes. Vardhan and Savithramma (1998) reported that a very high positive association of green pod yield with pods per plant. Rangaiah *et al.* (1999) reported that total seed weight was positively and significantly associated with all the traits except plant height and pod weight made the greatest contribution towards yield per plant in both crosses. Plant height, 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 plant height, number of branches per plant and number of pods per plant.

Belhekar *et al*. (2003) revealed that by studying F_2 generation, the seed yield per plant exhibited positive and significant correlation with plant height, 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 number 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, 100 seed 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 having positive significant association with yield. These characters can be considered during selection for yield improvement.

2.4 PATH COEFFICIENT ANALYSIS

Standard partial correlation or regression (path coefficients) offered a much realistic interpretation of the factors involved. Path coefficient analysis permits the partitioning the correlation coefficients into direct and indirect effects of a set of independent variables on the dependent variable and gives a more realistic relationship of the character and helps in identifying the effective components. This technique was originally developed by Wright (1921) but the technique was first used for plant selection by Dewey and Lu (1959). To use this path coefficient analysis, it requires cause and effect situation among the variables.

In any crop, grain yield has been associated with a number of yield contributing characters and these characters themselves are inter related. Path coefficient analysis permits the separation of direct and indirect effect through the other related characters by apportioning the correlation coefficients. The available literature on path analysis on seed yield with their component traits in cowpea was briefly reviewed.

Patil *et al.* (1989) reported that pods per plant, 100 seed weight and seeds per pod had greatest positive direct effect on yield.

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

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.

Altinbas Sepetoglu (1993) revealed by path analysis study that the most important yield component was number of pods per plant affecting the yield through path analysis.

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.

Vardhan and Savithramma (1998) 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 width and number of primary branches were major traits contributing to yield. Amanakapoor *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 I60 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.

Kalaiyarasi and Palanisamy (2002) stated that number of seeds per pod, number of pods per plant, crude protein content and plant height 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 F_3 population of cowpea. Pod length and hundred seed weight had positive indirect effects on seed yield through number of pods per plant, number of seeds per pod and crude protein content. The study suggested that the characters like number of pods per plant, number of seeds per pod and crude protein content could be considered while formulating selection indices in the improvement of cowpea.

Santosh kumar *et al.* (2002) studied five cowpea cultivars, and showed that dry fodder yield had the highest direct positive contribution towards green fodder yield followed by number of days to 50% flowering, leaf: stem ratio, number of branches, plant height, leaf breadth and leaf length respectively.

Kutty *et al.* (2003) stated that, the number of pods per plant, number of pickings, average weight of pods and pod length were positively and significantly correlated with yield per plant both at phenotypic and genotypic levels. Path analysis indicated that the number of pods per plant followed by average weight of pods and number of pickings had the greatest positive direct effect on yield.

Belhekar *et al.* (2003) revealed that, Plant height and number of branches per plant showed a strong positive direct effect, the number of pods per peduncle and seed index showed a strong negative direct effect and leaf area per plant and number of peduncles per plant showed a moderate negative effect. The number of seeds per pod and pods per peduncle showed a strong positive direct effect. The seed index and number of branches per plant showed a moderate positive direct effect at the genotypic level. The direct negative effect was observed for 100 seed weight, complete maturity and leaf area per plant.

The path analyses for ten traits were conducted by using 20 genotypes of cowpea (Venkatesan *et al.*, 2003) and it showed the positive direct effect of number of pods per plant, pod length, number of clusters per plant, number of seeds per pod, and 100 seed weight on seed yield.

Yadav *et al.* (2003), revealed that studying 28 F_1s and 28 F_2s, green pod yield per plant had positive and significant association with plant height, pods per cluster, pod length, seed per pod and pod dry matter in all the three generations. Path analysis revealed that dry matter in pod, pods per plant, seeds per pod and plant height was the main components of green pod yield in the early generation of cowpea.

Vineeta-Kumari *et al.* (2003) revealed that the number of clusters, pods, seeds per pod, and 100 seed weight showed the greatest positive direct effects on seed yield

2.5 GENOTYPE AND ENVIRONMENT EFFECTS

The performance of different genotypes in varying environments might be varied 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.

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

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.

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.

The 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 all characters except pod length.

2.6 GENETIC DIVERGENCE

Estimation of the degree of the divergence between biological populations and computation of relevant contributions of different components to the total divergence is done completely by Mohalanobis's generalized distance estimated by D^2 statistic (Nair and Mukharjee, 1960; Mourya and Singh, 1977). Nair and Mukharjee, were the pioneers to use D^2 statistic as measure of genetic divergence in the field of plant breeding for classification of teak plants.

Renganayaki and Rangasamy (1991) analyzed the mung bean (*Vigna radiata*), Black gram (*Vigna mungo*) and Cowpea (*Vigna unguiculata*) using the Mahalanobis D^2 value and revealed that the genotypes of the *Vigna radiata*, V. *mungo* and V. *unguiculata* were grouped in seven, five and four clusters respectively and also concluded that hundred seed weight, pod length and seed yield contributed most towards genetic divergence.

Santos *et al.* (1997) reported genetic divergence of cowpea under two different environments using Mahalanobis D^2 statistic that length of the main branch, hundred seed weight and pod length were the most important characters to affect divergence.

Sharma and Misra (1997) revealed that days to 50 % flowering, plant height, pods per peduncle and harvest index contributed the most towards genetic divergence and seed yield had a high positive phenotypic correlation with pods per peduncle, number of seeds per pod and harvest index.

Bakiyarani *et al.* (2000) concluded that genetic divergence for physiological traits like single plant yield, harvest index and earliness in flowering together accounted for 80 % of the total genetic divergence in cowpea.

Borah and Khan (2002) revealed on genetic divergence in fodder cowpea. Sixty cowpea cultivars were grouped into 10 clusters. Dry matter yield, green fodder yield and plant height were recorded highest contribution to total genetic divergence. These traits could be good criterion for the selection of parents in hybridization programme.

Ushakumari *et al.* (2002) reported that contribution towards divergence was 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%) in cowpea.

III. MATERIALS AND METHODS

The details of the materials used and methods adopted for collection and analysis of data and interpretations are described in this chapter. Two field experiments were carried out during *kharif* 2004 and *Summer* 2005 in the experimental site at Botany Garden, Department of Genetics and Plant Breeding, University of Agricultural Sciences Dharwad, Karnataka, India.

3.1 EXPERIMENTAL SITE DETAILS

Dharwad is located in the transitional tract of Karnataka state at $15^0$13' north latitude, $75^0$07' east longitudes and at an altitude of 678 m above mean sea level with an average rainfall of about 800 mm. The rainfall is well distributed between June to October. The weather information during the experimental period is given in Appendix III. The soil type of the experimental block was vertisol with pH in the range of 7.0 – 7.5.

3.2 EXPERIMENTAL MATERIALS

One hundred and sixty nine germplasm lines were used for the studies, of which one hundred and sixty nine indigenous collections of cowpea (*Vigna ungiculata* (L.) Walp) germplasm lines obtained from the National Bureau of Plant Genetic Resources (NBPGR), Pusa Campus, New Delhi (Table 3.1) and the check materials for the study were obtained from the Department of Genetics and Plant Breeding, University of Agricultural sciences, Dharwad (Table 3.2).

Experiment 1: *Kharif* 2004

First experiment was conducted during *kharif*. In this experiment, 169 genotypes including five recommended check varieties with Bailhongal local and eight exotic lines were evaluated for the yield, and yield attributing characters, qualitative and quantitative characters and diseases such as mosaic virus, rust, bacterial blight, and powdery mildew. The details of the observations are given in Table 3.3.

Experiment II: Summer 2005

Second experiment conducted during summer. The same 169 genotypes were used in summer 2005 also and evaluated for same characters. The observations collected on all the parameters as in first experiment except some of diseases like bacterial blight, powdery mildew and rust. The data collected based on the instructions given in cowpea descriptors (IPGRI).

3.3 DISEASE SCORING

The genotypes were screened for important diseases like mosaic virus, rust, bacterial blight and powdery mildew during *kharif* 2004 season and in the summer 2005 screened only for mosaic virus. Scoring for disease resistance was based on the use of different scales.

Rust

The following 0-9 disease scale was used given by Mayee and Datar (1986) to assess the disease.

Table 3.1: Qualitative traits of cowpea germplasm lines received from NBPGR, New Delhi

Sl. No.	Accession No.	Seed colour	Seed size	Plant type	Flower colour
1	IC257410	Dark brown	Medium	IB	MP
2	IC257411	Buff	Medium	D	MP
3	IC257420	Black	Medium	IB	MP
4	IC257422	Dark Brown	Medium	D	MP
5	IC97767	Dark Brown	Medium	IB	W
6	IC97787	Cream	Medium	D	MP
7	IC97806	Brown	Medium	D	MP
8	IC97806	Cream	Medium	D	MP
9	IC97829	Brown	Medium	IB	MP
10	IC97830	Brown	Medium	IB	MP
11	IC97830	Cream	Medium	D	W
12	IC97834	Dark Brown	Medium	D	MP
13	IC97838	Light Brown	Medium	D	MP
14	IC97856	Brown	Medium	IB	MP
15	IC15567	Light Brown	Medium	IB	MP
16	IC91556	Cream	Medium	D	MP
17	IC97764	Brown	Medium	IB	MP
18	IC198321	Brown	Medium	D	MP
19	IC198323	Brown	Medium	IB	MP
20	IC198327	Cream	Medium	IS	W
21	IC198333	Cream	Medium	IS	MP
22	IC198335	Brown	Medium	IB	MP
23	IC198342	Dark Brown	Medium	IS	V
24	IC198349	Cream	Small	IS	MP
25	IC198355	Brown	Medium	D	MP
26	IC198359	Brown	Medium	IB	MP
27	IC198361	Brown	Medium	IB	MP
28	IC199701	Buff	Medium	IS	V
29	IC199704	Brown	Medium	IS	MP
30	IC201079	Ash	Medium	D	MP
31	IC201087	Light Brown	Small	IB	MP
32	IC201095	Ash	Medium	IB	MP
33	IC201099	Light Brown	Small	IB	MP
34	IC202705	Light Brown	Medium	IB	MP
35	IC202707	Buff	Medium	D	MP
36	IC202709	Light Brown	Small	D	MP
37	IC202710	Brown	Small	D	MP
38	IC202718	Brown	Medium	IB	MP

Table 3.1. contd…..

Sl. No.	Accession No.	Seed colour	Seed size	Plant type	Flower colour
39	IC202720	Ash	Medium	IB	MP
40	IC202730	Brown	Medium	D	MP
41	IC202743	Brown	Medium	IB	MP
42	IC202762	Ash	Medium	IB	MP
43	IC202772	Cream	Medium	D	MP
44	IC202775	Brown	Medium	D	MP
45	IC202778	Brown	Large	D	MP
46	IC202779	Brown	Large	IB	MP
47	IC202781	Brown	Large	IB	MP
48	IC202782	Cream	Medium	D	MP
49	IC202786	Brown	Large	IS	MP
50	IC202787	Brown	Large	IB	MP
51	IC202789	Brown	Large	D	MP
52	IC202791	Brown	Small	IB	W
53	IC202797	Brown	Large	D	MP
54	IC202799	Cream	Small	D	MP
55	IC202803	Brown	Large	IB	MP
56	IC202804	Ash	Medium	IB	V
57	IC202809	Pink	Medium	IB	MP
58	IC202823	Cream	Medium	D	MP
59	IC202824	Buff	Large	IB	MP
60	IC202835	Black	Medium	IS	MP
61	IC202841	Light Brown	Medium	IB	MP
62	IC202846	Brown	Medium	IS	MP
63	IC202854	Cream	Small	IB	W
64	IC202860	Ash	Small	IS	MP
65	IC202867	Brown	Medium	IB	MP
66	IC202868	Brown	Large	D	MP
67	IC202873	Brown	Medium	IS	MP
68	IC202893	Cream	Medium	IB	MP
69	IC202901	Cream	Medium	IS	V
70	IC202924	Brown	Medium	IS	MP
71	IC202926	Cream	Medium	D	MP
72	IC202927	Cream	Small	IS	MP
73	IC204103	Ash	Medium	D	MP
74	IC206240	Brown	Small	D	MP
75	IC207813	Pink	Medium	IS	MP
76	IC208618	Ash	Medium	D	MP
77	IC214752	Ash	Medium	D	MP
78	IC214759	Ash	Medium	D	MP
79	IC214833	Ash	Medium	IB	MP

Table 3.1. contd…..

Sl.No.	Accession No.	Seed colour	Seed size	Plant type	Flower colour
80	IC214834	Buff	Medium	D	MP
81	IC214835	Brown	Medium	IB	MP
82	IC214836	Ash	Medium	IB	MP
83	IC215015	Dark Brown	Medium	D	MP
84	IC219141	Ash	Medium	IB	MP
85	IC219574	Cream	Medium	IS	MP
86	IC219592	Cream	Medium	D	MP
87	IC219594	Light Brown	Medium	IB	MP
88	IC219607	Cream	Medium	D	MP
89	IC219640	Light Brown	Medium	IB	MP
90	IC219872	Dark Brown	Medium	IS	MP
91	IC243312	Dark Brown	Medium	IB	MP
92	IC243353	Brown	Medium	IS	W
93	IC243486	Brown	Medium	D	MP
94	IC243489	Brown	Medium	IS	MP
95	IC243501	Ash	Medium	D	MP
96	IC247430	Black	Medium	IS	MP
97	IC249132	Ash	Medium	IB	MP
98	IC249133	Ash	Medium	IB	V
99	IC249137	Ash	Medium	IS	MP
100	IC249140	Ash	Medium	IB	W
101	IC249141	Ash	Medium	IS	MP
102	IC249583	Cream	Medium	IB	MP
103	IC249585	Light Brown	Medium	IB	MP
104	IC249586	Buff	Medium	IB	MP
105	IC249593	Light Brown	Medium	IB	MP
106	IC253181	Cream	Medium	IS	MP
107	IC253255	Light Brown	Medium	IB	MP
108	IC253268	Brown	Medium	IB	MP
109	IC253270	Dark Brown	Medium	D	V
110	IC253275	Dark Brown	Medium	IS	MP
111	IC253276	Dark Brown	Medium	D	MP
112	IC253277	Light Brown	Medium	D	MP
113	IC253281	Cream	Medium	IS	W
114	IC253288	Cream	Medium	IB	MP
115	IC257406	Light Brown	Medium	D	MP
116	IC257407	Black	Medium	IS	MP
117	IC257424	Brown	Medium	IB	MP
118	IC257425	Light Brown	Medium	IB	MP
119	IC257427	Light Brown	Medium	IB	MP
120	IC257435	Light Brown	Medium	IB	MP

Table 3.1. contd…..

Sl. No.	Accession No.	Seed colour	Seed size	Plant type	Flower colour
121	IC257441	Ash	Medium	IS	MP
122	IC257445	Light Brown	Medium	D	MP
123	IC257449	Light Brown	Medium	IS	W
124	IC257452	Cream	Medium	D	MP
125	IC257453	Black	Small	IB	MP
126	IC259058	Brown	Small	D	MP
127	IC259061	Light Brown	Medium	D	MP
128	IC259063	Light Brown	Medium	IB	W
129	IC259064	Light Brown	Medium	IB	W
130	IC259069	Ash	Medium	IB	MP
131	IC259071	Brown	Medium	IB	V
132	IC259072	Cream	Medium	IS	MP
133	IC259078	Cream	Medium	D	MP
134	IC259081	Brown	Medium	IS	MP
135	IC259083	Ash	Medium	IB	MP
136	IC259084	Brown	Medium	D	MP
137	IC259084	Brown	Medium	IB	MP
138	IC259085	Brown	Medium	IB	MP
139	IC259095	Brown	Medium	D	MP
140	IC259100	Dark Brown	Medium	D	MP
141	IC259107	Ash	Medium	IB	W
142	IC259105	Brown	Medium	IB	MP
143	IC259159	Brown	Medium	IB	MP
144	IC202784	Brown	Large	IB	MP
145	IC201098	Light Brown	Medium	D	MP
146	IC4506	Cream	Medium	IB	V
147	IC5969	Black	Medium	IB	MP
148	IC68786	Cream	Medium	IB	MP
149	IC68786	Light Brown	Medium	IB	MP
150	IC202702	Brown	Medium	IS	MP
151	IC202931	Light Brown	Medium	IS	MP
152	IC202932	Cream	Medium	D	V
153	IC247435	Black	Medium	IB	MP
154	Goa local	Brown	Large	IB	MP
155	C-152	Brown	Medium	D	MP
156	Bilahongal local	Brown	Medium	D	MP
157	V-118	Cream	Medium	IB	MP
158	EC394767	Light Brown	Small	D	MP
159	EC394691	Buff	Medium	D	MP
160	EC394823	White	Medium	IB	MP

Table 3.1. contd…..

Sl. No.	Accession No.	Seed colour	Seed size	Plant type	Flower colour
161	EC394740	Brown	Medium	IB	MP
162	EC394855	Brown	Medium	IB	MP
163	EC394805	Brown	Medium	IB	MP
164	EC394753	Brown	Medium	D	W
165	EC394745	Cream	Medium	IB	MP
166	IC97764	Brown	Medium	IB	MP
167	IC257437	Dark Brown	Medium	IB	MP
168	IC257447	Pink	Medium	IB	MP
169	GC-3	Cream	Medium	IB	MP

MP - Mave Pink W-White D-Determinate IB-Intermediate Bush

V – Violet IS- Intermediate Spreading not climbing

Table 3.2: List of genotypes used as checks in cowpea germplasm evaluation during *kharif* 2004 and summer 2005 seasons

Recommended varieties	Exotic lines
V-118	EC 394691
C –152	EC 394753
GC-3	EC 394823
Goa Local	EC 394740
Bailhongal Local	EC 394767
	EC 394855
	EC 394745
	EC 394805

Table 3.3: List of characters observed in cowpea germplasm evaluation during kharif and summer seasons

***Kharif* Season 2004**	**Summer Season 2005**
Initial germination (in the field)	Initial germination (in the field)
Plant height	Plant height
Primary branches	Primary branches
Flower colour	Flower colour
Pod colour	Pod colour
Plant pigmentation	Plant pigmentation
Clusters per plant	Clusters per plant
Days to flower initiation	Days to flower initiation
Days to flower termination	Days to flower termination
Immature pod pigmentation	Immature pod pigmentation
Days to physiological maturity	Days to physiological maturity
Pods per plant	Pods per plant
Pod length	Pod length
Seeds per pod	Seeds per pod
Seed yield per plant	Seed yield per plant
Harvest Index	Harvest index
Mosaic virus	Mosaic virus
Bacterial blight	
Powdery mildew	
Rust	

Scale	Intensity of disease
0	No symptoms on the leaves (Immune)
1	(Small, round, powdery, brown uredospores covering one per cent or less of the leaf area. (Resistant)
3	Typical uredospori covering 1- 10 per cent of the leaf area (Moderately resistant)
5	Typical uredospori, covering 11 to 25 per cent of the leaf area (Moderately susceptible)
7	Typical uredospori, covering 26 – 50 per cent of the leaf area (Susceptible)
9	Uredospori cover 51 per cent or more of the leaf area, withering of leaf (Highly susceptible)

Following 0-9 disease scale was used to assess the diseases such as rust, bacterial blight, powdery mildew and mosaic virus.

Score	Infected percentage	Reaction
0	No symptoms	Immune
1	1% or less plants exhibiting symptoms	Resistant
3	> 1 to 10 percent	Moderately resistant
5	11 – 20 percent	Moderately susceptible
7	21 – 50 percent	Susceptible
9	51 % and above	Highly susceptible

The disease incidence percentage was calculated using following formula

$$\text{Disease Incidence Percentage} = \frac{\text{Number of plants infected}}{\text{Total number of units assessed}} \times 100$$

Experiment I:

The experiment was conducted in Randomized Complete Block Design (RCBD) with two replications. Each genotype was sown in one row of 3m length with the spacing of 60 x 20 cm apart from the rows and plant respectively. Before sowing, recommended fertilizer was incorporated into the soil at the rate of N 12.5 kg/ha, P_2O_5 25 kg /ha and K 12.5 kg/ha and irrigation was done as required.

Experiment II:

The experiment was conducted in simple Latice Square Design with two replications. Each genotype was sown in two rows of 3m length with the spacing of 60 x 20 cm apart from the rows and plant respectively. Before sowing, the recommended fertilizer was incorporated into the soil and irrigation was done as required.

3.4 OBSERVATIONS RECORDED

The list of observations recorded in the two experiments are listed in Table 3.3. The observations were recorded on five randomly selected plants with in a row.

3.4.1 Growth Parameters

1. Initial seed germination: After five days of sowing, number of seedlings emerged were counted and expressed as percentage.
2. Plant height: The plant height was measured in centimeters (cm) from the ground level to tip of the main stem of the plant at the time of harvesting.
3. Number of primary branches per plant: The number of branches arising directly from the main stem was counted at the time of harvest.

3.4.2 Qualitative characters

1. Pigmentation of stem : Stem pigmentation was measured at flower initiation stage based on the scales in cowpea descriptors.
2. Plant type : The plant type was classified into determinate, semi determinate and indeterminate plant habits, which were recorded after complete growth of the plant in each genotype.
3. Flower colour : The colour of the flower was recorded at the time of flowering in the morning 7 am to 9 am.
4. Pod color : The pod color was recorded at the maturity stage before changing the colour.

3.4.3 Yield and yield contributing characters

1. Days to flower initiation : Total number of days from sowing to few flowers opening was counted at the relevant stage of each genotype.

2. Days to flower termination : Total number of days from sowing to termination of flowering was counted at the relevant stage of each genotype.

3. Days to physiological maturity : Total number of days from sowing to physiological maturity of 50 % of pods was counted at the relevant stage of each genotype.

4. Number of clusters per plant : The total numbers of pod bearing clusters per plant were counted at the time of harvest.

5. Number of pods per plant : Total number of pods per plant were counted at the time of harvest.

6. Pod Length : Pod length in centimeters (cm) was measured from the randomly selected five pods at the time of harvest.

7. Number of seeds per pod : Number of seeds per pod was taken as a mean number of seeds of five randomly selected pods at the time of harvest.

8. Hundred seed weight : Weight of 100 seeds was measured in grams.

9. Harvest Index : The harvest index was calculated using the formula of Donald (1968) and expressed as percent.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

10. Seed yield per plant : Seed weight in grams from each plant was recorded at the time of harvest.

3.5 STATISTICAL ANALYSIS

The statistical analysis of the data on the individual characters was carried out on the mean values of five random plants. For the statistical analysis spar-1 software package was used. Different statistical methods employed for the analysis are as follows.

3.5.1 Mean, Range and Variance

The mean, range and variance of each character were calculated for each genotype.

$$\text{Mean} = \frac{\text{Sum of observations of all the plants}}{\text{Number of plants}}$$

Range = The minimum and maximum values for each trait

$$\text{Variance} = \frac{1}{(n-1)} [\Sigma (X_i - \bar{X})^2]$$

Where,

X_i = Individual value

$\bar{X}$ = Population mean

n = Number of observations

3.5.2 Analysis of variance

The analysis of variance for different characters was carried out using the mean data in order to partition the variability due to different sources by following the method given by Panse and Sukhatme (1964).

The structure of ANOVA is as follows

Source of Variance	d.f.	MSS	Expected values of MSS
Replication (r)	(r -1)	M1	--
Genotypes (G)	(g – 1)	M2	$\sigma_e^2 + r\sigma_g^2$
Error	(r – 1) (g – 1)	M3	σ^2
Total	rg - 1		

Structure of ANOVA for Simple Latice Design

Source of variance	d.f.	SS	MSS
Replications (r)	r-1	SSQ_R	SSQ_R/r-1
Genotypes (G)	k^2-1	SSQ_t	SSQ_t/k^2-1
Block within replication	r (k-1)	SSQ_B	SSQ_B/r(k-1)

Intra block error	(k-1) × (rk-k-1)	SSQ_E	SSQ_E/ (k-1) × (rk-k-1)
Total	rk^2-1	SSQ_T	

Estimation of Genetic parameters

In order to assess and quantify the genotypic variability among the genotypes for the characters under study, the following parameters were estimated as given below.

Estimation of variance components

Phenotypic and genotypic variances were estimated using following formula,

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MSS (genotypes) - MSS (error)}}{\text{Number of replications}} = \frac{M_2 - M_3}{r}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + \text{MSS error} = \frac{M_2 - M_3}{r} + M_3$$

3.5.3 Coefficient of variability

Both genotypic and phenotypic coefficients of variability were computed as per the method suggested by Burton and Devane (1953).

$$\text{Genotypic coefficient of variability (GCV)} = \times 100 \frac{\sigma_g}{\bar{X}}$$

$$\text{Phenotypic coefficient of variability (PCV)} = \times 100 \frac{\sigma_p}{\bar{X}}$$

Where,

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

$\bar{X}$ = General mean of the character

GCV and PCV values were categorized as low, moderate and high as indicated by Siva Subramanian and Menon (1973). It is as follows,

0 – 10 % : Low

10 – 20% : Moderate

20 % and above : High

3.5.4 Heritability (h^2)

Heritability in broad sense was computed as the ratio of genetic variance to the total phenotypic variance as suggested by Hanson *et al.* (1956) and expressed as percentage.

$$\text{Heritability } (h^2) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

The heritability percentage was categorized as low, moderate and high as given by Robinson *et al.* (1949).

3.5.5 Genetic advance (GA)

Genetic advance was estimated by using the formula given by Johnson *et al.* (1955).

$$GA = h^2 \times k \times \sigma_p$$

Where,

h^2 = heritability estimate

k = Selection differential which is equal to 2.06 at 5 % intensity of selection (Lush, 1949).

σ_p= Phenotypic standard deviation

Genetic advance as per cent of mean (GAM)

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

Where,

GA = Genetic advance

$\bar{X}$ = General mean of the character

3.5.6 Correlation analysis

The correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components.

Phenotypic correlations were computed by using the formula given by Webber and Moorthy (1952).

$$r_{xy} = \frac{\text{Cov } XY}{\sqrt{\sigma_p^2 x \times \sigma_p^2 y}}$$

Where,

r_p = Phenotypic correlation

Cov X Y = Phenotypic covariance between the characters 'x' and 'y'

$\sigma_p^2 x$ X $\sigma_p^2 y$ = Phenotypic variance of the characters 'x' and 'y' respectively

Phenotypic correlation coefficients were compared against table r (n-2) degrees of freedom at the probability levels of 0.05 and 0.01 to test their significance Fisher and Yates (1963).

3.5.7 Path analysis

Path coefficient analysis was carried out by using the phenotypic correlation coefficients to know the direct and indirect effects of the components of yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Path coefficients were obtained by solving the simultaneous equations, which express the basic relationship between correlations and path coefficients. The equations were as follows.

$r_{1.y} = P_{1y} + r_{1.2} P_{2y} + r_{1..3} P_{3y} + \ldots\ldots\ldots + r_{1..k} P_{ky}$

$r_{2.y} = P_{2y} + r_{2.1} P_{1y} + r_{2..3} P_{3y} + \ldots\ldots\ldots + r_{1..k} P_{ky}$

....

....

$r_{k-1.y} = r_{k-1.1} P_{1y} + r_{k-1.2} P_{2y} + r_{k-1.3} P_{3y} + \ldots\ldots\ldots + P_{k-1y}$

Where, $r_{1.y}$ to $r_{k-1.y}$ denote the correlation coefficients between independent characters 1 to k -1 and dependent character 'y', $r_{1.2}$ to $r_{k-2.\ k-1}$ denote the correlation coefficients between all possible combinations of independent characters. $P_{1\ y}$ to P_{k-1y} denotes the direct effects of characters 1 to k-1 on character ' y'.

'F' test

To test the significance of the differences among the genotypes means:

$$F = \frac{M_1}{M_3}$$

3.5.8 Genetic diversity analysis

Multivariate analysis using D^2 statistics

Mahalanobis (1936) D^2 - statistic was used for assessing of the genetic divergence between genotypes.

The generalized distance between any two populations is defined as,

$$D = \sum y_{ij}\, \beta i\ \ \beta j$$

Where,

Yij = The reciprocal matrix to the common dispersion matrix

βi = The difference between the two mean values of the two populations for i^{th} character (µ i 1 -µi 2)

βj = The difference between the mean values of the two populations for the j^{th} character (µ j1 - µ j2)

µ = Vector mean values for all the characters

The formula for the estimation of distance, D^2 from samples

$$D^2\ p = d1\ (S\text{-}1)\ d$$

Where,

D^2p = Square of the distance considering P values.

d1 = $(Xi_1 – Xi_{2)}$

X = Vector for mean values of all the characters

S -1 = inverse of variance covariance matrix

Formula for computation of D values, which requires inversion of the matrix, becomes complicated especially when the numbers of variables under consideration are large. Therefore, the original correlated unstandardized variables (Xi) were transformed to standardized uncorrelated variables (Yi) so that the computation of D^2 values reduce to simple summation of squares of the differences between values of transformed variables of the two population ie., D^2i.

From the newly transformed uncorrelated variables, the square of the distance was computed using the following formula,

$$D^2 = \sum (\overline{Yi_1} - \overline{Yi_2})^2$$

Where,

$\overline{Yi_1}$ = Vector of transformed mean values, for first genotype

$\overline{Yi_2}$ = vector of transformed mean values, for second genotype

The square root of the D^2 values gives the generalized distance (D) between the two populations. The D^2 values were arranged in a matrix form. The significance of D^2 values between any populations was tested using the following formula,

$$F = \frac{(n_1 + n_2 - p - 1)}{(n_1 + n_2 - 2)\,P} \times \frac{(n_1 n_2)\,D^2}{(n_1 + n_2)}$$

This computed F values was compared with table F value at 5 per cent and 1 per cent levels of significance with P (number of characters) and $(n_1 + n_2 - p - 1)$ degrees of freedom.

Determination of population constellation

All the n (n-1) /2 D^2 values were considered for determining the population constellation. This was realized by using Tocher's method as described by Rao (1952). The criterion used in clustering by this is that any two varieties belonging to the same cluster, should at least, in average, show a smaller D^2 value than those belonging to different clusters. As per the device it was to start with two closely associated populations and find a third population, which had the smallest average D^2 from these two. Similarly, the fourth was chosen to have a smallest average from the first three and so on. The permissible increase in D^2 values for clustering into the same group was fixed approximately nearer the maximum D^2 value shown by a population to the nearest population. This procedure was continued till D^2 values of all the pairs of genotypes were exhausted. After the formation of the clusters inter and intra group distance was calculated. The square root of the average D^2 values obtained from the above represents the distance (D) between and within clusters.

IV. EXPERIMENTAL RESULTS

The productivity of cowpea is very low due to non-availability of high yielding varieties with good plant types and resistance to diseases also, it is a major hindrance to the breeders for further research. An attempt was made to identify such varieties, having high yields with good plant types and resistance to diseases. The results obtained from the investigations on quantitative and qualitative characters related to yield and yield contributing characters and disease resistance are presented in the following sub headings.

4.1 Analysis of variance, mean, range and genetic variability parameters

4.2 Disease resistance

4.3 Character association studies

4.4 Path coefficient analysis

4.5 Genotype and environment effects

4.6 Genetic diversity analysis

4.1 ANALYSIS OF VARIANCE, MEAN, RANGE AND GENETIC VARIABILITY PARAMETERS

4.1.1 Analysis of variance

4.1.1.1 Experiment- 1 (*Kharif* 2004)

Analysis of variance was carried out for thirteen quantitative characters including yield and yield contributing characters of hundred and sixty nine genotypes, which were evaluated in experiment-1 during *kharif* 2004. The results obtained are listed in the Table 4.1a. All the analyzed traits were shown highly significant difference among the genotypes.

4.1.1.2 Experiment- II (*Summer* 2005)

The results of the analysis of variance was carried out for the thirteen quantitative characters including yield and yield contributing characters of hundred and sixty nine genotypes which were evaluated in experiment- II during *Summer* 2005 are presented in Table 4.1b. All the analyzed traits were shown highly significant difference among the genotypes.

4.1.2 Mean, range and genetic variability parameters

The results on mean, range and genetic variability parameters of both *Kharif* 2004 and *Summer* 2005 seasons were presented in tables 4.1.2a and 4.1.2b respectively.

4.1.2.1 Experiment - I (*Kharif* 2004)

Germination percentage

The mean germination percentage was 76.35 and the observed minimum and maximum range was between 15 and 99. The character showed high genotypic coefficient of variation (23.45%) and high phenotypic coefficient of variation (23.54%) and it showed the high heritability percentage (99.2%) with higher value of genetic advance over mean (48.12%).

Plant height

The overall mean for plant height was 42.39 cm, with a minimum and maximum value of 32.5 cm and 57.00 cm respectively. It showed the moderate GCV (12.24%) and PCV (12.53%) values, while it showed high heritability percentage (95.30%) with a high GAM percentage (24.60%).

Table 4.1a: Analysis of variance (ANOVA) for thirteen quantitative characters in one hundred sixty nine genotypes of cowpea during *kharif* 2004

Sl. No.	Characters	Mean Sum of Squares		
		Genotype	Replication	Error
1	Germination percentage	643.66**	2.25	2.48
2	Plant height	55.12 **	27.88	1.31
3	Days to flower initiation	50.98 **	0.06	1.05
4	Days to flower termination	60.54 **	0.13	1.73
5	Days to physiological maturity	72.14**	0.25	1.59
6	Number of branches per plant	0.56**	1.69	0.18
7	Number of clusters per plant	10.68**	10.47	0.69
8	Number of pods per plant	29.16**	20.88	0.76
9	Pod length	4.79**	1.59	1.57
10	Seeds per pod	3.78**	2.07	0.16
11	Hundred seed weight	20.38**	0.04	0.07
12	Harvest index	0.0032**	0.000053	0.00009
13	Seed yield per plant	40.32**	0.43	0.49

* Significance at 5% probability level
* * Significance at 1 % probability level

Table 4.1b: Analysis of variance (ANOVA) for thirteen quantitative in one hundred sixty nine genotypes of cowpea during summer 2005

Sl. No.	Characters	Mean Sum of Squares		
		Genotype	Replication	Error
1	Germination percentage	651.53**	9.00	7.93
2	Plant height	52.63**	19.69	1.99
3	Days to flower initiation	45.25**	30.75	1.78
4	Days to flower termination	44.81**	17.00	2.07
5	Days to physiological maturity	43.92**	26.25	1.83
6	Number of branches per plant	0.64**	2.53	0.12
7	Number of clusters per plant	9.63**	16.11	0.71
8	Number of pods per plant	38.62**	12.39	1.27
9	Pod length	7.13**	3.07	0.64
10	Seeds per pod	5.05**	1.44	0.63
11	Hundred seed weight	19.94**	0.07	0.09
12	Harvest index	0.006**	0.0001	0.00009
13	Seed yield per plant	43.64**	3.76	0.79

* Significance at 5% probability level
* * Significance at 1 % probability level

Days to flower initiation

The over all average of days to flower initiation was 54.80 days with the range of 43.5 days to 76.5 days. The lower GCV (9.12%) and PCV (9.31%) values were recorded while the trait showed the high heritability (95.90%) with moderate GAM (18.39%).

Days to flower termination

The mean for days to flower termination was 71.44 days with the range of 54.5 days to 87.00 days. It showed low GCV (7.59%) and low PCV (7.81%) value, while the trait showed the high heritability value (94.5%) with moderate GAM (15.20%).

Days to physiological maturity

The mean of the character was 78.80 days with the range of 61 days to 95 days. It showed the low GCV (7.54%) and PCV (7.71%) values, while the character showed high heritability (95.70%) with moderate GAM (15.19%).

Number of main branches

The range observed for main branches was 2.4 to 5.00 with a mean of 3.88. The character showed moderate GCV (11.29%) and PCV (15.66%) values with moderate heritability percentage (52.00%) and moderate GAM (16.75%).

Number of Clusters

The average of 8.34 clusters per plant with 3.00 to 16.5 range were recorded. The character showed high GCV (26.80%) and PCV (28.6%) values with high heritability percentage (87.8%) and GAM (51.68%).

Number of pods per plant

The over all average of the trait was 11.75 with the range of 3.5 to 31.5. The character showed the high GCV (32.08%) and PCV (32.93%) values and also it showed high heritability percentage (94.90%) with GAM (64.34%).

Pod length

The mean pod length was 12.26 cm with the range of 8.00 cm to 17.00 cm. For this character, it was observed that moderate GCV (10.36%), PCV (14.55%), heritability (50.7%) values and moderate GAM (15.17%).

Seeds per pod

This character showed 10.54 mean values with the range of 7.00 to 14.00. Seeds per pod showed low GCV (9.86%) value, while it showed the moderate PCV (15.59%), moderate heritability percentage (40.00%) and moderate GAM (12.81%).

Hundred seed weight

The range observed for hundred seed weight was 5.35 g to 22.30 g with the average of 10.85 g. This trait showed high GCV (29.37%) and high PCV (29.47%) values and also high heritability percentage (99.30%) with high GAM (42.11%).

Harvest Index

The mean of harvest index was 0.19 with the minimum and maximum values of 0.05 to 0.28, respectively. It showed the high GCV (21.06%), PCV (21.65%) value and also high heritability value (94.60%) with high GAM (42 11%).

Seed yield per plant

The average seed yield per plant was 12.49 g and it showed variability between values of 4.8 g to 26.2 g. This character recorded high GCV (35.73%) and PCV (36.16%) values. The trait showed high heritability value (97.60%) with high GAM (72.69%).

4.1.2.2 Experiment - II (Summer 2005)

Germination percentage

The over all average of the germination percentage was 76.55 and the observed minimum and maximum range was between 16.66 to 100.00. This character showed high GCV (23.43%) and PCV (23.72%) values and high heritability percentage (98.00%) with high value of GAM (47.69%).

Table 4.1.2a: Mean, range and variability parameters for thirteen characters in cowpea genotypes during *kharif* 2004

Sl. No.	Traits	Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
1	Germination percentage	76.35	15.00-99.00	23.45	23.54	99.20	48.12
2	Plant height (cm)	42.39	32.50-57.00	12.24	12.53	95.30	24.60
3	Days to flower initiation	54.80	43.50-76.50	9.12	9.31	95.90	18.39
4	Days to flower termination	71.44	54.50-87.00	7.59	7.81	94.50	15.20
5	Days to physiological maturity	78.80	61.00-95.00	7.54	7.71	95.70	15.19
6	Number of branches per plant	3.88	2.40-5.00	11.29	15.66	52.00	16.75
7	Number of clusters per plant	8.34	3.00-16.50	26.80	28.60	87.80	51.68
8	Number of pods per plant	11.75	3.50-31.50	32.08	32.93	94.90	64.34
9	Pod length (cm)	12.26	8.00-17.00	10.36	14.55	50.70	15.17
10	Seeds per pod	10.54	7.00-14.00	9.86	15.59	40.00	12.81
11	Hundred seed weight (g)	10.85	5.35-22.30	29.37	29.47	99.30	60.28
12	Harvest index	0.19	0.05-0.28	21.06	21.65	94.60	42.11
13	Seed yield per plant (g)	12.49	4.80-26.20	35.73	36.16	97.60	72.69

Plant height

The mean plant height was 43.41 cm with a minimum and maximum value of 32.9 cm and 57.65 cm respectively. It showed moderate GCV (11.59%) and moderate PCV (12.04%) values where as it showed high heritability percentage (93.00%) with high GAM percentage (22.99%).

Days to flower initiation

The over all average of days to flower initiation was 59.75 days with the range of 49.00 days to 78.00 days. Low GCV (7.80%) and PCV (8.12%) values were recorded by the trait, while it showed high heritability (92.00%) with moderate GAM (15.45%).

Days to flower termination

The average for days to flower termination was 72.95 days with the variation of 58.00 days to 87.50 days. It showed low GCV (6.34%) and PCV (6.64%) values, while this trait showed high heritability value (91.00%) with moderate GAM (12.46%).

Days to physiological maturity

The overall average of days to physiological maturity was 75.36 days with the range of 61 days to 95 days. It showed the low GCV (6.09%) and low PCV (6.35%) values, while the character showed the high heritability (92%) with moderate GAM (12.02%).

Number of main branches

The average for number of main branches was 4.43 and the range observed was 3.2 to 6.4. The character showed moderate GCV (11.51%) and moderate PCV (13.85%) values, while it showed high heritability percentage (69.00%) where as the character showed moderate GAM (19.64%) value.

Number of Clusters

The average for the number of clusters per plant was 10.81 with the range of 3.45 to 15.50. This character showed medium GCV (19.53%) while PCV, heritability and GAM values were high, which were 21.03%, 86.00% and 37.37 respectively.

Number of pods per plant

The average for number of pods per plant was 16.02 with the range of 5.65 to 29.65. This character showed high GCV (26.97 %) and PCV (27.88%) values. Also, it showed high heritability (94.90%) with high GAM (53.75 %).

Pod length

The minimum and maximum pod length was 8.06 cm and 18.76 cm respectively with the mean of 14.39 cm. For this character it was observed that moderate GCV (12.52%) and PCV (13.69%) values, while it showed high heritability (84.00%) and GAM (23.63 %) values.

Seeds per pod

This character showed mean value of 12.81 with the range from 6.95 to 16.20. Seeds per pod showed moderate GCV (11.60%) and PCV (13.15%), while it showed high heritability (78.00%) and GAM (21.08%).

Hundred seed weight

The minimum (5.56 g) and maximum (22.67 g)hundred seed weight was observed with the mean value of 11.25 g. This trait showed high GCV (28.00%) and PCV (28.13%) values and it showed the highest heritability value (99.00%) among the tested characters with high GAM (57.42%).

Table 4.1.2b: Mean, range and variability parameters for thirteen characters in cowpea genotypes during summer 2005

Sl. No.	Character	Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
1	Germination percentage	76.55	16.66-100.00	23.43	23.72	98.00	47.69
2	Plant height (cm)	43.41	32.90-57.65	11.59	12.04	93.00	22.99
3	Days to flower initiation	59.75	49.00-78.00	7.80	8.12	92.00	15.45
4	Days to flower termination	72.95	58.00-87.50	6.34	6.64	91.00	12.46
5	Days to physiological maturity	75.36	61.00-95.00	6.09	6.35	92.00	12.02
6	Number of branches per plant	4.43	3.20-6.40	11.51	13.85	69.00	19.64
7	Number of clusters per plant	10.81	3.45-15.50	19.53	21.03	86.00	37.37
8	Number of pods per plant	16.02	5.65-29.65	26.97	27.88	94.00	53.75
9	Pod length (cm)	14.39	8.06-18.76	12.52	13.69	84.00	23.63
10	Seeds per pod	12.81	6.95-16.20	11.60	13.15	78.00	21.08
11	Hundred seed weight (g)	11.25	5.56-22.67	28.00	28.13	99.00	57.42
12	Harvest index	0.22	0.08-0.30	24.45	24.82	97.00	50.00
13	Yield per plant (g)	16.79	6.48-25.80	27.57	28.08	96.00	55.75

Harvest Index

The mean value of harvest index was 0.22 with the variation of minimum and maximum values from 0.08 to 0.30. It showed the high GCV (24.45%), PCV (24.82%) values and also, high heritability value (97.00%) with high GAM (50.00%).

Seed yield per plant

The average seed yield per plant was 16.79 g with the variation of 6.48 g to 25.80 g. This character recorded high GCV (27.57%), PCV (28.08%) and heritability value (96.00%) with high GAM (55.75).

Characterization of germplasm lines for qualitative traits

Germplasm lines were characterized based on the stem colour, plant type, flower colour and immature pod pigmentation. The variations for these characters are presented in Table 4.1.2c. Majority of germplasm lines (98) did not show any special pigmentation and rest of the germplasm showed very slight to solid pigmentation on the stem (Plate 2b). Sixty one germplasm lines showed determinate plant type and rest was intermediate bush type (74) and 34 lines were intermediate spreading but not climbing types (Plate 1). Most of the germplasm lines (145) had mave pink flowers and others were varying in flower colour (Plate 2a). Majority of germplasm (144) did not show special pod pigmentation. Number of germplasm lines with pigmented sutures, splashes of pigment and uniformly pigmented pods were 8,11 and 6 respectively (Plate 3). Plate 4 represents variation for size and colour of seeds in genotypes.

4.2 DISEASE RESISTANCE

Disease incidence is the most important biotic stress in any of the crop, which causes high reduction in the productivity. Screening for disease resistance under field condition would be effective to identify most adaptable variety through any of the breeding programme. Hundred and sixty nine genotypes were screened under field condition for major diseases such as mosaic virus, rust, bacterial blight and powdery mildew during 2004 and 2005.

4.2.1 Experiment – I (*Kharif* 2004)

4.2.1.1 Mosaic Virus

The performance of genotypes against mosaic virus is presented in Table 4.2.1.1 (Plate 5). Among the hundred and sixty-nine genotypes none of the genotypes were recorded immune (Disease scale 1) to mosaic virus under field condition. Ten of them exhibited resistant (Disease scale 1) and five varieties were moderately resistant (Disease scale 3). The highest number of genotypes (114) was highly susceptible (Disease scale 9) and thirty genotypes were susceptible (Disease scale 7).

4.2.1.2 Rust

The performance of cowpea genotypes against rust resistance is presented in Table 4.2.1.2 (Plate 5). Out of 169 seventy six genotypes, 76 were recorded to be resistant (Disease scale 1) to rust under field condition where as only six genotypes were highly susceptible (Disease scale 9). The genotypes moderately resistant (Disease scale 3), moderately susceptible (Disease scale 5) and susceptible (Disease scale 7) were 39, 23, and 25 respectively.

4.2.1.3 Powdery Mildew

Disease scoring results are presented in Table 4.2.1.3 (Plate 5). The powdery mildew severity was ranged from 1-9 disease scale. The highest number of genotypes (75) out of 169 were resistant (Disease scale 1) to powdery mildew under field condition and 37, 25, and 30 genotypes were moderately resistant (Disease scale 3) moderately susceptible (Disease scale 5) and susceptible (Disease scale 7) respectively. While, only two genotypes

Table 4.1.2c: Variation for qualitative characters in cowpea germplasm

No.		Characters	Number of germplasm	Percent of germplasm
1		**Stem colour**		
	A	None	98	57.99
	B	Very slight	23	13.61
	C	Moderate at the base & tips of the petioles	34	15.38
	D	Intermediate	22	13.02
2		**Plant type**		
	A	Determinate	61	36.09
	B	Indeterminate Bush	74	43.79
	C	Indeterminate spreading, not climbing	34	20.12
3		**Flower colour**		
	A	White	15	8.89
	B	Violet	6	3.56
	C	Mave pink	145	85.78
	D	Others	3	1.77
4		**Immature pod pigmentation**		
	A	None	144	85.33
	B	Pigmented sutures	8	4.44
	C	Splashes of pigment	11	6.67
	D	Uniformly pigmented	6	3.56

were highly susceptible (Disease scale 9) and none of them found to be immune (Disease scale 0) to the powdery mildew.

4.2.1.4 Bacterial Blight

Performance of genotypes against bacterial blight is presented in Table 4.2.1.4. Out of 169 genotypes 56 were resistant (Disease scale 1) and 27, 47, and 22 genotypes were moderately resistant (Disease scale 3), moderately susceptible (Disease scale 5) and susceptible (Disease scale 7) respectively. Where as 17 genotypes were highly susceptible (Disease scale 9) and could not observe immune genotypes.

4.2.2 Experiment – II (Summer 2005)

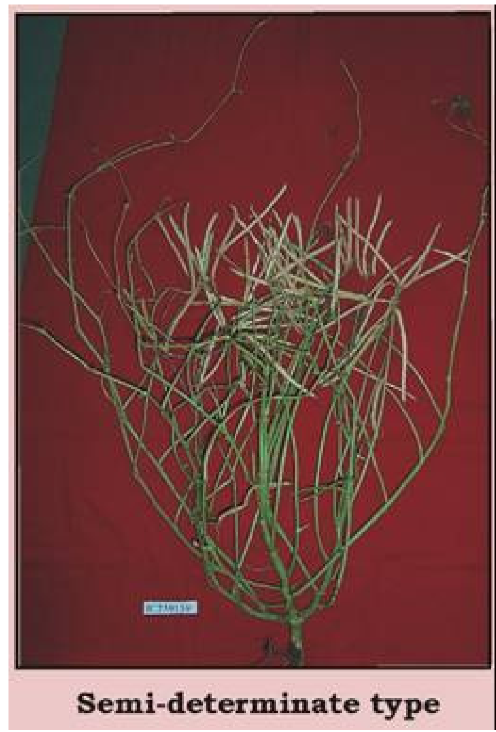
4.2.2.1 Mosaic Virus

The performance of cowpea genotypes against mosaic virus is presented in Table 4.2.2. Variation in the initial appearance of the disease was observed among different genotypes. Out of 169 genotypes screened against mosaic virus, none of them were found to be immune (Disease scale 0) and highly susceptible (Disease scale 9). Eighty four genotypes were found resistant (Disease scale 1) while 78 genotypes found moderately resistant (Disease scale 3) six genotypes were moderately susceptible (Disease scale 5) and only one susceptible (Disease scale 7) genotype was found.

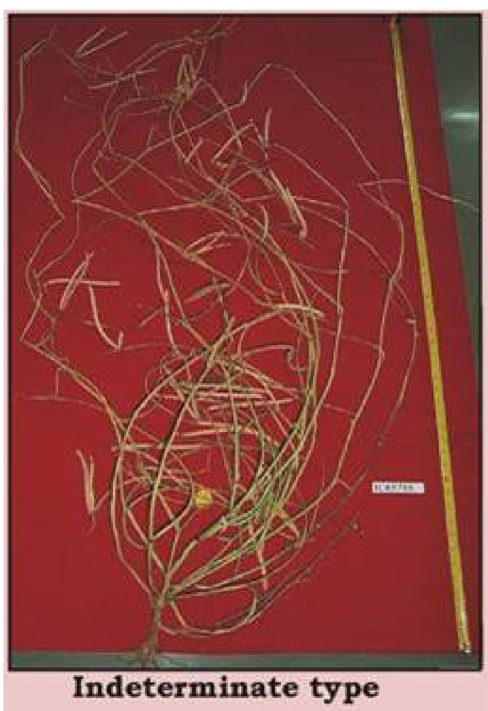
Table 4.2.1.1: Performance of cowpea genotypes against mosaic virus (MV) during *kharif* 2004

Disease reaction	Grade	Number of genotypes	Variety
Immune	0	NIL	
Resistant	1	10	IC198333, IC97834, IC97829, IC97787, IC249583, IC249586, IC259071, IC259084, IC259095, IC97767
Moderately resistant	3	5	IC257407, IC97838, IC215015, IC219141, BAILHONGAL LOCAL
Moderately susceptible	5	10	IC97764, IC257410, IC97856, IC97830, IC208618, IC247435, IC259105, IC259078, IC97830, EC394753
Susceptible	7	30	IC198327, IC202772, IC259159, IC202775, IC202778, IC202781 IC202789, IC202797, IC202854, IC202860, IC202868, IC214834, IC214835, IC247430, IC249137, IC257424, IC257449, IC257453, EC394805, IC259083, IC202782, IC219607, IC257437, IC202779, IC202784, GOA LOCAL, V-118, EC3947, EC394855, GC-3, EC394823
Highly susceptible	9	114	IC198323, IC202730, IC202743, IC202762, IC15567, IC257411, IC198342, IC198359, IC199704, IC201079, IC201099, IC202705, IC202707, IC202709, IC202710, IC202720, IC253275, IC253276, IC253281, IC257406, IC257435, IC257441, IC257445, IC257452, IC259100, IC259105, IC202931, IC202932, C-152, IC97806, IC257420, IC257422, IC198349, IC198355, IC198361, IC199701, IC202718, IC202779, IC202782, IC202786, IC202787, IC202791, IC202799, IC202803, IC202804, IC202809, IC202823, IC202824, IC202835, IC202841, IC202846, IC202867, IC202873, IC202893, IC202901, IC202924, IC202926, IC202927, IC204103, IC206240, IC207813, IC214752, IC214759, IC214833, IC219574, IC219592, IC219594, IC219640, IC219872, IC243312, IC97764, IC243353, IC243486, IC243489, IC243501, IC249132, IC249133, IC249140, IC249141, IC249585, IC249593, IC253181, IC253255, IC253268, IC257447, IC253270, IC253277, IC253288, IC257425, IC257427, IC257445, IC257453, IC259058, IC259061, IC259063, IC259064, IC259069, IC259072, IC259085, IC259104, IC201098, IC4506, IC68786, IC202702, IC5969, EC394745, EC394641, EC394740, IC202778, IC214836, IC202781, IC202797, IC259081

Determinate type



Semi-determinate type



Indeterminate type

Plate 1: Different types of growth habits in cowpea

Plate 2a: Variation for flower colour among genotypes

Plate 2b: Stem pigmentation of cowpea

Plate 3: Variation in pod size and colour

Plate 4: Variation for seed size and colour

Table 4.2.1.2: Performance of cowpea genotypes against rust during *kharif* 2004

Disease reaction	Grade	Number of genotypes	Variety
Immune	0	NIL	
Resistant	1	76	IC257410, IC257411, IC257420, IC257422, IC97767, IC97787, IC97806, IC97830, IC201098, IC5969, IC97834, IC97838, IC91556, IC97764, IC198323, IC198333, IC198335, IC198342, IC198355, IC198361, IC201087, IC201095, IC202787, IC202789, IC201099, IC202791, IC202797, IC202803, IC202804, IC202823, IC202824, IC202835, IC202841, IC202846, IC202854, IC202860, IC202867, IC202868, IC202873, IC202893, IC202901, IC207813, IC219592, IC219640, IC243312, IC243486, IC243489, IC243501, IC247430, IC249583, IC253181, IC253255, IC253275, IC253276, IC253277, IC253281, IC253288, IC257406, IC257407, IC257424, IC257425, IC257435, IC257441, IC257445, IC257452, IC257453, IC259058, IC259064, IC259071, IC259072, IC259073, IC97856, IC202926, IC202927, IC253268, IC253270,
Moderately resistant	3	39	IC198321, IC198349, IC199704, IC201079, IC202720, IC215015, IC219141, IC219574, V-118, GOA LOCAL, IC202782, EC394855, EC394753, IC247435, EC3947, EC394691, IC199701, IC202784, IC259100, IC97764, IC259084, IC202932, IC202762, IC202772, IC214834, IC259081, IC259083, IC202786, IC219594, IC249132, IC249137, IC249586, IC259078, IC202924, IC204103, IC206240, IC198327, IC202709, IC257449
Moderately susceptible	5	23	EC394823, EC394740, IC259095, IC68786, IC259085, IC202702, IC259104, IC259105, IC202809, IC15567, IC198359, IC202710, IC208618, IC214752, IC214759, IC214833, IC249133, IC249140, IC249141, IC249585, IC259069, IC202705, IC202707,
Susceptible	7	25	IC202718, IC202730, IC202743, IC202775, IC249584, IC259061, IC259063, EC394805, EC394745, IC214836, IC202778, GC-3, IC259159, IC202931, IC202779, IC202781, BAILHONGAL LOCAL, IC4506, IC219607
Highly susceptible	9	6	IC202799, C-152, IC214835, IC97829, IC243353, IC259085

Table 4.2.1.3: Performance of cowpea genotypes against powdery mildew (PM) during *kharif* 2004

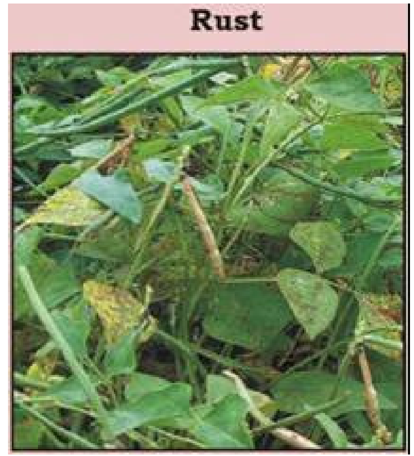
Disease reaction	Grade	Number of genotypes	Variety
Immune	0	NIL	
Resistant	1	75	IC257410, IC257411, IC257420, IC257422, IC97787, IC97806, IC97830, IC97834, IC97838, IC198323, IC198333, IC198335, IC198342, IC198355, IC198361, IC201087, IC201095, IC202787, IC202789, IC201099, IC202791, IC202803, IC202804, IC202823, IC202824, IC202835, IC202841, IC202846, IC202854, IC202860, IC202867, IC202868, IC202873, IC202893, IC202901, IC207813, IC219592, IC219640, IC243312, IC243486, IC243489, IC243501, IC247430, IC249583, IC249594, IC253181, IC253255, IC253275, IC253276, IC253277, IC253281, IC253288, IC257406, IC257407, IC257424, IC257425, IC257427, IC257435, IC257441, IC257445, IC257452, IC257453, IC259058, IC259064, IC259071, IC259072, IC219607, IC202926, IC202927, IC253268, IC253270, IC201098, IC259159, IC259105, IC259095
Moderately resistant	3	37	IC198321, IC198349, IC199704, IC201079, IC202720, IC215015, IC219141, IC219574, IC219594, IC219872, IC249132, IC249137, IC249586, IC259078, IC202924, IC204103, IC206240, IC202709, IC257449, IC98756, IC97767, IC97829, IC202778, IC202782, IC202781, IC202786, GOA LOCAL, GC-3, IC207435, IC202932, IC202931, EC394823, IC202784, EC394805, IC4506, IC202797, IC5969
Moderately susceptible	5	25	IC202809, IC202710, IC208618, IC214752, IC214759, IC214833, IC249133, IC249140, IC249141, IC249585, IC259069, IC257447, IC202707, IC202705, IC259081, IC202707, IC214834, EC394691, EC394740, EC394753, IC259083, IC259100, IC97764, IC259104, IC214834
Susceptible	7	30	IC199701, IC202718, IC202730, IC202743, IC202775, IC249584, IC202779, IC68786, IC214836, EC394745, IC219607, IC259061, IC202709, IC259063, IC249592, IC257437, IC249593, IC202779, IC68786, IC214836, EC294735, IC219607, C-152, V-118, EC394855, BAILHONGAL LOCAL, IC202762, IC243353, IC202772, IC259081, IC259085
Highly susceptible	9	2	IC202799, IC214835

Table 4.2.1.4: Performance of cowpea genotypes against bacterial blight during *kharif* 2004 .

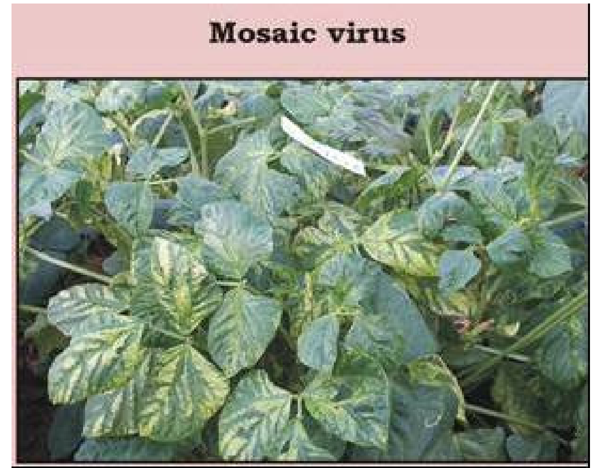
Disease reaction	Grade	Number of genotypes	Variety
Immune	0	NIL	
Resistant	1	56	IC257410, IC257411, IC257420, IC257437, IC257447, IC97767, IC97787, IC97806, IC97830, IC97856, IC91556, IC198321, IC198323, IC198327, IC199704, IC201079, IC201087, IC201095, IC202705, IC202707, IC202762, IC202772, IC202775, IC202781, IC202787, IC202789, IC202799, IC202803, IC202804, IC202809, IC202823, IC202824, IC202846, IC202860, IC202873, IC198342, IC198333, IC259100, IC259104, IC201098, IC4506, IC5969, IC68786, IC247435, IC202932, IC219872, IC97764, IC202791, IC204103, IC207813, IC219594, IC249593, IC253281, IC253288, IC259072, IC259078
Moderately resistant	3	27	IC257422, IC97834, IC97838, IC97764, IC198361, IC201099, EC394805, IC202797, C-152, IC243501, IC247430, IC249132, IC249133, IC249137, IC219592, IC202778, V-118, IC243312, IC202782, IC257453, IC259061, IC259058, IC259063, IC214836, IC219607, IC68786, IC 257437
Moderately susceptible	5	47	IC202743, IC198359, IC15567, IC198349, IC198355, IC199701, IC202709, IC202710, IC202718, IC202720, IC202730, IC202835, IC 97764, IC202841, IC202854, IC202868, IC202893, IC202901, EC394823, EC394740, EC394753, EC3947, IC257449, IC257452, IC259064, IC259069, IC259071, IC257445, IC259105, IC259159, IC259084, IC259083, IC253277, IC249140, IC243489, IC243486, IC202926, IC202927, IC206240, IC215015, IC253181, IC253270, IC253255, IC202702, IC253268, IC215015, IC219640
Susceptible	7	22	IC202867, EC394855, EC394745, GC-3, IC259085, GOA LOCAL, BAILHONGAL LOCAL, IC257435, IC198335, IC257427, IC208618, IC257441, IC214752, IC202784, IC214759, IC202781, IC214833, IC202786, IC219141, IC257447, IC97829, IC253275
Highly susceptible	9	17	IC202924, IC214834, IC214835, IC257425, IC219574, IC257406, IC249141, IC249583, IC257407, IC249585, IC257424, IC249586, IC253276, IC202931, IC243353, IC259081, IC202779

Powdery mildew

Rust



Mosaic Virus



Susceptible plants

Resistant plants

Plate 5: Major diseases observed in different cowpea genotypes

4.3 CHARACTER ASSOCIATION

The ultimate objective in any of the crop improvement programme is to increase the yield, which is the interaction and contribution of many of other quantitative and qualitative traits. Understanding of association of these characters with yield is worthy to increase the fruitfulness of the any of breeding programme.

The analysis of phenotypic correlation of yield and yield components were worked using data generated from 169 genotypes raised during *kharif* 2004 and Summer 2005, which are presented in Table 4.3.1 and 4.3.2.

4.3.1 Experiment- I (*Kharif* 2004)

4.3.1.1 Association analysis for over all hundred and sixty nine genotypes

Character association among yield and yield contributing characters recorded during *Kharif* 2004 are presented in the Table 4.3.1.

Seed yield with yield components

The seed yield per plant was associated positively and significantly with plant height, number of clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight and harvest index. Among them the highest positive correlation value showed by harvest index. Days to flower initiation and number of branches per plant showed positive correlation but non significant. Germination percentage, days to flower termination and days to physiological maturity negatively correlated with seed yield but they were not significant.

Association among the yield components

Germination percentage was positively correlated with plant height, seeds per pod and harvest index. The highest positive correlation showed with plant height. Plant height positively correlated with all characters, among these characters pod length, seeds per pod and hundred seed weight positively and significantly associated.

Days to flower initiation showed highly significant association showed with days to flower termination and days to physiological maturity where as negative association was with harvest index. Days to flower termination and days to physiological maturity recorded a significant and positive association with seeds per pod and showed negative association with number of branches per plant while days to flower termination showed highly significant positive association with days to physiological maturity.

Number of branches per plant showed positive and significant association with number of clusters per plant and number of pods per plant while pod length had negative association. Number of clusters per plant showed positive and significant association with number of pods per plant, pod length, seeds per pod and harvest index, while hundred seed weight was negatively associated. Number of pods per plant had highly significant association with pod length, seeds per pod, harvest index, where as hundred seed weight showed negative association.

Seeds per pod, hundred seed weight and harvest index showed positive significant association with pod length. Seeds per pod showed highly significant positive association with harvest index and also, hundred seed weight showed positive but non-significant correlation. Hundred seed weight positively correlated with harvest index.

4.3.2 Experiment – II (Summer 2005)

Character association studies among yield and yield component characters recorded during Summer 2005 are presented in the Table 4.3.2.

Table 4.2.2: Performance of cowpea genotypes against mosaic virus (MV) during summer 2005

Disease reaction	Grade	Number of genotypes	Variety
Immune	0	NIL	
Resistant	1	84	IC257411, IC257420, IC257422, IC97767, IC97787, IC97806, IC97829, GC-3 IC97830, IC97834, IC97838, IC97856, IC15567, IC198321, IC198323, IC198327, IC198333, IC198335, IC198342, IC198355, IC201087, IC202705, IC202718, IC202730,IC202743, IC202762, IC202775, IC202778, IC202779, IC202781, IC202786, IC202787, IC202789, IC202791, IC202792, IC202799, IC202803, IC202804, IC202809, IC202823, IC202841, IC202846, IC202854, IC202868, IC202873, IC202893, IC202901, IC202924, IC202926, IC204103, IC206240, IC207813, IC208618, IC214759, IC214834, IC214835, IC214836, IC215015, IC243486, IC243501, IC249133, IC249137, IC249140, IC249585, IC249593, IC253181, IC253275,IC253276, IC253281,IC257452, IC259081, IC259083, IC259095, IC259100, IC259105, IC259159, IC202784, IC202931, IC202932,GOA LOCAL, BAILAHONGAL LOCAL, V-118, EC394823,EC394805,
Moderately resistant	3	78	IC257410, IC91556, IC97764, IC198349, IC199704, IC201079, IC201095, IC201099, IC202707, IC202709, IC202710, IC 202797, IC202772, IC202782, IC202824, IC202835, IC202860, IC202867, IC202927, IC214752, IC214833, IC219141, IC219574, IC219592, IC219594, IC219607, IC219640, IC219872, IC243312, IC243353, IC243472, IC243489, IC247430, IC249132, IC97764, IC257437, IC257447, IC249141, IC249583, IC249586,IC253255, IC253268, IC253270, IC253277,IC253288,IC257406,IC257407,IC257424,IC257425, IC257427,IC257435,IC257441,IC257445,IC257449, IC257453, IC259058, IC259061, IC259063 ,IC259064, IC259069, IC259071, IC259072, IC259078, IC259084, IC259085, IC201098, IC4506, IC5969, IC68786, IC202702, IC247435, C-152, EC3947, EC394691, EC394740, EC394855, EC394753, EC394745
Moderately susceptible	5	6	IC198359, IC198361, IC198349, IC257441, IC199701, IC259104
Susceptible	7	1	IC202720
Highly susceptible	9		

Table 4.3.1: Phenotypic correlation among yield and yield attributing characters in cowpea genotypes during *kharif* 2004

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	**1.000**	0.136	-0.034	-0.017	-0.087	-0.032	-0.015	-0.063	-0.030	0.050	-0.052	0.021	-0.026
X2		**1.000**	0.108	0.095	0.038	0.072	0.116	0.146	0.163*	0.182*	0.168*	0.117	0.250**
X3			**1.000**	0.601**	0.535**	0.005	0.045	0.073	0.093	0.093	0.080	-0.007	0.036
X4				**1.000**	0.88**	-0.136	0.031	0.061	0.107	0.191*	0.024	0.016	-0.019
X5					**1.000**	-0.105	0.022	0.059	0.131	0.197*	-0.012	0.024	-0.037
X6						**1.000**	0.325**	0.164*	-0.038	0.014	0.017	0.129	0.140
X7							**1.000**	0.641**	0.171*	0.234*	-0.025	0.467**	0.562**
X8								**1.000**	0.242**	0.256**	-0.121	0.493**	0.656**
X9									**1.000**	0.635**	0.290**	0.229**	0.312**
X10										**1.000**	0.083	0.232**	0.310**
X11											**1.000**	0.095	0.224**
X12												**1.000**	0.808**
X13													**1.000**

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

* - Significant at 5% level probability
** - Significant at 1% level probability

Associations between yield and yield components

A significant positive association for the harvest index, hundred seed weight, number of pods per plant, clusters per plant and days to flower initiation with seed yield per plant was observed. A positive but non significant association was recorded for seed per pod, pod length, number of branch per plant, days to physiological maturity, days to flower termination with seed yield per plant where as germination percentage and plant height negatively associated with seed yield per plant which were non significant.

Association among the yield components

Germination percentage was positively associated with plant height, number of clusters per plant, pod length and seeds per pod but none of them were significant. Where as days to flower initiation, days to flower termination, days to physiological maturity, number of branches per plant, number of pods per plant, hundred seed weight and harvest index showed negative association with germination percentage.

A significant positive correlation was recorded for number of branches per plant, pod length and seeds per pod with plant height and number of clusters per plant, number of pods per plant showed positive association but non significant, while days to flower initiation, days to flower termination, days to physiological maturity, hundred seed weight and harvest index showed negative association.

Days to flower termination and days to physiological maturity showed positive and highly significant association with days to flower initiation. Also, the number of clusters per plant, number of pods per plant, pod length, seeds per pod and harvest index showed positive association, which were not significant where as number of branches per plant and hundred seed weight showed negative association.

Days to physiological maturity showed a highly significant positive association showed with days flower initiation. Number of clusters per plant, number of pods per plant, pod length, seeds per pod and harvest index were positively associated with this trait but not significant. However, number of branches per plant and hundred seed weight were negatively correlated.

Number of clusters per plant, pods per plant, pod length, seeds per pod and harvest index recorded positive association with days to physiological maturity, while other characters such as number of branches per plant and hundred seed weight showed negative correlation, which were not significant.

Number of clusters recorded a significant positive association with number of branches per plant and the number of pods per plant, hundred seed weight, harvest index showed positive association but they were not significant where as pod length and seeds per pod showed negative association.

Number of pods per plant and harvest index recorded significantly high positive association with number of clusters per plant and also pod length and seeds per pod showed positive association where as hundred seed weight showed negative association.

Harvest index showed highly significant, positive correlation with number of pods per plant where as hundred seed weight showed negative non-significant association. Seeds per pod, hundred seed weight recorded positive and significant association with pod length and harvest index showed positive and non-significant association. A significant and positive association showed hundred seed weight with seeds per pod and harvest index recorded highly significant and positive association with hundred seed weight.

4.3.2 Genotypic association

4.3.2.1 Experiment –I (*Kharif* 2004)

Genotypic association among yield and yield contributing characters recorded during *Kharif* 2004 and Summer 2005 are presented in the Tables 4.3.2a and 4.3.2b respectively.

Association between seed yield and yield components

A highly significant positive association was observed for plant height, branches per plant, number of clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight and harvest index with the seed yield per plant. Days to flower initiation showed positive association, where as germination percentage, days to flower termination and days to physiological maturity negatively associated to the yield per plant.

Association among the yield components

Germination percentage did not show significant association with all the other characters. Pod length, seeds per pod and hundred seed weight recorded significant positive association with plant height and all other characters associated positively but not significant.

Days to flower termination and days to physiological maturity showed highly significant positive correlation with the days to flower initiation. Other characters except harvest index showed positive correlation, which was not significant.

Days to physiological maturity and seeds per pod showed positive and significant association with days to flower termination. Number of clusters per plant, number of pods per plant, pod length, hundred seed weight and harvest index showed positive association, where as number of branches per plant showed negative association.

A positive significant association recorded for pod length and seeds per pod with physiological maturity, while positive but not significant association was observed with number of cluster per plant, number of pods per plant and harvest index, where as number of branches per plant and hundred seed weight showed negative association.

Number of clusters per plant, number of pods per plant and harvest index were positively associated with number of branches per plant, while pod length and seeds per pod correlated negatively. Number of pods per plant, pod length, seeds per pod and harvest index showed significant association with the number of clusters per plant, where as hundred seed weight was the only character showed negative association. Except hundred seed weight, pod length, seeds per pod and harvest index showed highly significant positive correlation with number of pods per plant. Seeds per pod, hundred seed weight and harvest index recorded highly significant positive association with the pod length. Harvest index showed a significant positive correlation with seeds per pod and it was positively associated with hundred seed weight but not significant.

4.3.2.2 Experiment – II (Summer 2005)

Association between seed yield and yield components

Highly significant and positive association recorded between number of clusters per plant, number of pods per plant, hundred seed weight and harvest index with seed yield per plant. Also pod length, seeds per pod, days to flower initiation, days to flower termination, days to physiological maturity and number of branches per plant showed positive association, which was not significant, where as the germination percentage and plant height showed negative correlation with the seed yield.

Association among the yield and yield components

Plant height, clusters per plant and seeds per pod showed positive association with germination percentage, while all other characters showed negative association but non significant.

Number of branches per plant was associated positively and significantly with plant height. Number of clusters per plant, pod length and seeds per pod showed positive association. Days to flower termination and days to physiological maturity were associated significantly with days to flower initiation. Number of clusters per plant, number pods per plant and harvest index showed positive association but they were not significant. Days to physiological maturity reported highly significant positive association with days to flower termination where as number of branches per plant, pod length, seeds per pod, hundred seed weight showed negative association which were not significant.

Table 4.3.2: Phenotypic correlation among yield and yield attributing characters in cowpea genotypes during summer 2005

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	**1.000**	0.099	-0.051	-0.075	-0.08	-0.022	0.013	-0.044	0.026	0.049	-0.235	-0.093	-0.082
X2		**1.000**	-0.095	-0.117	-0.112	0.197*	0.039	0.017	0.176*	0.165*	-0.049	-0.058	-0.029
X3			**1.000**	0.913**	0.897**	-0.034	0.110	0.112	0.028	0.027	-0.002	0.147	0.157*
X4				**1.000**	0.977**	-0.030	0.070	0.072	0.057	0.064	-0.031	0.128	0.121
X5					**1.000**	-0.041	0.045	0.047	0.048	0.056	-0.039	0.121	0.120
X6						**1.000**	0.184*	0.147	-0.048	-0.032	0.015	0.088	0.088
X7							**1.000**	0.631**	0.063	0.069	-0.018	0.294**	0.359**
X8								**1.000**	0.105	0.117	-0.013	0.365**	0.425**
X9									**1.000**	0.914**	0.188*	0.021	0.141
X10										**1.000**	0.158*	0.004	0.112
X11											**1.000**	0.274**	0.314**
X12												**1.000**	0.895**
X13													**1.000**

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

Table 4.3.2a: Genotypic correlation among yield and yield attributing characters in cowpea genotypes during *kharif* 2004

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	**1.000**	0.140	-0.033	-0.014	-0.088	-0.058	-0.013	-0.061	-0.024	0.094	-0.052	0.022	-0.026
X2		**1.000**	0.111	0.101	0.040	0.104	0.118	0.150	0.235**	0.284**	0.173*	0.123	0.261**
X3			**1.000**	0.600**	0.529**	0.024	0.039	0.069	0.119	0.130	0.082	-0.008	0.037
X4				**1.000**	0.891**	-0.173	0.037	0.060	0.137	0.285**	0.026	0.019	-0.019
X5					**1.000**	-0.131	0.025	0.056	0.165*	0.292**	-0.012	0.030	-0.035
X6						**1.000**	0.426**	0.232**	-0.044	-0.044	0.017	0.194*	0.207**
X7							**1.000**	0.666**	0.187*	0.320**	-0.024	0.510**	0.610**
X8								**1.000**	0.304**	0.363**	-0.122	0.526**	0.689**
X9									**1.000**	0.676**	0.407**	0.317**	0.442**
X10										**1.000**	0.141	0.392**	0.517**
X11											**1.000**	0.092	0.222**
X12												**1.000**	0.809**
X13													**1.000**

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

* - Significant at 5% level probability
** - Significant at 1% level probability

Table 4.3.2b: Genotypic correlation among yield and yield attributing characters incowpea genotypes during summer 2005

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	**1.000**	0.076	-0.081	-0.111	-0.116	-0.039	0.005	-0.070	-0.006	0.012	-0.244	-0.101	-0.100
X2		**1.000**	-0.165	-0.197	-0.186	0.228**	0.019	-0.040	0.119	0.094	-0.063	-0.076	-0.065
X3			**1.000**	0.918**	0.903**	-0.050	0.104	0.061	-0.040	-0.061	-0.015	0.139	0.129
X4				**1.000**	0.990**	-0.054	0.058	0.014	-0.019	-0.029	-0.045	0.116	0.090
X5					**1.000**	-0.074	0.033	-0.011	-0.026	-0.036	-0.053	0.113	0.090
X6						**1.000**	0.230**	0.174*	-0.084	-0.055	0.018	0.092	0.093
X7							**1.000**	0.679**	0.030	0.057	-0.021	0.316**	0.383**
X8								**1.000**	0.044	0.048	-0.023	0.370**	0.414**
X9									**1.000**	0.940**	0.193*	0.004	0.110
X10										**1.000**	0.159*	-0.017	0.073
X11											**1.000**	0.277**	0.314**
X12												**1.000**	0.902**
X13													**1.000**

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

* - Significant at 5% level probability
** - Significant at 1% level probability

Number of clusters per plant and number of pods per plant recorded positive significant association with number of branches per plant, while pod length and seeds per pod showed negative association. Number of pods per plant and harvest index were associated positively and significantly with the number of clusters per plant, while hundred seed weight showed negative association.

Harvest index showed highly significant positive association with number of pods per plant, while pod length showed non-significant positive association. A significant positive association was observed for seeds per pod and hundred seed weight with the pod length. Hundred seed weight showed positive and significant association with seeds per pod, while harvest index showed negative association. Harvest index showed highly significant association with hundred seed weight.

4.4 PATH COEFFICIENT ANALYSIS

Grain yield of any crop plant has been associated with a number of component characters and these characters themselves are inter related. Every component character will have a direct and indirect effect on yield. Path coefficient analysis offered a much more realistic interpretation of the factors involved. The use of this technique requires a cause and effect situation among the variables. Based on these effects exerted by characters on the yield one can consider that particular character for improvement of the crop

4.4.1 Phenotypic path analysis

4.4.1.1 Experiment – I (*Kharif* 2004)

The direct and indirect effects of various traits on seed yield per plant among genotypes are presented in Table 4.4.1.1.

Direct effects

Among the eleven characters, seven characters showed positive direct effects on the seed yield per plant. Harvest index recorded the highest direct effect on seed yield per plant and followed by number of pods per plant, seeds per pod and hundred seed weight. Although the plant height and days to flower initiation recorded positive direct effects at the values were low. Germination percentage, days to flower termination, days to physiological maturity and pod length showed negative direct effect on the seed yield per plant.

Indirect effects

It was found that indirect effects of germination percentage through all the characters were low to the seed yield per plant. Because there was a negative association was observed with seed yield per plant. Although the plant height recorded low direct effects but most of the characters such as harvest index, seeds per pod, number of pods per plant, hundred seed weight, clusters per plant and days to flower initiation recorded positive indirect effects with the seed yield per plant.

The highest indirect effect of days to flower initiation was contributed via seeds per pod. The negative indirect effect through days to physiological maturity was larger than the positive indirect effects. Because this character showed low association with the seed yield per plant. Even though the direct effect of days to flower termination was negative it showed positive indirect effects through other characters except days to physiological maturity and pod length. The highest indirect effect of days to flower termination was observed through seeds per pod. The indirect effect of days to physiological maturity through most of the traits was low because this character showed negative association with seed yield. It showed high indirect effects via seeds per pod. The pattern of contributive characters for indirect effects of number of clusters per plant and number of pods per plant to the seed yield was same. The highest indirect effects of these two characters were through harvest index and followed by seeds per pod. Because these traits had significantly higher positive association with the seed yield. Although the direct effect was negative but the highest indirect effect of the pod length observed through the harvest index followed by seeds per pod. The negative indirect effects of pod length recorded through days to flower termination and days to physiological maturity. Seeds per pod recorded higher direct effect and the highest indirect effects observed through harvest index. Even though the hundred seed weight had high association with seed yield but indirect effects of the trait were comparatively low. Indirect effects of harvest index through all the characters except pods per plant were negligible. Harvest index recorded the highest direct effect and the highest indirect effect through number of pods per plant and this trait recorded positive significant association with the yield.

Table 4.4.1.1: Phenotypic path coefficient analysis for yield in cowpea genotypes *(kharif* 2004)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	r
X1	**-0.048**	0.011	-0.001	0.001	0.009	-0.001	-0.020	0.001	0.018	-0.010	0.011	-0.026
X2	-0.007	**0.007**	0.008	-0.007	-0.004	0.011	0.048	-0.012	0.056	0.033	0.064	0.250
X3	0.002	0.008	**0.068**	-0.040	-0.057	0.004	0.022	-0.006	0.025	0.015	-0.004	0.036
X4	0.001	0.008	0.041	**-0.066**	-0.096	0.003	0.019	-0.007	0.056	0.005	0.010	-0.019
X5	0.004	0.003	0.036	-0.059	**-0.107**	0.002	0.018	-0.008	0.057	-0.002	0.015	-0.037
X6	0.001	0.009	0.003	-0.009	-0.053	**0.094**	0.214	-0.009	0.053	-0.005	0.264	0.562
X7	0.003	0.011	0.005	-0.004	-0.006	0.063	**0.321**	-0.015	0.071	-0.023	0.273	0.656
X8	0.001	0.018	0.008	-0.039	-0.018	0.018	0.028	**-0.049**	0.132	0.077	0.164	0.312
X9	-0.004	0.022	0.009	-0.019	-0.031	0.030	0.116	-0.033	**0.196**	0.026	0.203	0.310
X10	0.003	0.013	0.006	-0.002	0.001	-0.002	-0.039	-0.020	0.028	**0.188**	0.048	0.224
X11	-0.001	0.009	-0.001	-0.001	-0.003	0.048	0.169	-0.016	0.067	0.017	**0.518**	0.808

Residual = 0.1919

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of clusters per plant
X7 = Number of pods per plant
X8 = Pod length
X9 = Seeds per pod
X10 = Hundred seed weight
X11 = Harvest index
r= Phenotypic correlation with seed yield

4.4.1.2 Experiment –II (Summer 2005)

The direct and indirect effects of various traits on seed yield per plant among genotypes are presented in Table 4.4.1.2.

Direct effects

Out of eleven, eight characters recorded positive direct effects with the seed yield per plant. The highest positive direct effect to the yield recorded by the harvest index followed by days to physiological maturity. The highest negative direct effect recorded from days to flower termination.

Indirect effects

The indirect effects of both germination percentage and plant height through all the characters were negligible and also most of the characters showed indirect negative effect. Because the association of both characters were negative with the seed yield. The highest indirect effect of the days to flower initiation was through the days to physiological maturity followed by harvest index. Even though the days to flower termination recorded negative direct effect to the seed yield per plant its indirect effects were more and positive through the days physiological maturity and harvest index. However, the direct effects of the days to physiological maturity was positive, this trait showed higher negative indirect effects through days to flower termination and indirect effects through other characters also negligible.

Since both number of clusters per plant and number of pods per plant recorded highly significant association with the seed yield per plant, their indirect effect through harvest index was more and the indirect effects through other characters were almost same. The Indirect effects of pod length and seeds per pod recorded through all the characters were same and comparatively low. Despite the higher association of hundred seed weight with seed yield the direct effect was not much higher, but the high indirect effect through harvest index was recorded. The highest direct effect to the seed yield was recorded from the harvest index and also it showed highest association value with the seed yield.

4.4.2 Genotypic path analysis

4.4.2.1 Experiment –I (Kharif 2004)

The direct and indirect effect of various traits on seed yield per plant among genotypes are presented in Table 4.4.2.1

Direct effects

Out of total eleven characters which subjected to path analysis, seven characters showed positive direct effects viz., plant height, days to flower initiation, number of clusters per plant, number of pods per plant, seeds per pod, hundred seed weight and harvest index. The negative direct effects were observed from germination percentage, days to flower termination, days to physiological maturity and pod length. The negative effects were not much higher. The maximum positive direct effect was recorded from the harvest index followed by number of pods per plant.

Indirect effects

Indirect effects of germination percentage through the characters were not considerable to the yield per plant. Because, its direct effects and association with seed yield also showed negative values. Highest indirect effects of plant height could be observed through harvest index followed by seeds per pod. The association with seed yield of this trait was also positive and significant. Indirect effects of days to flower initiation did not influenced to the seed yield per plant considerably.

Indirect effects of days to flower termination and days to physiological maturity through all the characters were almost same. Both characters showed highest positive indirect effects through seeds per pod, followed by days to flower initiation. Number of clusters per plant and number of pods per plant showed higher positive association with seed yield. The highest indirect effect of these two characters was observed through the harvest index.

Even though pod length showed negative direct effects but its association with seed yield was significantly high and positive. The high positive indirect effect of pod length was observed through harvest index followed by seeds per pod.

Table 4.4.1.2: Phenotypic path coefficient analysis for yield in cowpea genotypes (summer 2005)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	R
X1	**0.013**	0.000	-0.004	0.020	-0.016	0.001	-0.003	0.003	-0.001	-0.017	-0.076	-0.082
X2	0.001	**-0.001**	-0.008	0.031	-0.022	0.002	0.001	0.023	-0.005	-0.004	-0.048	-0.029
X3	-0.001	0.000	**0.083**	-0.241	0.176	0.007	0.008	0.004	-0.001	0.000	0.121	0.157
X4	-0.001	0.000	0.076	**-0.264**	0.191	0.004	0.005	0.007	-0.002	-0.002	0.106	0.121
X5	-0.001	0.000	0.075	-0.258	**0.196**	0.003	0.004	0.006	-0.002	-0.003	0.100	0.120
X6	0.000	0.000	0.009	-0.018	0.004	**0.064**	0.048	0.008	-0.002	-0.001	0.243	0.359
X7	-0.001	0.000	0.009	-0.019	0.009	0.041	**0.076**	0.013	-0.004	-0.001	0.301	0.425
X8	0.000	0.000	0.002	-0.015	0.009	0.004	0.008	**0.129**	-0.028	0.014	0.018	0.141
X9	0.001	0.000	0.002	-0.017	0.011	0.004	0.009	0.118	**-0.031**	0.012	0.004	0.112
X10	-0.003	0.000	0.000	0.008	-0.008	-0.001	-0.001	0.024	-0.005	**0.074**	0.226	0.314
X11	-0.001	0.000	0.012	-0.034	0.024	0.019	0.028	0.003	0.000	0.020	**0.825**	0.895

Residual = 0.1648

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of clusters per plant
X7 = Number of pods per plant
X8 = Pod length
X9 = Seeds per pod
X10 = Hundred seed weight
X11 = Harvest index
r= phenotypic correlation

Table 4.4.2.1: Genotypic path coefficient analysis for yield in cowpea genotypes *(kharif* 2004)

	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**r**
X1	**-0.048**	0.011	-0.002	0.001	0.009	-0.001	-0.020	0.001	0.018	-0.010	0.011	-0.026
X2	-0.007	**0.077**	0.008	-0.007	-0.004	0.011	0.048	-0.012	0.051	0.033	0.064	0.261
X3	0.002	0.008	**0.068**	-0.040	-0.057	0.004	0.022	-0.006	0.025	0.015	-0.004	0.037
X4	0.001	0.008	0.041	**-0.066**	-0.089	0.003	0.019	-0.007	0.056	0.005	0.010	-0.019
X5	0.004	0.003	0.036	-0.049	**-0.107**	0.002	0.018	-0.009	0.057	-0.005	0.015	-0.035
X6	0.001	0.009	0.003	-0.002	-0.008	**0.094**	0.214	-0.009	0.053	-0.009	0.264	0.610
X7	0.003	0.011	0.005	-0.004	-0.006	0.063	**0.321**	-0.015	0.071	-0.023	0.273	0.689
X8	0.001	0.018	0.008	-0.009	-0.018	0.018	0.098	**-0.049**	0.132	0.077	0.164	0.442
X9	-0.004	0.022	0.009	-0.019	-0.031	0.030	0.116	-0.033	**0.196**	0.028	0.203	0.517
X10	0.003	0.013	0.006	-0.002	0.001	-0.002	-0.039	-0.020	0.028	**0.188**	0.048	0.222
X11	-0.001	0.009	-0.001	-0.001	-0.003	0.048	0.169	-0.016	0.068	0.019	**0.518**	0.809

Residual = 0.1607

×1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of clusters per plant
×7 = Number of pods per plant
X8 = Pod length
X9 = Seeds per pod
X10 = Hundred seed weight
X11 = Harvest index
r= Genotypic correlation with seed yield

The association of seeds per pod with seed yield per plant was significant and positive. The positive indirect effects of seeds per pod through harvest index were higher than its direct effects. Indirect effects of the hundred seed weight were not much high through any of the character. But it showed high positive direct effects and positive significant association with seed yield per plant.

Highest direct effect recorded by the harvest index, because of its significant highest association with seed yield. The highest positive indirect effects of harvest index were observed through number of pods per plant.

4.4.2.2 Experiment – II (Summer 2005)

The direct and indirect effects of various traits on seed yield per plant among genotypes are presented in Table 4.4.2.2.

Direct effects

Out of eleven characters subjected to path coefficient analysis eight characters (germination percentage, days to flower initiation, days to physiological maturity, number of clusters per plant, number of pods per plant, pod length, hundred seed weight and harvest index) showed positive direct effects to the seed yield per plant. The negative direct effects recorded by plant height, days to flower termination and seeds per pod. Highest positive direct effects expressed by harvest index followed by days to physiological maturity, while maximum negative effect was observed from days to flower termination.

Indirect effects

Indirect effects of the germination percentage and plant height were not much higher through any of the character. Among them, the highest positive indirect effects of these two characters to the seed yield expressed through days to flower termination and the maximum negative indirect effects through harvest index. Because, these two traits showed negative association with seed yield.

Even though the days to flower initiation showed positive direct effect and positive association with seed yield, the highest indirect effect was observed through days to physiological maturity than its direct effects. It showed high negative indirect effect through days to flower termination. Days to flower termination expressed its highest positive indirect effects through days to physiological maturity, followed by harvest index. The negative indirect values were not considerably high. Negative indirect effect expressed through days to flower termination was higher than its direct effects. Number of clusters per plant and number of pods per plant showed their highest indirect effects through harvest index because both of these traits showed high positive and significant association with seed yield per plant. The positive indirect effects of the pod length were negligible to the seed yield while it showed high direct effect. The maximum negative indirect effect was observed through seeds per pod.

The highest positive indirect effect of seeds per pod was observed through the pod length and it was higher than its direct effect. Harvest index showed the highest indirect effect of the hundred seed weight because the trait showed positive significant association with seed yield. The highest direct effect recorded from the harvest index because of its positive significant association with seed yield. The indirect effects of harvest index through any character were not considerably high.

4.5 GENOTYPE AND ENVIRONMENT EFFECTS

Genotype and season (environment) interaction results are given in Table 4.5. Highly significant variation was present among the genotypes and the significant variation was present among the environments except in germination percentage, which was not significant at any level. The genotype and season interaction exhibited high significance for all the characters except number of branches per plant, which suggests that genotypes interacted considerably with the season in the expression of the characters and behaved differently under varying environment. However, the magnitude of genotype and season interaction was smaller in most of the characters as compared to the variance due to genotype and environment separately. Number of branches per plant was the only character showed non-significant genotype and environment interaction.

Table 4.4.2.2: Genotypic path coefficient analysis yield in cowpea genotypes (summer 2005)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	r
X1	**0.006**	-0.002	-0.007	0.052	-0.044	0.000	-0.003	-0.001	-0.001	-0.016	-0.084	-0.100
X2	0.000	**-0.022**	-0.012	0.092	-0.070	0.002	-0.002	0.025	-0.011	-0.004	-0.063	-0.065
X3	0.000	0.004	**0.090**	-0.430	0.340	0.010	0.002	-0.008	0.007	-0.001	0.115	0.129
X4	-0.001	0.004	0.083	**-0.469**	0.373	0.006	0.001	-0.004	0.003	-0.003	0.096	0.090
X5	-0.001	0.004	0.081	-0.464	**0.377**	0.003	0.000	-0.005	0.004	-0.003	0.094	0.090
X6	0.000	0.000	0.009	-0.027	0.012	**0.099**	0.028	0.006	-0.007	-0.001	0.262	0.383
X7	0.000	0.001	0.005	-0.007	-0.004	0.067	**0.041**	0.009	-0.006	-0.001	0.307	0.414
X8	0.000	-0.003	-0.004	0.009	-0.010	0.003	0.002	**0.208**	-0.112	0.013	0.003	0.110
X9	0.000	-0.002	-0.005	0.014	-0.014	0.006	0.002	0.196	**-0.119**	0.010	-0.014	0.073
X10	-0.001	0.001	-0.001	0.021	-0.020	-0.002	-0.001	0.040	-0.019	**0.066**	0.230	0.314
X11	-0.001	0.002	0.013	-0.054	0.043	0.031	0.015	0.001	0.002	0.018	**0.832**	0.902

Residual = 0.1554

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of clusters per plant
X7 = Number of pods per plant
X8 = Pod length
X9 = Seeds per pod
X10 = Hundred seed weight
X11 = Harvest index
r=Genotypic correlation

Table 4.5: Analysis of variance (mean square) for seed yield per plant and yield contributing characters in cowpea

Source	d.f.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
Genotype (G)	168	795.24**	49.06**	59.88**	67.39**	72.05**	1.02**	15.61**	44.87**	6.93**	5.04**	39.67**	0.0057**	55.54**
Environment (E)	1	6.44	175.95**	4135.48**	381.75**	2004.28**	50.87**	1034.37**	3088.07**	769.12**	869.27**	26.76**	0.178**	3120.26**
G x E	168	96.01**	58.69**	36.35**	37.97**	44.01**	0.18	4.69**	22.90**	5.00**	3.79**	0.64**	0.0034**	28.41**
Error	338	5.21	1.78	1.5	1.94	1.78	0.16	0.78	1.11	1.11	1.13	0.083	0.000083	0.652

XI = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10= Seeds per pod
X11= Hundred seed weight
X12= Harvest index
X13= Seed yield per plant

4.6 GENETIC DIVERSITY ANALYSIS

Estimation of degree of divergence between biological population and computation of relevant contribution of different components to the total divergence is done completely by Mahalanobis's generalized distance estimated by D^2 statistic. During a hybridization programme, selection of parents by Mahalanobis D^2 statistic provide the required potential parents, which are under study with respect to a mass of characters. Selection of genotypes based on genetic distance and yield potential one can decide the crossing programme.

4.6.1 Experiment - I (*Kharif* 2004)

Table 4.6.1: Relative contribution of different traits of cowpea genotypes towards divergence in *kharif* 2004

Source	Traits	Times ranked first	% contribution
1	Germination percentage	208	1.47
2	Plant height	2006	14.13
3	Days to flower initiation	165	1.16
4	Days to flower termination	1999	14.08
5	Days to physiological maturity	191	1.35
6	Number of branches per plant	1967	13.86
7	Number of clusters per plant	127	0.89
8	Number of pods per plant	2127	14.98
9	Pod length	247	1.74
10	Seeds per pod	1802	12.69
11	Hundred seed weight	118	0.83
12	Harvest index	2055	14.48
13	Seed yield per plant	1184	8.34

* Significance at 5% probability level
* * Significance at 1 % probability level

4.6.1.1 Relative contribution of different characters towards divergence

Differences in relative contribution of different characters for genetic divergence (D^2) are presented in Table 4.6.1.

Out of thirteen characters, number of pods per plant (14.98%) contributed maximum to genetic diversity followed by harvest index (14.18%), plant height (14.13%) and days to flower termination (14.08%) respectively. The contribution of other traits such as number of branches per plant (13.86%), seeds per pod (12.12.69%), seed yield per plant (8.34%), pod length (1.74%), germination percentage

Table 4.6.1a: Average intra - cluster (bold) and inter - cluster D^2 values of cowpea during summer 2004

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**23.72**	247.54	246.37	79.11	200.86	208.05	231.03	259.69	168.78	122.85	169.32	227.43	189.60	270.23	228.89	202.65	204.45
2		**25.47**	219.87	235.23	293.23	54.24	211.53	274.97	257.43	239.40	116.17	318.62	264.07	254.42	318.99	173.87	291.69
3			**27.76**	217.69	226.01	193.21	198.09	296.11	160.99	209.50	183.98	264.69	177.08	228.22	257.76	182.63	221.38
4				**28.64**	159.37	191.95	211.91	246.39	115.87	52.06	151.58	191.96	145.98	254.41	191.49	179.66	163.01
5					**26.27**	259.86	268.56	271.88	115.88	145.09	232.19	50.99	212.87	299.03	254.69	247.06	229.75
6						**20.31**	184.06	247.56	217.03	196.43	69.25	288.19	228.65	232.39	290.21	139.71	259.99
7							**26.41**	229.97	217.13	210.50	161.74	298.62	177.66	61.26	255.25	64.89	220.92
8								**24.95**	254.74	250.05	205.20	287.65	291.98	267.12	337.25	197.88	313.09
9									**21.09**	94.90	182.79	160.69	132.06	254.78	190.12	190.28	157.15
10										**24.12**	159.05	180.46	129.88	252.59	177.18	178.75	147.17
11											**28.50**	262.54	203.59	214.59	270.54	110.82	237.89
12												**22.13**	253.41	326.35	289.58	278.89	267.69
13													**24.85**	204.07	105.56	171.08	64.28
14														**22.76**	276.15	119.18	244.65
15															**28.24**	249.34	48.87
16																**28.68**	213.85
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Table 4.6.1a contd…..

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	141.29	178.15	187.53	263.77	41.01	192.64	128.64	174.62	219.95	230.44	141.31	260.89	170.40	208.04	199.16	155.47	187.71
2	225.24	235.82	247.61	237.52	240.44	236.84	223.46	266.39	180.49	262.04	170.83	235.09	246.69	159.23	241.94	144.35	152.94
3	226.47	242.25	145.02	38.49	230.94	130.50	207.98	176.27	71.11	279.60	187.44	38.22	135.91	116.93	255.89	190.26	181.95
4	120.78	158.23	145.41	237.51	48.62	153.66	94.38	125.05	187.13	215.86	118.99	234.01	124.15	175.18	182.63	139.05	162.11
5	168.41	191.89	206.59	237.99	181.05	209.26	144.32	72.69	216.34	239.05	213.65	237.49	147.67	222.53	216.36	226.23	235.23
6	182.76	197.57	209.74	213.98	199.18	197.47	178.45	228.29	148.37	231.45	121.79	211.45	205.52	124.03	206.62	96.66	113.22
7	184.78	190.69	153.48	216.60	220.81	134.35	187.91	231.91	152.39	217.34	160.74	221.31	205.11	127.11	196.03	165.25	109.77
8	152.69	104.59	280.18	310.92	254.04	270.66	194.14	255.84	270.20	44.98	191.69	310.37	259.47	259.65	72.78	194.56	182.04
9	146.11	173.03	124.21	177.76	141.89	129.30	115.70	49.09	147.82	225.78	156.59	176.74	43.34	157.04	196.78	175.73	177.53
10	129.51	162.97	131.03	229.92	89.74	141.55	97.99	106.53	178.09	219.97	128.25	226.24	105.40	167.34	187.69	149.31	161.89
11	130.92	146.83	182.53	206.79	159.93	168.32	129.49	196.15	136.84	186.78	61.57	204.82	172.15	111.75	157.39	36.77	77.71
12	192.41	212.61	247.87	275.56	210.96	249.82	173.13	117.02	254.92	254.81	246.09	275.25	192.77	259.15	235.66	256.58	267.42
13	206.22	227.29	54.55	192.24	164.12	89.77	185.31	159.18	157.24	270.63	183.31	191.15	118.42	157.61	244.21	202.93	178.57
14	230.72	235.08	182.85	242.23	261.64	166.30	233.52	266.72	188.91	256.59	213.74	249.16	243.93	168.79	239.19	218.13	165.60
15	266.08	282.21	153.65	269.55	204.56	191.04	249.38	211.99	244.17	317.24	253.33	267.26	188.11	243.52	296.76	270.61	253.12
16	145.59	152.03	145.89	203.99	190.75	125.95	150.24	207.37	131.33	183.49	111.32	205.76	177.66	101.80	158.23	114.81	53.26
17	234.89	253.20	111.44	234.39	178.57	148.59	216.22	181.74	205.79	292.05	219.19	232.27	151.89	205.56	269.03	237.57	218.27
18	**23.33**	55.97	190.08	247.01	131.55	179.27	50.55	146.58	190.89	118.69	97.68	246.16	156.54	175.44	81.63	113.58	122.90
19		**29.74**	212.86	261.08	169.14	202.56	95.40	172.99	209.78	71.75	120.19	260.35	182.22	196.22	36.69	131.39	130.31
20			**28.44**	161.65	164.13	45.38	167.84	150.85	122.71	258.89	161.63	161.27	103.86	125.63	230.34	181.42	154.91
21				**0.00**	249.29	149.34	229.57	190.62	94.89	295.57	210.83	18.19	153.73	141.66	273.77	213.24	204.97
23					**24.69**	171.98	112.61	150.15	203.21	224.09	129.83	245.95	148.40	191.61	191.85	146.90	174.82
24						**20.99**	157.53	154.47	100.99	249.82	147.58	150.48	106.35	102.32	219.87	166.75	136.79
25							**23.55**	117.19	171.52	160.44	93.96	228.46	127.59	157.07	123.67	113.26	128.58
26								**22.11**	166.50	224.81	172.86	189.97	79.93	176.28	197.75	189.38	195.14
27									**28.36**	252.02	143.18	98.76	123.84	54.30	224.57	144.79	131.06
28										**29.42**	169.74	294.99	233.57	240.73	42.09	174.87	165.86
29											**24.34**	208.93	146.95	121.79	135.06	36.45	80.50
30												**0.00**	152.64	144.89	273.19	211.54	204.21
31													**28.98**	137.06	203.82	166.09	165.75
32														**26.92**	211.25	121.45	102.34
33															**0.00**	143.11	137.65
34																**0.00**	82.39
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1	228.16	226.09	275.19	189.87	247.25	270.45	211.89	195.57	229.13	183.38	190.06	165.87	299.37	172.17	183.71	304.96	182.27
2	179.39	42.84	257.49	277.27	237.34	36.47	241.27	80.68	193.62	274.78	274.91	254.96	285.54	98.27	260.95	288.49	176.01
3	52.57	206.32	59.57	203.24	213.54	231.93	251.12	189.43	199.75	194.93	196.85	161.73	253.91	184.44	176.24	88.99	166.53
4	196.89	213.27	249.69	143.38	230.58	258.90	189.76	179.65	212.02	136.89	145.36	116.22	285.99	155.15	137.56	281.51	134.28
5	222.11	275.25	246.09	216.04	281.59	312.04	217.89	250.04	269.44	44.52	53.23	93.20	325.87	234.78	207.07	264.82	86.68
6	151.28	36.48	234.52	242.30	208.74	80.69	206.89	39.75	168.58	238.25	237.88	214.26	266.51	51.38	225.04	268.25	237.77
7	167.02	196.23	241.29	206.72	33.41	224.94	193.69	170.54	35.85	245.02	244.05	216.03	97.95	169.91	184.76	269.91	238.69
8	277.08	246.38	323.43	301.09	236.38	290.59	67.07	216.88	211.42	258.67	257.35	245.05	296.48	233.62	287.15	350.15	265.97
9	155.86	237.15	187.73	135.29	233.51	278.32	196.58	206.13	220.94	79.41	93.92	40.46	285.03	188.70	120.90	213.13	55.72
10	188.25	218.65	242.12	125.13	229.63	262.20	190.64	185.57	212.23	120.37	130.12	99.33	284.34	162.34	119.79	274.01	116.59
11	145.45	84.93	226.73	217.32	185.91	142.82	158.82	43.49	148.97	207.43	206.49	178.61	251.03	48.71	199.18	262.21	205.51
12	260.49	301.54	283.17	256.01	310.24	336.57	237.84	278.59	298.59	86.51	87.18	136.71	351.57	264.79	248.67	299.93	129.75
13	164.87	249.67	205.46	43.36	190.07	278.95	242.45	222.24	186.28	183.37	194.88	150.43	227.98	203.85	34.67	231.96	154.71
14	202.54	242.19	266.68	234.77	37.62	264.57	236.50	221.23	79.11	278.34	277.61	253.37	44.15	221.35	214.34	290.45	271.94
15	248.59	306.85	278.43	73.66	264.88	330.51	295.05	285.82	260.29	233.66	252.49	214.41	294.57	271.43	103.62	299.89	209.83
16	145.54	154.34	227.61	195.52	87.93	190.93	155.97	122.06	53.23	221.29	219.77	189.05	156.80	122.09	173.49	260.37	215.96
17	210.85	278.39	244.53	34.27	231.89	304.83	267.33	254.74	226.97	205.07	222.18	180.62	265.56	238.79	61.35	268.37	178.92
18	203.64	198.41	262.19	214.98	201.03	249.89	94.61	159.04	177.79	150.47	149.28	133.73	265.12	147.83	199.11	292.82	163.75
19	220.55	207.18	275.49	236.05	203.87	257.79	49.18	169.59	179.06	176.04	174.91	161.37	268.76	170.19	220.66	305.14	187.87
20	131.76	232.33	176.97	87.63	167.44	263.87	228.61	202.27	163.62	174.29	180.72	135.77	209.39	182.37	62.80	205.64	145.43
21	73.54	225.16	34.47	218.46	229.43	247.59	268.72	210.76	217.39	208.32	210.78	177.87	265.45	207.14	191.47	60.94	178.44
23	211.66	218.86	260.82	162.30	238.24	263.80	202.09	187.14	219.81	161.04	169.18	141.46	291.84	163.02	156.81	291.71	158.16
24	118.97	220.82	167.76	123.54	149.56	254.24	218.15	188.58	146.05	176.15	177.86	134.96	195.19	168.66	96.21	197.65	150.76
25	185.16	198.50	244.85	193.54	206.47	249.21	132.05	159.52	185.94	122.84	122.33	103.69	267.84	140.55	177.12	275.94	135.89
26	173.19	246.61	199.57	163.55	246.85	286.60	198.30	217.55	234.52	37.51	57.19	33.77	295.83	200.65	150.83	222.02	35.26
27	36.10	165.04	122.39	184.12	171.57	196.13	219.93	143.36	154.58	184.94	185.00	148.98	219.33	137.47	157.59	153.96	165.12
28	260.04	233.60	308.55	279.01	225.69	279.83	43.36	201.84	200.68	226.66	225.84	215.11	287.32	213.23	264.88	335.93	237.08
29	155.84	140.22	228.66	195.85	183.06	197.71	139.02	96.31	153.95	185.97	184.99	152.33	250.42	85.73	178.16	264.17	181.23
30	74.17	223.03	30.68	216.23	235.29	244.99	268.15	208.72	220.68	207.70	210.32	177.15	273.12	204.44	189.34	62.81	177.61
31	131.81	226.57	164.42	127.08	222.26	267.32	202.75	195.27	209.68	109.56	118.99	61.95	274.71	177.92	108.97	191.85	76.15
32	74.11	143.19	168.99	182.92	149.77	177.17	207.31	118.43	129.64	193.03	191.88	158.28	202.02	111.84	158.93	201.46	180.87
33	234.46	212.77	287.91	253.35	207.25	262.30	25.73	176.89	181.59	201.05	199.76	185.89	272.17	183.24	238.26	317.05	210.94
34	155.48	111.05	232.08	215.85	188.04	172.07	146.14	68.54	155.16	200.59	199.01	170.26	254.53	69.04	198.20	267.65	198.23
35	143.46	130.27	226.56	197.60	133.98	172.93	36.09	91.84	95.01	208.83	206.95	175.88	203.62	91.20	177.05	261.26	205.24
36	**0.00**	165.57	100.07	191.07	185.88	192.55	229.13	148.17	166.08	190.34	192.51	157.18	231.58	145.03	163.35	133.67	170.02
38		**0.00**	245.42	262.83	219.10	65.76	211.32	46.17	178.28	255.34	255.21	233.75	274.93	80.38	246.11	278.06	255.79
39			**25.87**	229.68	253.61	267.16	283.13	231.25	241.39	216.94	220.02	187.80	289.07	227.00	203.35	43.19	184.71
40				**0.00**	219.88	292.35	251.80	236.38	213.03	188.32	203.54	159.01	258.57	218.12	37.98	255.65	161.01
41					**0.00**	246.63	204.79	194.64	49.49	259.21	258.14	231.69	73.21	195.48	198.82	279.99	252.52
42						**0.00**	260.35	105.34	205.51	294.76	295.35	276.43	293.93	124.60	276.49	296.38	295.74
43							**0.00**	175.89	178.76	202.04	200.77	186.63	269.45	187.01	236.56	312.31	210.86
44								**0.00**	153.91	227.53	226.77	202.15	256.67	51.32	218.37	266.08	227.03
45									**0.00**	246.74	245.76	218.89	114.69	157.83	191.89	270.90	242.08
46										**26.54**	35.52	54.69	306.79	211.30	177.04	238.06	51.94
47											**0.00**	60.41	306.36	210.54	192.09	241.66	64.89
48												**0.00**	283.89	184.59	144.02	213.11	38.03
49													**30.20**	257.37	239.49	309.91	300.14
50														**0.00**	200.02	261.66	210.29
51															**0.00**	230.69	149.18
																0.00	205.67
																	0.00

(1.47%), days to physiological maturity (1.35%), days to flower initiation (1.16%), number of clusters per plant (0.89%) and hundred seed weight (0.83%) were comparatively low.

4.6.1.2 Classification of cowpea genotypes

Genetic diversity (D^2) values were used to classify the genotypes in different groups. The genotypes studied (169) were grouped into 51 clusters. The average values within and between clusters are given in Table 4.6.1a.

The highest inter cluster distance was observed between cluster 12 and 47 (351.57) followed by clusters 8 and 50 (350.15) and clusters 8 and 15 (337.25), while the highest intra cluster distance was observed in 47 (30.20) followed by cluster 19 (29.74) and 27 (29.42). The minimum cluster distance expressed by cluster number 6 (20.31) other than the solitary clusters. Zero intra cluster distances observed in clusters 21, 28, 32, 33, 35, 36, 38, 39, 40, 41, 42, 43, 45, 46, 48, 49, 50 and 51.

4.6.1.3 Group constellation

The number and varietal composition of different clusters are given in Table 4.6.1b.

The largest cluster was 5, which had 9 genotypes followed by the clusters of 1,2 and 12, which had seven genotypes in each cluster. The clusters of 3,4, 16,19, and 26 consists of six genotypes in each cluster and clusters of 6,8,9,11,14,15,17,18, and 20 consists of 5 genotypes in each cluster and also clusters 10, 13, 27, 32, 35 and 39 consists of 4 genotypes in each. Clusters 7,22, 23, 25, 28, and 31 consists of 3 genotypes in each cluster and only one cluster (45) which consists of 2 genotypes. Clusters of 21, 28, 32, 33, 35, 36, 38, 39, 40, 41, 42, 43, 45, 46, 48, 49, 50 and 51 were consisted of only one genotype.

4.6.1.4 Mean performance of clusters

The mean cluster values for different traits are given in Table 4.6.1c.

A large variation in mean performance of genotypes in different clusters was observed. Highest mean values for pod length and seeds per pod were in cluster 50 and cluster 41 had greater mean values for harvest index. The highest mean germination percentage was in cluster 49 and highest mean value of number of branches per plant was in cluster 48. Cluster 38 had greater mean value for days to physiological maturity. Cluster 33 had highest mean values for plant height and seed yield per plant and 34 had greater mean values for days to flower initiation. Greater mean values for number of clusters per plant were observed in cluster 30. The cluster 1 had greater mean value for number of pods plant. The Cluster 30 had greater mean value for number of clusters per plant where as the lowest mean values for days to flower initiation, days to flower termination and days to physiological maturity, which was also consisting of only early maturing genotypes.

4.6.2 Experiment – II (Summer 2005)

4.6.2.1 Relative contribution of different characters towards divergence

Relative contribution of different characters for genetic divergence (D^2) is presented in Table 4.6.2. Among 13 characters studied, maximum contribution to divergence was by number of pods per plant (14.75%) followed by harvest index (14.74%). Similar contribution of 1.42% was observed in germination percentage and days to flower termination. Other traits such as days to flower termination (13.72%), number of branches per plant (13.45%), plant height (13.20%), seeds per pod (13.02%), seed yield per plant (9.18%), pod length (1.43%), days to physiological maturity (1.39%), number of clusters plant (1.30%) and hundred seed weight (0.97%) also contributed to the diversity.

4.6.2.2 Classification of cowpea genotypes

The estimates of genetic divergence D^2 were used to classify the genotypes into various groups. Hundred and sixty-nine genotypes were studied and grouped into 46 clusters. The mean values of D^2 within and between clusters are presented in Table 4.6.2a.

The highest inter cluster distance was observed between clusters 11 and 42 (349.31) followed by clusters 34 and 42 (346.10), 26 and 41 (343.99) and 25 and 42 (340.54). The lowest intra cluster distance other than the solitary clusters was in the cluster of 19 (17.19). Twenty two clusters in between minimum and maximum values were observed showing different divergence groups. While, the highest intra cluster distance was observed in cluster 37 (30.53) followed by cluster 10 (29.77) and 34 (28.99). The solitary clusters were 25, 28, 31, 32, 33, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45, and 46 and they showed zero cluster distances.

Table 4.6.1b: Number of clusters and their varietal composition of cowpea in *kharif* 2004

Cluster number	Number of genotypes	Name of genotypes
1	7	IC257410, IC257411, IC257420, IC257422, IC98706, IC97767, IC97787
2	7	IC2559100, IC5969, EC394740, IC257447, GOA LOCAL, IC259058, IC259078
3	6	IC259071, IC259085, IC201098, EC394691, IC202932, IC97764
4	6	IC249141, IC253268, IC243489, IC219594, IC257445, IC257406
5	9	IC214752, IC219141, IC243312, IC202924, IC249133, IC249593, IC202854, IC202804, IC202786
6	5	IC253281, IC257435, IC259061, IC259081, IC259104
7	3	IC249585, IC253275, IC257452
8	5	IC219607, IC243501, IC249583, IC253270, IC257407, EC394823, IC257437, IC247435
9	5	EC394823, IC257437, IC247435, IC259095, IC4506,
10	4	IC202709, IC202772, IC202787, IC198335
11	5	IC199701, IC202707, IC202762, IC97856, IC198333
12	7	IC207813, IC214836, IC202893, IC202841, IC202799, IC202781, IC202730
13	4	C152, GC3, EC394855, IC68786,
14	5	IC202927, IC214833, IC219592, IC243486, IC202867
15	5	IC259084, IC202784, IC259069, IC202931, EC3947
16	6	IC202720, IC202797, IC202779, IC202835, IC206240, IC202873
17	5	IC253288, IC257441, IC259063, IC259083, IC259105
18	5	IC202782, IC202803, IC202846, IC202743, IC202705
19	6	IC215015, IC219872, IC202901, IC208618, IC249132, IC249586
20	5	IC202710, IC202775, IC202823, IC202789, IC198342
21	1	IC259064
22	3	IC97829, IC91556, IC201079
23	3	IC97838, IC198327, IC198361

Table 4.6.1b contd……

Cluster number	Number of genotypes	Name of genotypes
24	1	IC68786
25	3	IC202860, IC202926, IC219574
26	6	IC202718, IC202791, IC202778, IC202824, IC204103, IC202868
27	4	IC257425, IC259072, IC257453, IC253276
28	3	IC97834, IC198359, IC198323
29	1	IC257427
30	1	IC259084
31	3	IC97806, IC15567, IC199704
32	4	IC97764, IC198349, IC97830, IC201087
33	1	IC253277
34	1	IC201099
35	4	IC97830, IC198321, IC201095, IC198355
36	1	IC214834
37	1	EC394805
38	1	IC257424
39	4	IC259159, IC202702, V-118, EC394753, IC253255
40	1	IC253255
41	1	BIALHONGAL LOCAL
42	1	IC257449
43	1	IC219640
44	1	IC214835
45	2	IC243353, IC253181
46	1	IC249137
47	1	IC202809
48	1	IC247430
49	1	IC249140
50	1	EC394745
51	1	IC214759

Table 4.6.1c: Mean performance of different clusters of cowpea during *kharif* 2004

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
1	74.71	41.79	54.79	71.00	80.36	3.85	10.19	21.00	13.14	11.50	8.76	0.23	18.31
2	65.79	45.07	54.86	71.00	79.00	4.25	8.26	11.21	12.29	10.38	12.59	0.18	12.17
3	85.17	45.67	54.00	69.42	77.00	4.15	8.33	10.50	12.83	11.08	11.98	0.15	9.75
4	82.00	42.17	53.17	69.08	76.25	4.45	9.08	10.92	12.08	10.33	10.75	0.20	11.98
5	77.11	42.44	55.94	72.67	79.72	3.91	8.00	11.89	12.33	10.44	10.93	0.19	12.15
6	67.50	38.40	55.80	70.10	76.90	4.00	8.30	11.20	11.60	9.90	10.00	0.18	10.15
7	76.33	43.33	53.00	70.83	79.50	3.90	11.33	15.33	12.83	11.17	11.73	0.21	17.43
8	81.30	40.30	53.00	70.80	79.90	4.16	8.00	10.70	12.30	10.80	10.92	0.16	10.28
9	62.70	42.30	55.60	72.60	78.70	4.02	9.70	11.70	12.20	10.20	12.33	0.19	14.41
10	66.88	46.63	54.75	70.50	76.13	3.60	8.50	13.75	12.31	9.88	12.59	0.18	13.06
11	83.10	46.80	56.30	72.20	78.40	3.78	8.70	11.30	12.05	10.75	9.17	0.17	10.85
12	67.14	41.21	55.57	73.00	79.71	3.63	7.00	9.79	12.93	10.71	11.67	0.18	10.04
13	71.63	49.25	55.50	70.50	78.13	4.18	8.50	11.25	11.88	10.38	12.51	0.19	12.91
14	64.20	34.70	50.70	65.80	74.70	3.56	6.10	8.70	10.60	9.30	9.02	0.19	12.01
15	86.90	40.50	52.60	66.40	73.00	4.56	8.30	10.80	12.20	10.20	13.03	0.18	13.08
16	88.50	41.50	54.92	72.33	77.58	3.76	7.23	10.42	12.08	10.33	12.62	0.22	15.43
17	82.90	42.50	56.00	71.10	77.60	4.06	9.70	11.50	12.60	10.00	9.53	0.19	12.76
18	76.50	41.50	53.20	72.40	79.00	3.55	7.60	10.50	12.40	11.20	10.06	0.18	11.98
19	64.58	43.25	55.42	73.25	83.50	3.58	8.42	10.08	11.75	10.42	11.87	0.19	10.87
20	73.40	41.90	54.10	72.00	79.70	3.74	8.90	12.30	11.20	9.90	11.56	0.19	11.80
21	91.50	52.00	63.00	81.00	86.50	3.50	7.00	10.50	11.50	10.50	10.35	0.19	14.00
22	69.33	49.50	57.00	72.67	80.17	4.08	9.00	15.17	13.17	11.83	11.02	0.22	15.90
23	79.83	44.50	51.33	72.83	80.33	3.73	7.67	10.50	13.17	10.83	8.17	0.20	10.10
24	82.00	41.50	52.50	64.50	71.50	4.10	8.00	12.50	9.50	8.50	10.65	0.15	9.10
25	89.17	37.83	58.50	76.50	82.00	3.47	9.50	10.33	12.17	11.00	9.90	0.16	10.80
26	80.75	41.83	56.33	76.75	84.75	3.26	6.17	8.08	12.23	10.48	9.85	0.17	9.78
27	73.63	36.75	54.75	68.25	76.25	4.03	9.63	11.75	11.13	9.63	11.70	0.18	11.33
28	68.33	40.67	56.00	71.67	81.67	3.68	9.33	15.33	12.67	11.17	10.88	0.23	18.27
29	65.50	40.50	56.00	69.00	75.50	4.70	11.00	13.50	11.50	10.50	7.35	0.23	17.60
30	68.00	36.00	43.50	58.00	63.00	3.50	12.50	12.50	11.50	10.00	15.30	0.20	16.70
31	81.17	43.33	57.33	77.67	84.00	3.77	8.83	12.00	13.00	11.25	10.07	0.21	14.70
32	84.38	43.00	55.25	73.13	78.25	3.74	8.83	14.25	13.06	11.10	9.40	0.20	14.60
33	86.00	58.00	51.00	77.00	85.50	4.00	12.00	14.50	12.00	10.50	11.10	0.27	19.80
34	98.50	39.00	67.00	79.00	83.00	3.50	5.00	6.50	10.00	7.50	9.50	0.15	6.50
35	78.63	45.75	56.13	72.00	79.75	3.78	7.65	13.88	12.75	11.00	9.79	0.21	12.86
36	87.00	47.00	54.50	73.50	78.50	3.60	5.00	10.50	12.50	10.50	9.15	0.16	8.00
37	76.50	40.00	61.50	69.00	79.50	4.10	7.00	12.00	14.50	8.50	19.60	0.20	12.90
38	58.00	36.00	55.50	78.50	89.00	4.00	8.50	12.50	12.50	10.50	7.50	0.20	9.65
39	78.00	44.38	54.50	68.13	74.38	3.88	8.38	11.13	11.63	11.38	10.49	0.16	10.81
40	68.00	47.00	50.00	79.00	86.00	3.60	8.50	10.00	11.50	10.00	12.65	0.19	11.60
41	76.50	47.00	59.00	75.00	77.00	3.50	11.60	16.50	13.00	10.60	10.40	0.24	18.95

Table 4.6.1c: contd……

42	95.00	39.50	52.50	72.50	82.00	3.90	8.50	11.00	12.00	10.50	11.05	0.15	9.35
43	68.00	39.00	48.00	69.50	75.00	3.40	5.00	9.50	12.50	10.50	10.00	0.16	10.00
44	86.50	42.50	52.00	67.50	73.00	2.70	8.50	10.50	12.50	10.50	9.50	0.15	9.00
45	68.00	37.75	55.00	68.25	75.75	4.50	5.50	8.50	12.25	10.50	11.83	0.17	9.50
46	89.00	39.50	55.00	66.00	75.50	3.50	8.50	11.00	14.00	11.50	11.95	0.23	18.80
47	68.00	32.50	58.50	75.00	87.00	3.00	4.00	6.50	10.00	8.50	5.35	0.14	5.20
48	68.00	38.00	51.50	65.50	77.00	5.50	7.50	13.00	12.00	11.50	5.95	0.17	10.30
49	99.00	37.50	54.00	61.00	73.50	4.00	7.50	13.00	12.50	11.50	8.70	0.22	13.00
50	88.00	42.00	50.00	75.00	82.00	4.80	8.00	11.50	14.50	12.50	11.60	0.22	14.85
51	89.00	45.00	52.50	71.00	79.50	4.00	7.50	12.00	13.00	11.00	10.20	0.18	11.20

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Number of seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

4.6.2.3 Group constellation

The number and varietal composition of different clusters are presented in Table 4.6.2b.

The clusters 6,8 and 9 were the biggest clusters with 7 genotypes in each cluster. Clusters 1, 2, 5, 10, and 24 are the second largest clusters with six genotypes in each. The clusters 3, 4, 7, 11, 12, 14, 15, 17, 18, 20, 21, 26, 27, 34 and 37 consists of five genotypes in each cluster and the clusters 13, 16, 22, 23, 29, and 30 consists of 4 genotypes in each. The clusters 25, 28, 31, 32, 33, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45, and 46 were solitary clusters with one genotype in each cluster.

4.6.2.4 Mean performance of clusters

The means of clusters for different traits are given in table 4.6.2c.

The cluster 35 had highest mean values for days to flower initiation, days to flower termination and days to physiological maturity and also, the cluster 36 showed the lowest means for the same traits and that indicates that the early maturing genotypes grouped in this cluster. Cluster 32 had greater mean values for pod length and seeds per pod and the cluster 33 had greater mean values for branches per plant. Clusters 40, 41, and 42 had higher mean values for seed yield per plant, harvest index and number of clusters per plant respectively. Cluster 45 had greater mean value for number of pods per plant. The clusters 20, 25 and 31 had highest mean values for hundred seed weight, germination percentage and plant height respectively.

Table 4.6.2: Relative contribution of different traits of cowpea genotypes towards divergence in summer 2005

Source	Traits	Times ranked first	% Contribution
1	Germination percentage	201	1.42
2	Plant height	1874	13.20
3	Days to flower initiation	201	1.42
4	Days to flower termination	1948	13.72
5	Days to physiological maturity	198	1.39
6	Number of branches per plant	1910	13.45
7	Number of clusters per plant	185	1.30
8	Number of pods per plant	2094	14.75
9	Pod length	203	1.43
10	Seeds per pod	1849	13.02
11	Hundred seed weight	137	0.97
12	Harvest index	2093	14.74
13	Seed yield per plant	1303	9.18

Table 4.6.2a: Average intra - cluster (bold) and inter - cluster D^2 values of cowpea during summer 2005

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**26.72**	183.79	242.47	225.72	71.11	211.92	195.45	147.50	220.89	188.57	254.89	153.79	122.89	222.60	238.49	178.03
2		**26.33**	137.51	130.71	128.99	164.51	91.82	146.51	168.85	93.68	249.79	178.16	95.43	163.64	187.63	166.22
3			**24.89**	48.99	205.57	154.54	114.41	203.22	155.09	146.43	277.78	173.21	188.88	236.81	167.26	215.00
4				**22.75**	185.69	122.02	98.43	181.76	121.89	133.87	262.46	146.69	167.67	228.52	136.53	194.56
5					**25.41**	172.70	144.43	119.76	183.72	137.16	239.65	135.24	59.41	182.75	205.52	151.32
6						**24.59**	132.38	127.98	50.84	159.08	180.86	96.97	159.72	241.23	87.85	126.19
7							**24.74**	165.09	128.73	59.13	257.96	161.19	119.83	165.69	142.62	182.02
8								**27.72**	139.75	181.77	150.13	112.21	122.01	249.74	165.11	51.78
9									**22.36**	157.04	187.89	117.34	170.33	240.82	45.97	137.36
10										**29.77**	269.75	180.88	110.84	113.59	168.93	197.93
11											**25.97**	184.08	240.69	319.48	203.04	106.11
12												**25.55**	146.56	254.56	146.47	121.09
13													**22.96**	163.83	193.36	149.30
14														**27.75**	248.81	262.07
15															**27.47**	161.64
16																**20.42**
17																
18																
19																
20																
21																
22																
23																
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Table 4.6 2a contd…..

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	272.73	196.86	217.75	251.73	184.19	192.93	204.85	228.34	229.84	260.40	203.79	128.46	163.77	292.60	231.64	255.01
2	162.60	114.09	140.69	197.27	49.89	209.52	200.71	149.12	234.88	271.17	99.92	139.89	183.74	183.63	175.34	140.85
3	62.34	179.79	85.46	174.29	156.77	174.69	238.84	239.04	267.35	215.09	193.86	204.85	164.95	100.61	251.50	38.61
4	104.22	168.66	43.32	145.13	151.05	148.10	220.61	234.35	251.39	194.31	188.86	183.02	137.49	143.29	243.94	78.67
5	240.49	148.63	177.27	219.72	133.83	178.37	185.36	194.86	217.14	250.47	162.15	100.49	146.19	263.15	193.91	218.76
6	204.62	188.87	98.17	121.12	180.27	114.61	141.26	252.62	170.12	182.02	212.69	143.74	94.65	239.13	254.03	179.78
7	150.73	100.18	101.77	149.05	121.43	190.26	210.87	219.38	243.91	252.44	170.16	162.69	163.52	178.39	184.20	127.97
8	241.59	205.34	170.15	187.71	141.52	166.08	89.71	185.93	126.21	245.17	157.08	43.43	130.72	267.33	259.09	217.86
9	204.29	187.01	97.19	77.94	184.26	135.98	150.88	255.83	177.64	198.64	215.87	155.30	117.15	239.61	253.79	182.34
10	174.61	51.73	137.08	175.05	124.06	207.37	224.87	219.85	255.68	265.96	173.29	178.47	182.56	197.73	132.61	156.15
11	307.11	288.19	253.31	231.31	246.49	223.41	65.92	275.94	34.55	287.99	255.96	187.07	201.98	328.72	323.86	290.33
12	218.39	207.98	128.93	173.99	188.15	81.80	139.72	254.55	166.60	269.24	218.12	120.85	45.85	248.69	266.67	195.06
13	225.75	124.16	160.22	206.73	100.78	186.22	186.94	171.47	221.83	255.79	134.39	106.85	155.97	249.86	175.96	201.86
14	253.03	71.80	231.17	253.89	184.93	273.90	282.79	257.30	306.98	320.97	222.97	246.27	255.01	267.99	34.05	241.61
15	212.89	196.63	114.17	45.21	201.92	159.64	171.56	269.57	194.11	213.53	231.24	180.14	144.71	247.83	261.43	194.97
16	251.99	220.63	183.37	187.77	161.79	173.87	48.93	202.25	85.49	251.38	175.49	86.81	141.77	277.38	269.83	229.50
17	**23.79**	202.99	142.39	217.43	178.99	219.77	272.57	255.03	297.57	252.91	212.61	243.43	211.16	46.73	266.32	95.40
18		**26.80**	171.08	201.51	141.90	231.05	245.73	230.03	274.49	284.86	187.80	201.31	208.65	223.17	89.78	187.47
19			**17.19**	124.89	160.48	129.02	209.90	240.91	241.72	179.24	196.81	171.29	118.39	181.74	246.89	116.82
20				**25.18**	210.56	184.19	200.07	275.13	222.31	231.38	237.99	198.90	170.78	252.06	266.63	202.15
21					**27.39**	219.72	197.65	108.80	231.13	280.15	60.59	133.40	194.52	197.93	195.69	159.32
22						**25.88**	188.12	278.75	209.85	92.23	245.57	171.46	49.04	252.20	285.10	200.17
23							**22.87**	234.63	43.10	261.88	210.41	125.74	159.71	296.39	289.28	252.18
24								**26.99**	261.90	328.04	56.42	176.39	259.42	269.04	263.78	240.83
25									**0.00**	278.35	241.22	161.87	185.36	319.41	312.04	280.13
26										**28.22**	300.23	248.74	133.80	283.66	330.54	239.84
27											**24.41**	148.10	223.65	228.99	231.89	196.07
28												**0.00**	136.08	268.82	256.49	219.16
29													**24.58**	242.97	267.19	188.94
30														**28.45**	280.31	69.69
31															**0.00**	255.80
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Table 4.6 2a contd…..

	33	34	35	36	37	38	39	40	41	42	43	44	45	46
1	92.68	66.37	205.67	39.09	225.82	144.33	134.11	186.17	250.39	314.62	227.71	228.14	143.47	46.72
2	117.37	238.13	135.11	213.32	241.21	170.08	163.77	38.82	183.18	206.26	174.52	212.48	118.24	160.87
3	197.48	282.36	208.78	265.37	193.89	180.91	177.17	115.16	264.76	128.69	250.90	250.42	185.94	224.33
4	176.37	268.06	197.44	250.07	170.32	155.41	151.36	109.17	259.10	171.84	239.03	232.51	163.44	206.24
5	38.17	129.35	161.01	102.56	214.93	122.98	112.14	131.93	220.78	287.73	188.32	205.10	102.04	52.88
6	167.34	252.91	210.86	235.54	144.76	104.50	99.46	151.13	272.96	268.03	244.76	154.07	131.80	193.31
7	137.37	244.35	132.54	223.18	222.16	155.00	147.74	65.96	248.35	204.17	177.63	222.79	143.14	169.09
8	114.88	188.52	224.29	167.61	203.43	96.04	92.45	149.30	203.64	292.01	252.43	114.41	49.66	141.45
9	178.18	260.61	209.63	243.43	163.36	122.47	119.42	155.34	276.29	266.79	244.31	162.62	143.82	202.45
10	133.26	239.24	81.01	217.61	237.58	175.51	165.85	79.13	252.43	221.04	127.16	235.97	161.69	160.75
11	237.62	280.24	300.42	267.42	247.12	178.38	181.46	249.02	288.19	349.31	322.08	53.17	186.48	251.02
12	135.94	185.53	227.13	171.86	122.79	37.92	37.43	165.61	274.31	276.73	259.46	159.41	118.77	145.75
13	39.81	183.10	139.03	156.01	222.18	134.88	125.46	101.26	199.65	275.27	169.60	201.19	92.09	103.14
14	185.03	268.57	39.06	249.09	198.25	251.11	239.73	166.99	292.69	285.28	41.14	291.36	235.54	198.10
15	200.42	275.34	218.30	259.19	182.09	152.07	149.12	174.79	289.59	272.76	252.17	181.71	170.35	221.25
16	145.48	216.08	237.84	196.96	208.36	107.44	107.73	167.76	218.58	301.39	264.58	68.75	83.38	171.29
17	234.23	308.83	230.09	293.38	235.34	224.89	221.27	142.60	281.33	71.27	270.82	283.49	226.17	256.45
18	147.35	246.84	39.05	225.63	259.03	203.44	192.48	110.17	264.92	243.95	83.57	255.93	187.14	169.27
19	167.94	260.35	198.38	242.31	153.30	139.03	134.75	121.63	263.88	210.54	238.05	222.35	152.99	197.83
20	213.51	287.33	223.39	271.18	204.12	178.86	175.42	185.23	294.82	275.07	257.24	209.23	188.73	234.44
21	116.73	238.86	162.37	212.81	250.53	179.74	174.11	70.29	142.24	218.39	196.02	209.61	112.65	169.59
22	177.31	220.47	248.13	209.47	49.74	113.41	104.63	198.69	297.23	280.30	279.16	204.37	169.08	185.61
23	183.21	235.66	260.78	220.04	218.70	129.51	130.99	200.54	249.34	319.14	285.26	44.01	127.25	199.87
24	175.58	276.53	242.39	250.78	303.42	248.19	243.43	173.29	46.18	283.14	266.52	244.25	164.72	227.29
25	216.88	254.33	287.39	242.54	236.21	159.18	161.19	234.56	274.86	340.54	309.71	48.37	165.52	227.31
26	248.26	282.19	298.69	274.18	55.44	202.08	192.42	262.47	343.99	309.12	326.53	274.66	246.24	254.89
27	143.07	255.58	204.23	229.29	273.09	210.98	206.16	122.27	87.41	246.34	233.61	221.27	131.54	196.49
28	96.29	171.86	220.71	149.29	209.45	104.39	98.29	145.02	194.26	293.62	248.87	151.56	38.89	123.92
29	146.03	194.80	227.72	181.87	89.70	73.20	62.19	171.73	279.27	271.39	260.07	178.42	134.19	155.13
30	258.13	326.21	248.71	311.74	267.02	253.65	250.25	165.29	295.17	36.63	288.27	307.02	252.64	277.51
31	196.73	276.55	57.05	257.48	308.44	263.63	252.11	182.27	300.49	296.73	37.55	297.06	246.47	207.94
32	211.29	294.05	216.11	277.36	219.29	200.31	196.86	118.83	267.33	97.61	257.45	263.69	200.28	237.31
33	**0.00**	152.70	161.48	125.05	213.63	124.29	114.07	121.77	201.00	283.02	190.48	199.32	87.81	80.58
34		**28.99**	254.35	33.49	249.25	177.91	169.67	238.56	295.59	346.10	273.34	260.74	192.76	92.53
35			**0.00**	233.77	274.32	223.32	212.09	138.68	277.56	268.20	50.15	270.02	208.33	179.35
36				**0.00**	240.28	162.92	154.00	215.17	270.56	332.42	254.11	244.63	168.63	69.09
37					**30.53**	155.47	147.09	231.31	320.39	293.86	303.88	232.79	207.33	219.97
38						**0.00**	24.64	157.34	268.12	281.21	255.47	150.35	102.47	135.65
39							**0.00**	152.12	264.58	277.97	243.75	152.25	97.79	124.32
40								**0.00**	204.67	189.75	180.28	212.14	122.09	161.76
41									**0.00**	309.33	302.35	258.32	184.49	252.45
42										**0.00**	306.08	329.18	278.07	300.77
43											**0.00**	293.21	238.83	203.25
44												**0.00**	144.72	220.75
45													**0.00**	133.07
46														**0.00**

Table 4.6.2b: Number of clusters and their varietal composition of cowpea in summer 2005

Cluster number	Number of genotypes	Name of genotypes
1	6	IC243489, IC249141, IC253268, IC219594, IC257445, IC257406
2	6	IC198321, IC198355, IC257422, IC201095, IC202720, IC202779
3	5	IC208618, IC215015, IC219872, IC202901, IC202846
4	5	IC202743, IC202782, IC202803, IC202705, IC198361
5	6	IC202824, IC202868, IC202791, IC204103, IC202778, IC202718
6	7	IC198333, IC199701, IC97856, IC202707, IC202762, IC97806, IC202786
7	5	IC198359, IC201099, IC198323, IC97767, IC97834
8	7	IC201079, IC202710, IC202775, IC198342, IC91556, IC202789, IC202823
9	7	IC202854, IC202924, IC214752, IC219141, IC243312, IC249133, IC202804
10	6	IC202730, IC202781, IC202799, IC202841, IC202893, IC207813
11	5	IC68786, BIALHONGAL LOCAL , EC394805, IC259083, IC259105
12	5	IC198335, IC199704,IC202709, IC202772, IC97806
13	4	IC97764, IC198349, IC257420, IC97830,
14	5	IC259071, IC259085, IC257452, IC201098, IC202932
15	5	IC259058, IC259078, IC253277, IC257427, IC249593
16	4	IC202927, IC214833, IC202867, IC219592
17	5	IC249586, IC253276, IC257425, IC257453, IC259072
18	5	IC247430, IC253275, IC214836, IC219640, IC249585
19	3	IC97787, IC198327, IC97838
20	5	GOA LOCAL, EC394740,IC257447, IC5969, IC259100
21	5	IC202873, IC214835, IC202835, IC206240, IC202797
22	4	IC219574, IC243353, IC214759, IC249137
23	4	IC249140, IC253255, IC253288, IC243486
24	6	IC257449, IC259069, IC259084, IC202784, IC202931, EC3947
25	1	IC259063

Table 4.6.2b contd….

Cluster number	Number of genotypes	Name of genotypes
26	5	EC394855, GC-3, C-152, IC68786, IC259104
27	5	IC249583, IC257407, IC243501, IC253270, IC219607
28	2	IC257411
29	4	IC202787, IC202809, IC202926, IC202860
30	4	IC247435, EC394823, IC259095, IC4506
31	1	IC97764
32	1	IC249132
33	1	IC201087
34	5	V-118, EC394753, IC259084, IC202702, IC259159
35	1	IC257424
36	1	IC259064
37	5	IC253181, IC253281, IC257435, IC259061, IC259081
38	1	IC257410
39	1	IC15567
40	1	IC97830
41	1	EC394745
42	1	IC257437
43	1	EC 394691
44	1	IC257441
45	1	IC97829
46	1	IC214834

Table 4.6.2c: Mean performances of different clusters of cowpea during summer 2005

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
1	85.50	45.64	60.83	74.50	76.58	4.94	11.93	16.23	15.38	14.02	11.15	0.18	13.58
2	81.92	44.57	60.75	74.75	77.08	4.21	10.17	15.85	13.69	12.43	11.29	0.25	19.21
3	76.90	41.51	56.70	70.80	73.10	4.13	9.59	10.14	15.20	13.35	11.42	0.18	13.55
4	79.60	39.14	58.80	70.90	73.40	3.96	10.16	16.14	13.90	11.84	11.07	0.21	16.23
5	71.25	40.69	61.25	74.50	76.92	3.79	10.38	17.84	13.94	12.35	10.45	0.23	17.03
6	78.71	45.01	61.00	73.86	76.36	4.19	10.38	17.98	15.38	13.47	11.06	0.23	17.80
7	79.10	43.67	59.90	72.50	74.80	4.20	11.84	18.61	13.44	12.24	11.65	0.22	15.42
8	78.14	45.39	59.29	72.64	74.86	4.42	11.26	17.73	15.05	13.33	11.77	0.23	17.73
9	81.93	41.59	59.14	72.00	74.71	4.45	9.93	15.20	14.95	13.24	10.44	0.19	14.12
10	50.67	42.15	60.75	74.00	76.50	4.28	10.03	12.14	13.60	12.10	11.92	0.19	13.77
11	76.10	43.24	55.90	69.20	71.70	4.47	11.81	17.63	14.59	12.83	13.34	0.28	21.79
12	80.50	41.95	58.20	72.20	74.40	4.09	12.42	18.61	15.23	13.94	10.37	0.20	15.80
13	86.25	42.21	61.00	74.13	76.75	4.41	11.69	18.24	14.08	12.51	9.20	0.25	19.75
14	74.70	45.29	63.40	77.80	80.10	4.89	10.36	14.55	14.05	12.22	11.51	0.20	16.06
15	87.00	48.43	58.40	71.10	73.60	4.93	12.98	13.04	13.17	12.10	9.05	0.17	12.27
16	77.88	44.14	59.13	71.13	74.25	4.21	9.11	15.23	14.31	12.47	10.03	0.19	12.90
17	79.70	45.15	60.60	75.30	77.40	4.43	11.28	16.61	14.12	12.65	11.79	0.23	16.54
18	74.60	47.17	63.20	74.80	77.60	4.66	10.69	14.70	14.46	13.16	11.30	0.26	18.27
19	86.00	42.50	60.50	73.67	75.00	4.32	13.38	21.52	14.45	12.58	8.60	0.25	20.84
20	55.40	45.84	58.30	72.40	75.00	4.68	9.08	13.83	14.09	12.32	14.68	0.21	16.98
21	74.80	41.54	63.30	75.10	77.10	4.03	9.39	16.39	15.97	13.80	11.31	0.25	18.14
22	78.50	41.39	60.50	72.13	74.88	4.23	10.93	17.49	14.86	13.25	11.55	0.21	15.89
23	88.38	42.64	57.00	70.00	72.80	4.59	10.30	14.00	15.22	13.13	9.79	0.20	14.86
24	75.75	43.71	57.25	71.00	73.33	5.03	10.75	15.23	13.90	12.12	12.62	0.25	18.89
25	100.00	46.40	59.00	70.00	74.00	4.50	8.80	11.50	16.05	13.66	9.44	0.18	14.06
26	65.70	45.16	57.50	70.10	73.00	5.06	12.34	19.19	15.20	13.29	12.26	0.27	21.77
27	81.00	41.44	59.60	71.90	74.00	4.41	9.02	12.19	12.64	11.64	11.03	0.19	13.89
28	97.50	45.28	64.00	76.50	81.50	4.00	12.50	14.25	12.40	11.50	8.07	0.22	19.12
29	80.75	40.04	62.88	74.75	77.13	4.14	11.60	17.09	13.43	12.33	11.21	0.21	15.24
30	72.75	40.76	57.13	71.75	74.25	4.75	9.21	13.65	12.82	11.59	12.88	0.22	16.06
31	46.00	48.85	67.50	80.00	82.50	4.90	9.30	17.90	17.90	15.75	12.05	0.27	22.80
32	97.50	46.55	59.00	74.50	77.00	3.40	13.70	22.10	18.08	16.20	12.34	0.14	13.10
33	69.00	43.75	60.50	77.00	76.50	3.20	13.75	19.40	16.27	14.40	9.86	0.22	14.62
34	80.00	41.77	56.70	71.50	73.90	4.73	11.46	16.04	15.24	13.44	12.21	0.26	20.42
35	85.00	40.85	69.50	81.00	84.00	4.45	9.00	11.15	14.64	11.96	7.73	0.15	12.57
36	94.00	45.75	55.50	69.00	72.30	3.90	9.00	10.80	8.25	8.10	10.51	0.25	16.92
37	68.10	47.58	56.80	70.30	73.10	4.83	10.85	16.10	14.05	13.13	11.71	0.22	16.13
38	84.00	37.00	61.00	74.00	76.50	3.70	11.00	16.60	12.20	11.20	8.17	0.24	16.75
39	95.00	40.55	66.00	78.00	80.00	4.15	9.70	16.85	15.85	14.70	10.90	0.19	15.15

Table 4.6.2c : contd……

40	47.50	40.85	62.50	75.50	78.00	4.15	11.50	23.55	13.23	12.60	10.30	0.27	24.53
41	72.00	41.65	59.00	74.50	77.50	4.90	10.85	17.10	13.36	11.90	11.76	0.29	21.71
42	74.00	43.00	62.00	74.50	76.50	5.45	13.15	20.55	16.85	14.40	12.67	0.22	21.73
43	79.00	46.65	59.50	73.00	72.50	5.40	12.90	17.85	12.70	12.02	14.48	0.27	23.61
44	91.00	46.55	65.50	78.00	81.00	4.50	12.15	11.95	14.75	13.38	7.01	0.14	13.85
45	37.50	34.65	59.00	70.50	72.50	4.10	13.00	24.00	15.72	13.09	10.85	0.28	21.21
46	43.50	37.45	59.00	74.00	76.50	4.10	8.50	15.60	14.65	13.40	9.64	0.19	15.25

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Number of seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

V. DISCUSSION

Cowpea (*Vigna unguiculata* (L.) Walp.) is an autogamous crop having low out crossing ranging from zero to four percent. The study of variance and other genetic parameters greatly help in formulating a suitable breeding programme for improvement of the crop. The variability of the genetic material is a prerequisite for any successful crop improvement method.

The extent of variation in presently cultivated varieties is relatively low. The purpose of studying variability is to partition the total variation present in the collections into different components such as genotype and phenotype components.

Variability is the key factor for any selection programme, which can be generated through various ways. To achieve or create the variability, addition of some more diverse genotypes with the present collection is necessary or creation of new variability by other means is very much needed. Since the productivity of cowpea is very low due to lack of high yielding varieties with resistance to biotic stresses such as diseases, which is the major hindrance of the crop getting unique production. It is necessary to identify high yielding varieties with resistant to major diseases which causes low productivity. Allard and Bradshaw (1964), Magod (1994) indicated the need for thorough evaluation and utilization of germplasm for improvement of productivity in the field crops.

Aiming of these aspects, one hundred sixty nine genotypes comprising exotic and indigenous collections of cowpea collected from diverse sources were evaluated in present study for the yield and yield attributing components with disease resistance.

Discussion is made on the results obtained from the present study under the following sub headings.

5.1 Analysis of variance and mean performance

5.2 Genetic variability

5.3 Disease resistance

5.4 Character association

5.5 Path coefficient analysis

5.6 Genotype and environment effects

5.7 Genetic diversity studies

5.1 ANALYSIS OF VARIANCE AND GENETIC VARIABILITY

5.1.1 Analysis of variance

In *kharif* 2004, genotypes recorded highly significant variation for all the characters such as germination percentage, plant height, days to flower initiation, days to flower termination, days to physiological maturity, number of branches per plant, number of clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight, harvest index and seed yield per plant. In Summer 2005 experiment, the similar trend of significant variation was observed among the same parameters. It indicates presence of sufficient variability for these characters, thus there is a lot of scope for selection. Preeti *et al.* (2003) and Sarvamangala (2004) reported the similar results in studying 32 mungbean genotypes and fifty cowpea genotypes, respectively.

From the present study it can be concluded that presence of sufficient variability among genotypes for the characters, which can be utilized during selection process of suitable basic material for breeding for further improvement. This can be further confirmed by studying genetic variability components such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability and genetic advance.

5.1.2 Mean performance of genotypes

The mean performance of genotypes for all observed characters was comparatively low during *kharif* 2004 (Appendix III). This may be due to unfavorable climatic conditions like frequent showers, high relative humidity and temperature during flowering and pod setting stages.

Lower mean values for days to flower termination and days to physiological maturity are better advantageous to select short age varieties. Lower mean value for days to physiological maturity was observed in the genotypes IC259084 and IC 259071.

Average plant height was more favoured in summer season but it was lower than the check varieties Goa local and C-152. The range of mean values was wide, indicating more influence of the environment on the character. Sarvamangala (2004) suggested plant height should not be extremely high or low which may be resulted to either more vegetative growth or lodging condition respectively.

In *kharif* 2004, genotypes showed higher mean value for clusters per plant over the check Goa Local. However, in summer 2005, Goa Local, Bilahongal local and GC –3 showed higher clusters per plant over the mean. Tamilselvan and Das (1994) suggested that number of clusters per plant, number of pods per plant and test weight should be used as a selection criterion in the development of high yielding genotypes of cowpea.

Mean hundred seed weight of this study in both the seasons did not show much variation. In both the seasons, check variety Bailhongal local showed low hundred seed weight over the mean.

The mean seed yield per plant was higher (16.79g) during Summer 2005 compared with *Kharif* 2004 (12. 49g). In both the seasons, all the check varieties recorded higher seed yield per plant over the mean. Eight and 25 genotypes were recorded higher seed yield per plant over the best check variety Goa Local during *Kharf* 2004 and summer 2005 respectively.

5.2 GENETIC VARIABILITY

Genetic variability is the basic knowledge needed for breeders to improve the crops by adopting appropriate method of selection based on variability that exist in the materials. In this regard, it is necessary to partition the total variability into heritable and non-heritable components *viz.,* genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV) and further to compute heritability and genetic advances for various metric traits.

5.2.1 Range of variation

One of the ways of assessing the variability is through examining the range of variation. The range in the values reflects the extent of phenotypic variability in respect of the characters, includes genotypic, environmental and genotype environmental interaction components. In the present study the genotypes exhibited considerable amount of variation for thirteen characters, out of that, eight characters such as germination percentage, number of branches per plant, number of clusters per plant, number of pods per plant, pod length, hundred seed weight, harvest index and seed yield per plant showed higher variation during *kharif* 2004 and same trend observed in summer 2005. Similar results were observed by Sawant (1994) and recorded higher range for the characters. The characters germination percentage, number of clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight, harvest index and seed yield per plant showed higher variation in both the seasons compared to other characters. The high range of values indicated the good scope for selection of suitable basic material for breeders for further improvement.

5.2.2 Phenotypic and genotypic coefficient of variability and genetic advance as a percent mean

Breeders cannot depend only on the knowledge of variability alone to improve the crop but variance has to be partitioned into phenotypic and genotypic coefficient of variation, which are more reliable for effective selection. Also absolute variability values of different characters do not reveal which of the characters showing high variability. Therefore, the components of variation such as phenotypic and genotypic coefficients of variability, heritability and predicted genetic advance as percent means were computed in respect to yield and yield component characters.

Both genotypic and phenotypic coefficients of variation observed for all the characters studied during *kharif* 2004 showed similar trend. While PCV values were higher than the GCV values. The higher GCV and PCV values were obtained for the germination percentage, number of clusters per plant, number of pods per plant, hundred seed weight, harvest index and seed yield per plant. This indicates the substantial variability existing for these characters and also indicating greater scope for selection of these characters for better expression. While the low GCV and PCV obtained for the characters such as days to flower termination and days to physiological maturity were low for these traits.

GCV and PCV values observed during *summer* 2005 for the characters of germination percentage, number of pods per plant, hundred seed weight, harvest index and seed yield per plant were high. In both the seasons, germination percentage, number of pods per plant, hundred seed weight, harvest index and seed yield per plant showed high GCV and PCV indicating greater scope for selection. Rangaiah and Nehru (1998), Selvam *et al.* (2000) and Vineeta – Kumari *et al.* (2003) reported that high GCV and PCV values for pods per plant, hundred seed weight and seed yield per plant.

Moderate GCV and PCV estimates observed for plant height in both the seasons, while Selvi *et al.* (1994), Tyagi *et al.* (1999) and Selvam *et al.* (2000) showed higher GCV and PCV values for the character. As in *kharif* 2004 and *summer* 2005, GCV and PCV values for the characters, days to flower termination and days to physiological maturity were low. Maranagppanavar (1984), Apte *et al.* (1987) and Patil and Baviskar (1987) reported that low GCV and PCV for days to maturity. The selection is difficult for these characters because of low variation among genotypes. High GCV and PCV values estimated by number of pods per plant in both seasons and similar results were recorded by Patil and Baviskar (1987), Gowda *et al.* (1991), and Selvi *et al.* (1994). Pod length recorded moderate GCV and PCV values. Similar results were reported by Savithramma (1992), Selvi *et al.* (1994) and Selvam *et al.* (2000) where as Sawant (1994) recorded higher GCV and PCV for the character. In this experiment, high GCV and PCV values were recorded for seed yield per plant. Similar results were obtained by Sawant (1994), Selvam *et al.* (2000) and Vineetha- Kumari *et al.* (2003). The characters which are having high GCV and PCV indicate greater scope for selection and increase the expression of these characters.

Genotypic coefficient of variation together with heritability estimates would give the best information on extent of the advance to be expected from selection. The estimates of heritability have a role to play in determining the effectiveness of selection of character provided they are considered in conjunction with the predicted genetic advances.

In the present set of material, where diverse germplasm collections were involved, high heritability and high genetic advance over the mean were exhibited by most of the characters which indicates the genotypes have high variability and the selection can be more effective for the traits. Proving this, same results were observed by Sohoo *et al.* (1971) and revealed that high heritability ranging between 74.2 % to 94. 4 % coupled with moderate genetic advance and GCV. Hence, this indicates the scope for augmenting the germplasm collection for wider variability, which forms a source to improve the yield and yield component characters. The highest heritability was recorded by hundred seed weight in both the seasons. High heritability recorded by Thiyagarajan (1989), Rawale *et al.* (1995), Sharma (1999) and Sarvamangala, (2004) for this character. In *kharif* 2004, high heritability was observed for all the characters except number of branches per plant, pod length and seeds per pod, where as in summer 2005 all the characters exhibited high heritability. Sharma (1999) and Tyagi *et al.* (2000) reported similar results that most of the yield contributing characters showed high heritability. Even though, some characters such as days to flower termination and days to physiological maturity recorded low GCV and PCV which showed high heritability in both the seasons.

The highest genetic advance over mean was observed for the seed yield per plant during *kharif* 2004. Vineeta-Kumari *et al.* (2003) recorded high genetic advance for the character, where as in 2005,the highest GAM was recorded by hundred seed weight, which were showed the highest heritability. The characters such as days to flower termination and days to physiological maturity were expressed low GCV, PCV and heritability, low GAM. Pod length and seeds per pod showed moderate heritability while, Selvi *et al.* (1994) recorded high heritability. High heritability recorded by the seed yield per plant in both the seasons. Similar results were observed by Selvi *et al.* (1994) and Vineetha – Kumari *et al.* (2003), where as the lowest GAM was observed by seeds per pod in 2004 *kharif* which showed low GCV, moderate PCV and low heritability while, Savithramma (1992) reported that low GCV and moderate PCV and high heritability for the character. However, in summer 2005 these characters recorded low GAM values. The present study showed that direct selection for any of the character is effective for yield improvement because of high variability is the key factor for any selection programme to achieve better results.

5.2.3 Variability for qualitative characters

Qualitative characters are useful for characterization of any genotype, which are associated with the yield and contributing characters. Associations of any qualitative character with yield and yield components, resistance to diseases can serve as a marker for selection process.

The variability in four qualitative characters such as stem colour, plant type, flower colour and immature pod pigmentation have been studied as it is essential to characterize the local germplasm collections for future use.

The total of 169 genotypes including exotic genoptypes showed higher variation for stem colour with very slight stem colour (13.6 %), moderate at the base and tips of the petioles (15. 38 %) and intermediate colour (13.02 %) while, 57 .99 percent of genotypes had no special colour formation on the stem.

Plant type is a very important character for the breeders which can be used as a selection criterion in plant breeding. The genotypes showed higher variability for plant type with determinate (36. 09 %), intermediate bush (43.79 %) and intermediate spreading non-climbing (20.12 %). The determinate types are much better plant type for further improvement of cowpea compared to other two plant types.

Flower colours of the genotypes were grouped into four *viz.,* white (8.89 %), violet (3.59 %) mave pink (85 .78 %) and others (1.77 %), which had higher variability. Few numbers of genotypes were in the group of others, which showed different flower colours deviated from the standard colour groups, which indicates more variation in the genotypes. Dadepeer (2002) reported high variability for flower colour by studying mungbean genotypes.

Pod colour is highly visible trait for characterization of genotypes. The genotypes showed higher variability for immature pod pigmentation. However, most of the genotypes did not show special pigmentation on pods which were included into the group of None (85 .33 %) and rest of the genotypes were grouped into three groups *viz.,* pigmented sutures on the pods (4.44 %), splashes of pigment (6.67 %) and uniformly pigmented pods (3.56 %).

5.3 DISEASE RESISTANCE

Among the biotic stresses, the diseases have virtual effect on the crop yield. Developing on the resistance against prevailing diseases of any crop through any of the breeding programme would be much effective and stable compared to other controlling methods. Screening of diverse genotypes for diseases is more effective and convenient to identify resistant varieties that can be utilized in further improvement of the prevailing susceptible varieties.

In the present study, 169 germplasm lines were screened against major diseases such as mosaic virus, rust, powdery mildew and bacterial blight under prevailing environmental conditions.

In the experiment conducted during *kharif* 2004, it was found that 10 genotypes were resistant, five genotypes moderately resistant, 10 genotypes moderately susceptible, 30 genotypes susceptible and 114 genotypes were highly susceptible for mosaic virus. None of the genotypes were shown immune reaction to the mosaic virus. The variety IC97834 was resistant to the mosaic virus in addition, it has recorded highest seed yield per plant and higher pods per plant, while the genotypes of IC249583 and IC259071 recorded disease resistance but their seed yields were very low.

In the experiment conducted during summer 2005, 84 genotypes were found resistant, 78 genotypes moderately resistant, six genotypes moderately susceptible and only one genotype was susceptible. None of the genotypes were immune or highly susceptible. However, some genotypes like IC97797, IC97829, IC97834 and IC198333 were resistant to mosaic virus in both the years, which can be used for further crop improvement programmes of the cowpea. Resistant genotypes such as IC257420, IC97787, IC97767, IC97830, IC97838, IC97856, IC202729, IC202781, IC202787, IC202786, 206240, IC259083, IC202784, Goa Local and EC394805 recorded higher seed yield and harvest index, among them IC257420, IC97787, IC97767, IC97830, IC97838, IC97856 and Goa Local recorded higher number of pods per plant and number of clusters per plant. The resistant genotypes of IC202229, IC202781, IC202787, IC202784 and EC394805 recorded higher hundred seed weight, in addition to, high seed yield and harvest index. Even though, the genotype IC202841 recorded high degree of disease resistance but it showed low seed yield per plant, harvest index, hundred seed weight and low number of pods per plant. Sohoo *et al.* (1991) reported highly resistant cowpea variety to yellow mosaic virus and Bashir *et al.* (2002) recorded ten varieties resistant to viral infection.

Performance of cowpea genotypes against rust resistance was observed that 76 genotypes were resistant, 39 genotypes moderately resistant, 23 genotypes moderately susceptible, 25 genotypes susceptible. There were no immune genotypes while, six genotypes such as IC202799, C-152, IC214835, IC97829, IC243353, and IC259085 were highly susceptible, similarly Uma and Salimath (2003) reported that C-152, as a highly susceptible variety. Zeng – Yong San *et al.* (1999a) observed the relationship between disease severity and duration of saturated humidity. Resistant genotypes such as IC257420, IC257422, IC97834, IC202823, IC202797 and IC202803 showed higher seed yield and harvest index, among them IC257420, IC257422, IC97834 and IC 202823 showed higher number of pods per plant. Even though, IC202823, IC253181 and IC259071 were resistant to the rust but they were very low yielders with low harvest index and number of pods per plant. IC219592 was short duration genotype with resistance to the disease.

The performance of cowpea genotypes against resistance to powdery mildew revealed that 75 genotypes were resistant, 37 genotypes moderately resistant, 25 genotypes moderately susceptible, 30 genotypes susceptible and highly susceptible genotypes were hardly found which were only two out of the 169 genotypes. None of the genotypes was immune to powdery mildew. Wargpiyasatid *et al.* (1999) and Raju and Anilkumar (1990) reported some resistant and partial resistant varieties respectively. Genotypes such as IC257420, IC257422 and IC97834 showed resistance with high yield, harvest index and number of pods per plant and IC202803 was a short age variety but it's pods per plant, seeds per pod, harvest index and seed yield were very low.

Genotypes with resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible reaction to bacterial blight were 56, 27, 47, 22 and 17 respectively. Similarly Bua *et al.* (1998) grouped the genotypes into four categories based on the performances. While, there was no genotype recorded immune to the bacterial blight. Bua *et al.* (1998) and Sushma Neema *et al.* (2000) observed that higher blight disease during rainy season. Amusa and Okechukwu (1998) recorded 16 lines resistant to bacterial blight. Resistant genotypes such as IC202823, IC257420, and IC97767 showed high seed yield, harvest index and number of pods per plant while, IC202791, IC202809, IC202846 and IC259072 showed lower seed yield, harvest index, hundred seed weight and low number of pods per plant. IC202803 and IC201079 were resistant to bacterial blight short age genotypes with high seed yield per plant and harvest index. Where as, the IC202705 was also resistant genotype for blight with lower performance for same characters.

Genotypes such as IC198333 and IC97787 showed resistance to all the tested diseases under the prevailing condition. IC98787 was high yielding genotype in both the season with high harvest index, higher number of pods per plant and number of clusters per plant where as the performance of the same traits in IC198333 was not much higher.

Genotypes, which are having high disease resistance with favourable traits, can be utilized for the future crop improvement programme. Where as, none of the genotypes were highly susceptible for all the tested diseases. However, the climatic conditions like continuous showers, high relative humidity was unfavourable to the crop, which caused to increase the disease severity during the year 2004 compared to year 2005. It is obvious that, in the year 2005 it was able to observe only yellow mosaic virus while other diseases were not found at measurable level. Because the most of the environmental conditions were favourable to the crop resulted that initiation of diseases was hardly found. However, the dry situation in the cropping period was favourable to spread of mosaic disease.

5.4 CHARACTER ASSOCIATION

5.4.1 Correlation studies

Correlation analysis gives a picture of association pattern of different yield related characters with seed yield among themselves. Seed yield is a complex quantitative character governed by a large number of genes. For the rational approach towards the improvement of the yields, selection has to be made for the component of the yield. Genetic correlation between different characters of plant often arises because of either linakge or pleiotropy (Horland, 1939). The correlation pattern is expected to differ with material that is studied, since it is a reflection of the genetic make up of the population.

In this investigation, harvest index recorded the highest value of phenotypic correlation that was highly significant with seed yield followed by the number of pods per plant. The same trend was observed in both the seasons. Suma (2001) also recorded same results. While, Sharma *et al.* (1988) Patil *et al.* (1989) concluded that improvement of seed yield, should be based on selection for number of pods per plant and number of seeds per pod.

Plant height was positively associated with seed yield per plant and the pod length, seeds per pod, hundred seed weight were also positively and significantly associated with the seed yield. Belhekar *et al.* (2003) revealed that seed yield per plant estimated positive and significant association with plant height and hundred seed weight both at the phenotypic and genotypic levels. This shows that selection based on these characters to be effective in improvement of seed yield. Hundred seed weight showed positive significant phenotypic association with seed yield in both the seasons. The harvest index showed positive phenotypic correlation but not significant. Seeds per pod was positively correlated with hundred seed weight and harvest index and the correlation of harvest index was highly significant in 2004 while hundred seed weight was highly significant in 2005. By improving these traits one can increase the yield per plant because of these characters were positively associated. Patil and Baviskar (1987) concluded that yield improvement should be based on test weight. The Pod length positively and significantly associated with seed yield per plant, harvest index, seeds per pod and pod length. This character also showed positive association with the same characters during *summer* 2005. This association indicates that one can improve the seed yield per plant by increasing the performance of these characters. Number of pods per plant showed significant positive association with seed yield. Pod length, seeds per pod and harvest index were associated significantly and positively with number of pods per plant and the positive association were observed in same characters during *summer* 2005. Selection will be efficient if the breeders take the advantage of these characters for increasing the yield per plant.

Positive, significant association of number of clusters per plant with seed yield was observed. Harvest index, seed yield per plant, pod length, and pods per plant were positively associated with number of clusters per plant in both the seasons. Use of these characters to increase the seed yield through increasing the clusters per plant via increasing the pods per plant due to direct association of characters will be much effective. However, germination percentage was negatively associated with seed yield per plant in both the seasons.

5.4.2 Genotypic correlation

Significant positive genotypic association with plant height and seed yield per plant, pod length, seeds per pod and hundred seed weight was observed, while the other studied characters such as harvest index, number of pods per plant, clusters per plant, branches per plant, days to physiological maturity, days to flower initiation and days to flower termination were positively associated with plant height. To increase the seed yield per plant, manipulation of the plant height can be practiced however, increasing of plant height more would be a reason for lodging like unfavourable effects. Days to flower initiation was positively associated with seed yield except harvest index. Other characters showed positive association with days to flower initiation. Branches per plant was associated significantly with seed yield per plant and the clusters per plant, pods per plant and harvest index was associated positively with branches per plant. Through increasing branches per plant one can increase the seed yield through increasing clusters per plant and pods per plant because of this significant positive association.

Clusters per plant was positively associated with seed yield per plant, pods per plant and pod length, while seeds per pod and harvest index also showed significant positive association with clusters. Venkatesan *et al.* (2003) reported that the number 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 genotypic and phenotypic levels. This shows that selection for more number of clusters leads to improvement in number of pods per plant there by seed yield per plant. Pods per plant showed positive significant association with seed yield per plant that can be directly utilized for selection. The pod length, seeds per pod and harvest index were also associated positively with pods per plant. Pod length was positively associated with seed yield per plant and seeds per pod, hundred seed weight and harvest index was associated positively and significantly with pod length. This shows that selection for pod length leads to improvement in seeds per pod, harvest index and hundred seed weight there by seed yield per plant.

Seeds per pod recorded significant positive association with seed yield per plant. Harvest index and hundred seed weight were positively associated with seeds per pod. The selection for these characters resulted to increase the seed yield per plant. Hundred seed weight is highly heritable trait and this character associated positively with seed yield per plant and harvest index. Hundred seed weight showed positive and highly significant association with seed yield per plant.

Seed yield per plant possessed positive significant association with plant height, number of branches per plant, number of clusters per plant, pods per plant, pod length, seeds per pod, hundred seed weight and harvest index. The association of these characters with seed yield per plant shows that these characters are the chief yield attributing characters in cowpea. Similar findings were reported by Uma (2001), Hadapad (2001) and Suma (2001) while Hanumanthraya (2003) reported seed yield per plant possessed positive significant correlation with number of pods per plant, number of seed per pod, number of pods per cluster and number of pods bearing branches.

Based on phenotypic and genotypic association between yield and yield attributing characters, it is suggested that selection should be made for the characters, which are having positive significant association to improve the seed yield per plant in cowpea.

5.5 PATH COEFFICIENT ANALYSIS

Partitioning of phenotypic and genotypic correlation into direct and indirect effects revealed the interesting picture regarding character association. Further, it provides an insight in to the interrelationship of various characters with seed yield.

In the present study, all the 11 characters *viz.,* germination percentage, plant height, days to flower initiation, days to flower termination, days to physiological maturity, number of clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight and harvest index were considered for the path analysis. Among the eleven characters, eight characters showed positive association with seed yield in both the season.

Positive direct effects showed by days to flower initiation, clusters per plant, pods per plant, hundred seed weight and harvest index in both *Kharif* 2004 and *summer* 2005. Sawant (1994) revealed that pods per plant had the highest direct effect on seed yield followed by hundred seed weight, seeds per pod and pod length and Patil *et al.* (1989)

reported pods per plant, hundred seed weight and seeds per pod had greatest positive direct effect on yield. Maximum direct positive effect on seed yield was recorded by harvest index in both the seasons. This character showed significant positive association with seed yield. Direct effect of hundred seed weight on seed yield was positive in both seasons and showed higher association with seed yield. But its indirect effects through other characters were low while its higher indirect effects through harvest index. Oseni *et al.* (1992) concluded that major components of contributing to seed yield were days to flowering, hundred seed weight, days to pod filling and pod length. Similarly, Siddique and Gupta (1991a) reported that pods per plant, hundred seed weight and seed per pod as major yield attributing characters. The direct effect of seeds per pod was considerably high. The indirect effect through the harvest index was high while other indirect effects through other characters were comparatively low. It showed positive significant association with seed yield per plant. Selection through this character itself and through improving harvest index one can increase the seed yield per plant.

Comparatively higher direct effect was observed by the number of pods per plant, while the indirect effect through harvest index was high and the trait showed high association with seed yield in both seasons. There is a higher scope for selection through these traits to improve the yield per plant at both genotypic and phenotypic levels.

Clusters per plant had positive direct effect in both seasons and at phenotypic and genotypic levels. It showed higher indirect effect through harvest index. The high positive association with seed yield per plant was observed under genotypic and phenotypic levels in both the seasons. Comparatively higher indirect effect was observed through pods per plant.

The direct effect of phenotypic path coefficients of days to flower termination and physiological maturity was negative in *kharif* 2004 and the association of these traits with seed yield was also negative and the indirect effects through other characters were not much higher while, in summer 2005, days to flower termination recorded negative direct effect whereas the days to physiological maturity showed positive direct effect. However, both the characters positively associated with seed yield during *summer* 2005. The indirect effects through the characters such as germination percentage, seeds per pod and hundred seed weight showed negative indirect effects. High indirect effects of the characters recorded through harvest index. Both the characters showed phenotypic negative direct effects to seed yield in 2004 while in 2005, negative direct effects showed by only days to flower termination. However, the association with seed yield was positive during 2005 where as in 2004 it was negative. Therefore, selection through these characters either at genotypic level or phenotypic level in both the seasons was not effective for seed yield per plant.

The direct effects and indirect effects of germination percentage were low and negative association with seed yield was also observed in both the season. Most of the indirect effects through other characters were negligible. So the germination percentage cannot be used for selection for seed yield.

Hence, the perusal of correlation and path analysis studies of the present investigation during both the seasons revealed that pods per plant, clusters per plant, hundred seed weight and harvest index as highly important yield components in the order of having direct bearing on the improvement of seed yield per plant.

All these studies envisage that considerable variability exists in quantitative characters. It is more rewarding, if selection is carried on multiple characters related to seed yield than one or two characters.

5.6 GENOTYPE AND ENVIRONMENT EFFECTS

An understanding of the nature and degree of interaction played by the genotype with environment is of major importance to augment the productivity of any crop. In the present study, 169 cowpea genotypes were tested to identify the season and genotype interaction effects.

The analysis of variance was conducted for yield and yield components in two seasons of the study indicated that the presence of significant variability of genotypes for all the thirteen characters. Lopes *et al.* (2000) recorded high genetic variation for most of the studied traits of cowpea. Except germination percentage, significant variability among environments was present, while germination percentage did not show variability over the season at any level.

The genotype and season interaction exhibited significance for all the characters, which suggests that genotypes interacted considerably with the environments in the expression of characters, and behaved differently under the different seasons. Chattopadhyay *et al.* (2001) revealed that significant interaction between genotypes and environment for all the characters except pod length. However, magnitude of genotype and season interaction variance was smaller as compared to the variance due to genotype and season where as the plant height showed high value of genotype and season interaction over the genotype variability.

The results of the experiment showed that the genotypes having specificity to favorable environment which indicated by the significant genotype and season interaction while the genotypes did not show such specificity over environment in number of branches per plant which indicate that prediction for this trait for most of the genotypes are dependable on the environmental condition. While, Cisse (2001) stated that, the most productive genotypes can be identified through concomitant selection for yield in high productivity environments and for harvest index in low productivity conditions. Prediction of characters for most of the genotypes appeared independent to the environmental condition existed in the seasons of testing.

5.7 GENETIC DIVERSITY ANALYSIS

Diversity available in the crop decides the success of any crop improvement programme and the assessment of the divergence in the germplasm is essential to know the magnitude of the diversity. D^2 statistic has been employed widely to resolve genetic divergence at inter varietal, sub species and species levels in classificatory problems in crop plant (Murthy *et al.*, 1967 and Siddique and Swaminathan, 1971).

The magnitude of variability and its qualitative estimation for each character would only indicate the potentiality of the collection and the scope for improving the studied character through selection.

In present investigation, 169 genotypes of cowpea were considered for assessment of nature of genetic diversity between genotypes by cluster analysis of which were grouped into 51 clusters and 46 clusters during *kharif* 2004 and summer 2005 respectively. It is indicating that wide diversity is present in the experimental material for majority of the characters. Renganayaki and Rangasamy (1991) reported that cowpea genotypes were grouped into four clusters, Borah and Khan (2002) subjected to 60 genotypes to D^2 statistics and grouped in to ten clusters. The diversity was found in both exotic and indigenous collections of cowpea in both the seasons.

The contribution of each character towards genetic divergence was estimated. It was observed that highest contribution to divergence by number of pods per plant followed by harvest index. Santos *et al.* (1997) revealed that hundred seed weight and pod length were most important characters to affect divergence while, Bakiyarani *et al.* (2000) concluded single plant yield and earliness in flowering together accounted for 80 per cent of the total genetic divergence. Among the character studied the least contribution by hundred seed weight whereas Renganayaki and Rangasamy (1991) reported that hundred seed weight, pod length and seed yield contributed most towards genetic divergence. The genotypes representing diverse agro climatic conditions were distributed at random among the clusters formed based on their genetic divergence. Maximum number of nine genotypes in cluster 5 was the largest one followed by 1, 2 and 12 clusters consists of seven genotypes. Other than the solitary clusters, 45 cluster involving two genotypes, which are IC243353 and IC253181. The clusters of 21, 24, 29, 30, 33, 34, 36, 37, 38, 40, 41, 42, 43, 44, 46, 47, 48, 49, 50 and 51 were solitary clusters which was having single genotypes. The maximum intra cluster distance was observed for cluster 47 involving the genotypes IC202809 followed by cluster 19 involving the genotypes IC215015, IC219872, IC202901, IC208618, IC249132 and IC249586.

The highest inter cluster distance of 351.57 was observed between clusters 12: 47 followed by 350.15 between 8: 50 clusters. Based on the mean values of different clusters, the mean seed yield per plant was highest in cluster 33 involving only one genotype IC253277 followed by cluster 41 involving Bilahongal Local.

The diversity was found in 169 of both exotic and indigenous collections of cowpea genotypes were grouped into 46 clusters using D^2 statistics during summer 2005. It indicated that very high divergence in the genotypes evaluated. The contribution of each character towards genetic divergence was estimated. It was observed that highest contribution of 14.75 percent was number of pods per plant. Among the characters studied the least contribution of 0.97 percent, by hundred seed weight.

Maximum number of seven genotypes was found in clusters 6, 8 and 9. These were the largest clusters followed by 1,2, 5,10 and 24 clusters consist of six genotypes. Other than the solitary clusters, 19 cluster involving three genotypes, which are IC97787, IC198327 and IC97838. The clusters of 25,28, 31, 32, 33, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45 and 46 were solitary clusters, which is having single genotypes. The maximum intra cluster distance of 30.53 was observed for the cluster of 37 involving the genotypes IC253181, IC253281, IC257435, IC259061 and IC259081 followed by cluster 10 involving the genotypes IC202730, IC202781, IC202799, IC202841, IC202893 and IC202813.

The highest inter cluster distance of 349.31 was observed between clusters 11:42 followed by 346.10 between 34:46 clusters. The genotypes of early maturing, high yielding and disease resistance were IC259084, IC97834, IC97838, IC198333 and IC97787 respectively, which were belonging to clusters such as 15, 24, 28, 19, 11, and 1 respectively. In future, these genotypes can be utilized for the hybridization programme to increase the grain yield per plant with desirable traits. In respect of mean values of different clusters, the highest mean seed yield of 24.53 g/plant was observed in cluster 40 involving only one genotype IC97830 followed by cluster 43 involving EC394745.

On the basis of diversity study, it is clear that contribution of different traits towards yield and it can be achieved by selecting the diverse genotypes for further breeding programme to improve the seed yield per plant with favorable traits.

FUTURE LINE OF WORK

1. Further evaluation of identified promising genotypes over locations and years.
2. Hybridization programme between following genotypes would be needed for development of unique varieties

- High yielding and disease resistance

  IC257420, IC257422, IC202803 Vs. IC198333, IC97787
- High yielding and mosaic virus resistant

  IC257420, IC257422, IC202803 Vs. IC97829
- High yielding and short duration

  IC257420, IC257422, IC202803 Vs. IC259071, IC259084
- High yielding and bold seeded

  IC257420, IC257422, IC202803 Vs. IC202784, IC202781
- Disease resistance and bold seeded

IC198333, IC97787 Vs. 202784, 202781

3. Identified resistant genotypes for the diseases should be confirmed under artificial inoculation condition.
4. Molecular studies need to be carried out to estimate the genetic diversity among selected genotypes.

VI. SUMMARY

Profound knowledge on variability of the genetic material would be gained in any of the breeding programmes. Continuous breeding will be ceiling the further improvement of yield in any crop through narrow down the variability among genotypes. One of the ways to increase the variability is introduction of genetically diverse new genotypes. An experiment was conducted at Botany garden, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad during *kharif* 2004 and *summer* 2005 seasons with the objectives to assess the genetic variability, genetic divergence of genotypes and to study the magnitude of association consisting of genetic material collected from various divergent environments

The most salient results of the study are summarized in this chapter.

The genotypes revealed that high significant variability for all the tested traits such as germination percentage, Plant height, days to flower initiation, days to flower termination, days to physiological maturity, number of branches per plant, number clusters per plant, number of pods per plant, pod length, seeds per pod, hundred seed weight, harvest index and seed yield per plant. High variation recorded for all the characters except plant height, days to flower initiation, days to flower termination days to physiological maturity and number of branches per plant.

All the PCV values were higher than the GCV values for each character. The high PCV and GCV values were recorded by seed yield per plant, hundred seed weight, harvest index, number of pods per plant, and germination percentage. Low GCV and PCV values were recorded in days to flower initiation, days to flower termination and days to physiological maturity. Both GCV and PCV values showed similar pattern of changing over the characters.

All the characters showed high heritability except seeds per pod, pod length and number of branches per plant. The highest heritability was recorded by hundred seed weight. High genetic advance was observed for germination percentage, plant height, number of cluster per plant, number of pods per plant, hundred seed weight, harvest index and seed yield per plant.

Genotypes screened against four main diseases such as mosaic virus, rust, powdery mildew and bacterial leaf blight could be grouped into five groups such as resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible. None of the genotypes found as immune for any of the diseases tested. Two of the genotypes IC198333 and IC97787 found to be resistant for all the diseases. IC97787 was high yielding genotype, which recorded resistance to all the tested diseases.

The observed four qualitative characters such as stem colour, plant type, flower colour and immature pod pigmentation showed high variability for each. The highest percentage of genotypes recorded for stem colour, plant type, flower colour and immature pod pigmentation were none; no special pigmentation on stem (57.99%), intermediate bush (43.79%), mave pink (85.78 %) and none; no pigments on pods respectively.

The highest significant phenotypic association of harvest index could be observed with seed yield followed by pods per plant. Hundred seed weight, seeds per pod, pod length, clusters per plant, branches per plant and days to flower initiation recorded positive association with seed yield while, germination percentage associated negatively with the seed yield per plant. Pod length positively associated with hundred seed weight. The clusters per plant and pods per plant were positively associated with harvest index and seeds per pod. The clusters per plant, pods per plant and pod length were positively associated with seeds per pod.

The highly significant positive genotypic association was recorded between seed yield and harvest index. Hundred seed weight, seeds per pod, pod length, number of pods per plant, number of clusters per plant, branches per plant and days to flower initiation recorded positive genotypic association with seed yield. High positive association was observed between days to flower initiation and days to physiological maturity, clusters per plant and number of pods per plant and pod length and seeds per pod.

Highly significant variation was present among the genotypes and significant variation was present between environments except for germination percentage. The genotype and season interaction exhibited high significance for all the characters except for number of branches per plant

Positive direct effects were recorded by days to flower initiation, clusters per plant, pods per plant, hundred seed weight and harvest index. Among them, the highest direct effect on seed yield was recorded by harvest index at both phenotypic and genotypic level. Harvest index and hundred seed weight had positive indirect effects of pod length and seeds per pod at phenotypic level. The highest positive indirect effects of clusters per plant, pods per plant and hundred seed weight were observed through harvest index, both at phenotypic and genotypic level.

All studied characters contributed to diversity, in which the highest contribution was recorded by the number of pods per plant followed by harvest index where as the least contribution to diversity was by hundred seed weight. Based on D^2 values, genotypes were grouped into 51 clusters, in which the most divergent clusters were 12 and 47 followed by 8 and 50. Genotypes in cluster 33 had higher plant height which was more productive than others with respective to seed yield during *kharif* 2004. While genotypes were grouped into 46 clusters in summer 2005, in which the highest divergent clusters were 11 and 42 and the cluster 40 was the highest productive in respect to seed yield.

Based on the overall performance of the studied genotypes, very high variation was observed among genotypes for the studied traits with high GCV, PCV, heritability and GAM for the characters of germination percentage, number of pods per plant, hundred seed weight, harvest index, and seed yield per plant. High variability was observed for the disease resistance and qualitative characters. Highest genotypic and phenotypic association was recorded between seed yield per plant and harvest index followed by pods per plant while highest direct effect recorded by harvest index. The highest contribution for the diversity was observed through number of pods per plant followed by harvest index.

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Appendix I: Mean values of different traits in cowpea during *kharif* 2004

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
IC257410	87.00	38.50	51.00	72.50	85.00	3.10	8.50	19.50	12.00	11.00	7.75	0.20	9.90
IC257411	78.00	41.00	52.50	71.00	83.00	4.00	9.50	11.50	11.50	10.50	8.20	0.23	10.30
IC257420	99.00	38.50	57.50	69.50	77.00	3.85	11.00	31.50	12.00	10.00	8.45	0.26	25.85
IC257422	75.00	48.00	54.50	69.00	75.00	3.95	8.50	25.50	12.00	11.50	6.60	0.24	22.60
IC97767	66.00	39.00	55.00	68.00	72.50	3.95	13.00	20.00	15.50	14.00	13.50	0.26	24.00
IC97787	57.00	43.50	58.00	76.00	87.00	4.10	10.00	18.50	12.50	11.50	9.35	0.22	18.90
IC97806	61.00	44.00	55.00	71.00	83.00	4.00	10.80	20.50	16.50	12.00	7.45	0.19	16.60
IC97806	57.50	44.50	55.00	74.00	81.50	3.80	9.50	14.50	12.50	10.25	8.50	0.18	14.90
IC97829	56.00	42.50	60.00	78.00	85.00	4.05	11.50	20.00	12.50	12.00	10.50	0.19	11.00
IC97830	85.00	46.00	56.00	68.00	72.00	3.95	9.50	14.00	15.00	12.00	10.95	0.23	15.00
IC97830	98.50	47.50	54.00	65.50	73.00	3.50	6.50	14.00	17.00	12.00	11.05	0.22	12.30
IC97834	56.00	43.00	55.00	64.50	73.00	4.20	13.50	26.00	12.00	10.00	9.70	0.25	26.20
IC97838	56.50	37.00	54.00	68.50	74.00	4.00	8.50	11.50	12.50	9.00	7.00	0.20	9.10
IC97856	99.00	45.50	57.00	68.50	74.00	4.15	8.50	12.50	12.00	11.50	8.15	0.16	10.00
IC15567	99.00	46.50	66.00	80.50	89.50	3.80	9.50	10.00	14.50	13.00	10.95	0.25	17.60
IC91556	66.00	48.00	62.00	73.00	83.00	4.00	6.50	9.00	13.50	11.00	11.45	0.22	12.50
IC97764	65.50	39.50	55.00	75.00	84.00	4.00	8.80	17.00	13.50	12.00	10.30	0.22	19.30
IC198321	39.50	39.00	57.50	79.00	85.50	4.00	10.10	20.50	11.00	10.00	6.60	0.20	11.00
IC198323	72.00	36.00	55.00	77.00	85.50	3.35	8.00	10.00	14.00	12.00	13.05	0.25	14.80
IC198327	85.00	47.50	54.00	79.00	84.00	3.20	8.50	11.00	14.50	12.00	8.05	0.22	11.20
IC198333	48.00	48.50	69.00	81.00	84.00	4.00	7.50	14.50	11.75	9.75	9.45	0.18	12.95
IC198335	74.00	43.50	60.00	74.00	79.50	3.35	8.00	16.50	12.75	11.00	10.40	0.12	10.85
IC198342	32.00	41.50	56.50	73.00	81.00	3.90	9.50	15.50	11.50	11.00	11.35	0.16	11.00
IC198349	99.00	39.50	55.00	79.00	84.00	4.00	7.50	10.00	10.50	9.50	7.80	0.16	8.15
IC198355	77.00	43.00	58.00	73.50	86.50	3.50	6.50	10.00	12.00	11.50	9.90	0.20	13.80
IC198359	85.50	42.50	60.00	77.00	84.00	3.00	8.50	14.00	13.50	12.50	10.95	0.28	18.90
IC198361	98.00	49.00	46.00	71.00	83.00	4.00	6.00	9.00	12.50	11.50	9.45	0.17	10.00
IC199701	99.00	46.00	50.00	75.00	84.00	3.95	11.00	12.00	11.00	10.00	7.95	0.19	11.70
IC199704	87.00	39.00	51.00	78.50	81.00	3.70	7.50	11.50	12.00	10.50	10.75	0.20	11.60
IC201079	86.00	58.00	49.00	67.00	72.50	4.20	9.00	16.50	13.50	12.50	11.10	0.24	24.20
IC201087	88.00	47.00	55.00	70.50	73.00	3.00	9.50	16.00	13.25	10.90	8.56	0.18	15.95
IC201095	99.50	53.50	55.00	70.00	74.00	4.10	7.50	11.00	11.00	10.50	11.60	0.20	14.35
IC201099	98.50	39.00	67.00	79.00	83.00	3.50	5.00	6.50	10.00	7.50	9.50	0.15	6.50
IC202705	98.50	37.50	49.50	66.50	74.00	2.80	5.50	7.50	11.50	10.00	11.10	0.15	8.00
IC202707	99.00	45.00	53.00	64.50	72.00	2.90	6.00	6.50	12.00	11.00	9.70	0.15	8.20
IC202709	58.00	41.00	48.50	63.00	69.00	4.00	10.50	11.00	10.50	9.00	6.75	0.20	12.80
IC202710	91.50	37.00	46.00	64.50	71.00	3.50	7.50	9.50	9.50	7.50	8.60	0.15	6.40
IC202718	95.00	42.50	51.00	73.50	82.50	3.35	10.50	12.50	12.00	11.00	8.35	0.25	15.80
IC202720	85.00	47.50	47.50	67.00	73.00	4.25	9.90	11.50	12.50	11.50	10.65	0.26	21.40
IC202730	78.00	49.00	49.50	68.00	74.00	3.40	4.00	8.00	10.50	9.50	8.80	0.22	8.00
IC202743	57.00	45.00	64.00	79.00	86.00	3.65	8.00	13.00	12.00	9.50	10.85	0.16	11.20
IC202762	70.50	49.00	52.50	72.00	78.00	3.90	10.50	11.00	13.50	11.50	10.60	0.16	11.40
IC202772	77.00	57.00	55.50	72.00	77.00	3.65	7.50	15.50	11.50	8.50	11.25	0.18	14.70
IC202775	77.50	46.00	50.00	70.50	81.00	3.50	5.50	7.50	8.00	7.00	11.50	0.17	8.00
IC202778	68.00	44.50	56.00	73.00	79.00	3.00	5.50	8.50	13.50	11.00	14.80	0.18	13.10
IC202779	87.00	42.50	51.00	71.00	73.00	3.65	5.50	9.00	14.00	11.00	19.75	0.18	13.80
IC202781	44.50	39.00	59.00	70.50	79.00	3.50	4.00	4.50	14.00	11.00	22.10	0.21	16.00
IC202782	85.00	41.50	51.00	75.50	81.00	4.00	9.50	10.50	11.50	11.00	9.35	0.23	11.90
IC202786	85.00	50.50	59.50	75.50	81.00	4.00	5.50	7.50	11.50	10.50	19.55	0.11	10.20
IC202787	58.50	45.00	55.00	73.00	79.00	3.40	8.00	12.00	14.50	11.00	21.95	0.20	13.90
IC202789	67.00	43.50	57.00	74.50	81.50	3.50	5.50	8.50	13.50	10.50	17.00	0.19	10.70
IC202791	98.50	35.00	48.00	75.00	80.00	2.50	4.00	6.00	9.50	8.50	6.70	0.16	7.00
IC202797	99.00	43.00	63.00	79.00	81.00	4.25	12.50	15.50	12.00	11.00	17.03	0.26	23.50
IC202799	86.00	38.00	56.00	79.50	82.50	4.70	9.00	14.50	10.00	9.50	5.05	0.19	7.80
IC202803	89.00	44.00	47.00	73.00	79.00	3.70	8.00	15.00	15.00	14.00	11.90	0.26	23.90
IC202804	69.00	38.00	54.00	83.00	90.00	4.00	11.00	15.50	13.50	13.50	9.65	0.21	13.60
IC202809	68.00	32.50	58.50	75.00	87.00	3.00	4.00	6.50	10.00	8.50	5.35	0.14	5.20
IC202823	99.00	41.50	61.00	77.50	84.00	4.30	16.50	20.50	13.50	13.50	9.35	0.28	22.90
IC202824	85.00	38.00	51.00	73.50	81.00	3.50	6.00	8.00	13.00	12.50	10.00	0.20	8.90

Appendix I contd…..

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
IC202835	99.00	38.50	52.00	69.50	73.50	3.00	4.50	9.50	11.50	11.00	9.95	0.20	10.90
IC202841	63.00	43.50	58.00	70.00	74.00	3.70	7.50	9.00	12.50	11.00	8.10	0.13	6.80
IC202846	53.00	39.50	54.50	68.00	75.00	3.58	7.00	6.50	12.00	11.50	7.10	0.08	4.90
IC202854	68.00	38.00	66.00	75.00	81.00	4.20	11.00	12.50	10.50	9.50	9.25	0.23	10.90
IC202860	70.00	40.50	61.50	77.00	84.00	3.90	8.50	12.50	12.50	11.50	6.25	0.15	9.40
IC202867	68.00	38.50	56.00	73.50	83.50	3.90	11.00	11.00	12.50	11.50	10.45	0.22	15.15
IC202868	53.00	47.00	76.50	87.00	95.00	3.80	3.50	3.50	12.35	9.90	9.10	0.05	5.30
IC202873	75.00	38.00	63.00	72.50	78.00	3.40	4.00	5.50	10.50	8.00	10.70	0.20	9.70
IC202893	55.00	39.00	62.00	79.00	89.00	3.90	8.50	12.50	16.00	10.00	14.70	0.20	12.70
IC202901	99.00	46.50	65.00	82.50	94.00	2.90	11.00	11.50	15.00	11.50	16.30	0.25	17.00
IC202924	68.00	33.50	61.00	71.50	80.00	3.50	7.50	10.50	12.50	9.50	10.75	0.13	8.70
IC202926	99.00	40.50	65.00	81.50	85.00	3.50	10.50	11.00	13.50	12.00	10.05	0.19	14.10
IC202927	59.50	26.00	49.00	66.00	74.00	3.00	4.00	6.00	8.50	7.00	7.15	0.18	10.60
IC204103	85.00	44.00	55.50	78.50	91.00	3.40	7.50	10.00	13.00	10.00	10.15	0.17	8.60
IC206240	86.00	39.50	53.00	75.00	87.00	4.00	7.00	11.50	12.00	9.50	7.65	0.21	13.30
IC207813	75.50	41.00	53.00	73.00	78.50	3.80	9.50	10.50	12.00	11.00	10.85	0.11	6.40
IC208618	68.00	45.00	55.00	73.50	81.00	4.10	7.50	9.50	10.00	11.50	10.15	0.22	13.00
IC214752	98.50	44.00	50.50	70.50	76.50	4.10	7.50	12.50	12.50	11.00	12.05	0.22	15.90
IC214759	89.00	45.00	52.50	71.00	79.50	4.00	7.50	12.00	13.00	11.00	10.20	0.18	11.20
IC214833	99.00	34.50	53.50	71.00	79.00	3.50	6.50	11.00	12.00	11.00	11.75	0.18	11.20
IC214834	87.00	47.00	54.50	73.50	78.50	3.60	5.00	10.50	12.50	10.50	9.15	0.16	8.00
IC214835	86.50	42.50	52.00	67.50	73.00	2.70	8.50	10.50	12.50	10.50	9.50	0.15	9.00
IC214836	68.00	39.00	51.50	71.00	81.00	2.40	6.50	9.50	15.50	13.00	12.10	0.19	12.60
IC215015	15.00	36.50	52.50	76.50	91.50	3.50	7.50	10.00	12.00	10.50	10.30	0.18	8.10
IC219141	45.00	40.00	52.00	73.00	91.00	3.72	5.00	11.00	14.00	10.50	9.05	0.19	12.90
IC219574	98.50	32.50	49.00	71.00	77.00	3.00	9.50	7.50	10.50	9.50	13.40	0.15	8.90
IC219592	19.00	37.50	46.00	59.50	71.00	3.90	6.00	9.00	11.50	10.00	8.35	0.20	11.20
IC219594	98.00	43.50	57.00	66.00	76.00	5.50	10.00	12.00	11.50	10.50	11.40	0.22	16.10
IC219607	78.00	37.50	53.00	65.50	76.50	4.50	9.50	10.50	12.00	10.50	10.50	0.19	11.10
IC219640	68.00	39.00	48.00	69.50	75.00	3.40	5.00	9.50	12.50	10.50	10.00	0.16	10.00
IC219872	56.50	40.50	48.50	61.00	75.00	4.50	9.50	9.50	10.00	7.50	11.75	0.19	9.90
IC243312	63.00	49.00	53.50	67.50	74.00	3.50	7.00	15.00	13.00	9.00	11.60	0.22	14.30
IC243353	54.00	37.50	60.50	70.50	76.50	4.50	6.50	10.50	13.00	11.50	11.10	0.22	13.00
IC243486	75.50	37.00	49.00	59.00	66.00	3.50	3.00	6.50	8.50	7.00	7.40	0.18	11.90
IC243489	85.00	42.50	49.00	64.50	73.00	3.90	10.00	11.50	13.00	10.00	13.00	0.20	15.00
IC243501	89.00	43.00	54.00	66.00	74.00	4.50	6.50	7.00	12.00	10.00	11.80	0.19	10.70
IC247430	68.00	38.00	51.50	65.50	77.00	5.50	7.50	13.00	12.00	11.50	5.95	0.17	10.30
IC249132	79.00	46.00	56.50	66.00	74.00	3.00	5.50	8.50	11.50	11.00	11.95	0.14	8.10
IC249133	98.50	43.50	56.00	67.00	73.00	4.50	9.50	12.50	12.50	11.00	8.10	0.25	15.35
IC249137	89.00	39.50	55.00	66.00	75.50	3.50	8.50	11.00	14.00	11.50	11.95	0.23	18.80
IC249140	99.00	37.50	54.00	61.00	73.50	4.00	7.50	13.00	12.50	11.50	8.70	0.22	13.00
IC249141	60.00	41.50	54.00	63.50	69.00	4.50	8.50	10.50	12.50	11.00	9.75	0.21	10.70
IC249583	99.00	49.50	54.00	73.00	85.50	3.50	7.00	12.00	12.50	11.50	11.05	0.08	5.30
IC249585	99.00	43.50	57.00	72.50	86.00	3.60	12.50	19.00	13.00	11.50	9.95	0.22	19.80
IC249586	70.00	45.00	55.00	80.00	85.50	3.50	9.50	11.50	12.00	10.50	10.75	0.16	9.10
IC249593	99.00	45.50	51.00	71.00	71.00	3.70	8.00	10.00	11.00	9.50	8.40	0.13	7.50
IC253181	82.00	38.00	49.50	66.00	75.00	4.50	4.50	6.50	11.50	9.50	12.55	0.11	6.00
IC253255	68.00	47.00	50.00	79.00	86.00	3.60	8.50	10.00	11.50	10.00	12.65	0.19	11.60
IC253268	68.50	35.00	53.00	81.00	85.50	4.00	7.50	12.50	12.50	11.00	12.17	0.17	10.10
IC253270	60.50	32.50	49.00	68.00	74.00	3.80	10.00	12.50	13.00	11.00	12.30	0.20	14.90
IC253275	44.00	46.00	49.50	68.50	74.00	3.60	10.00	13.00	14.50	13.00	16.15	0.23	17.70
IC253276	51.00	37.50	55.00	71.50	81.00	3.60	10.50	13.50	12.00	11.00	9.00	0.19	10.90
IC253277	86.00	58.00	51.00	77.00	85.50	4.00	12.00	14.50	12.00	10.50	11.10	0.27	19.80
IC253281	75.00	33.50	52.50	69.00	74.00	3.50	6.50	11.00	12.50	11.00	8.70	0.16	9.00
IC253288	94.00	51.00	57.50	78.00	83.50	4.10	10.50	11.50	11.50	9.00	8.55	0.21	13.45
IC257406	93.50	49.00	52.00	70.50	80.00	4.30	11.00	12.00	12.00	9.50	9.90	0.22	12.60
IC257407	80.00	39.00	55.00	81.50	89.50	4.50	7.00	11.50	12.00	11.00	8.95	0.16	9.40
IC257424	58.00	36.00	55.50	78.50	89.00	4.00	8.50	12.50	12.50	10.50	7.50	0.20	9.65
IC257425	66.00	39.50	55.50	64.00	76.00	4.50	11.50	12.50	11.50	11.00	9.20	0.19	13.60

Appendix I contd…..

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
IC257427	65.50	40.50	56.00	69.00	75.50	4.70	11.00	13.50	11.50	10.50	7.35	0.23	17.60
IC257435	57.00	40.50	60.50	71.00	80.00	4.00	9.50	12.50	11.00	11.00	9.80	0.18	10.20
IC257441	85.00	37.50	61.50	72.00	79.50	3.70	11.50	12.50	10.50	9.50	6.30	0.19	12.50
IC257445	87.00	41.50	54.00	69.00	74.00	4.50	7.50	7.00	11.00	10.00	8.25	0.15	7.35
IC257449	95.00	39.50	52.50	72.50	82.00	3.90	8.50	11.00	12.00	10.50	11.05	0.15	9.35
IC257452	86.00	40.50	52.50	71.50	78.50	4.50	11.50	14.00	11.00	9.00	9.10	0.19	14.80
IC257453	88.50	37.00	55.00	66.50	72.00	4.30	11.00	12.50	10.50	8.50	18.90	0.19	14.00
IC259058	68.00	43.50	55.00	67.00	75.00	4.50	13.00	13.50	10.00	8.50	7.25	0.22	15.70
IC259061	93.00	39.50	54.50	66.00	73.00	4.50	9.50	11.50	13.50	9.50	10.25	0.17	9.20
IC259063	86.00	40.00	56.00	69.50	74.50	4.00	7.00	8.00	11.50	9.00	9.20	0.16	7.90
IC259064	91.50	52.00	63.00	81.00	86.50	3.50	7.00	10.50	11.50	10.50	10.35	0.19	14.00
IC259069	94.50	39.00	51.50	68.00	75.00	4.50	9.50	12.50	13.00	11.00	6.10	0.15	9.40
IC259071	94.00	45.00	46.00	58.50	65.00	4.00	6.50	7.50	12.00	9.50	9.55	0.12	5.40
IC259072	89.00	33.00	53.50	71.00	76.00	3.70	5.50	8.50	10.50	8.00	9.70	0.13	6.80
IC259078	58.00	39.00	46.00	63.50	74.00	4.50	9.50	10.50	11.00	9.50	10.15	0.16	8.50
IC259081	63.50	40.00	49.00	65.00	73.00	4.50	8.50	10.50	11.00	9.00	8.30	0.20	11.35
IC259083	69.50	40.00	51.00	67.00	75.50	4.50	12.50	16.00	18.00	11.00	15.20	0.23	20.05
IC259084	68.00	36.00	43.50	58.00	63.00	3.50	12.50	12.50	11.50	10.00	15.30	0.20	16.70
IC259084	87.00	41.50	45.50	54.50	61.00	4.50	10.50	11.50	11.50	9.00	13.10	0.20	16.70
IC259085	86.50	49.00	54.50	69.00	75.00	4.30	8.00	11.50	12.00	10.00	11.15	0.18	9.00
IC259095	28.00	53.00	52.50	70.00	76.00	3.50	12.50	14.00	13.00	11.00	11.00	0.20	20.60
IC259100	61.00	52.50	53.50	69.00	75.00	4.50	8.00	11.00	12.50	10.50	12.10	0.18	12.80
IC259104	49.00	38.50	62.50	79.50	84.50	3.50	7.50	10.50	10.00	9.00	12.95	0.18	11.00
IC259105	80.00	44.00	54.00	69.00	75.00	4.00	7.00	9.50	11.50	11.50	8.40	0.16	9.90
IC259159	85.50	39.50	55.00	67.00	74.00	4.50	9.50	11.50	12.00	11.00	8.70	0.16	10.70
IC202784	76.00	41.00	56.00	70.50	79.50	4.40	7.50	9.50	13.00	11.00	22.90	0.18	14.90
IC201098	84.50	46.50	50.00	72.50	80.00	4.00	9.00	11.50	12.00	11.00	13.30	0.14	13.00
IC4506	63.00	36.00	51.00	72.50	81.00	4.10	8.50	10.50	12.50	11.00	10.70	0.16	10.90
IC5969	95.00	44.00	62.50	74.00	86.50	4.00	6.00	8.50	13.00	11.00	9.65	0.12	7.10
IC68786	30.50	46.00	49.00	67.00	74.00	4.00	7.00	9.00	10.00	7.50	10.10	0.16	11.00
IC68786	82.00	41.50	52.50	64.50	71.50	4.10	8.00	12.50	9.50	8.50	10.65	0.15	9.10
IC202702	70.00	38.00	51.50	69.00	74.00	3.50	7.50	10.00	11.00	11.00	9.80	0.12	6.50
IC202931	92.00	43.50	52.50	69.00	75.50	4.50	6.00	8.00	13.00	11.50	10.90	0.17	8.25
IC202932	90.00	42.50	54.50	70.50	76.50	3.20	5.50	6.00	14.00	12.00	12.25	0.11	4.80
IC247435	99.00	44.00	55.50	66.00	71.00	4.00	7.50	10.50	12.00	10.00	11.90	0.19	11.15
Goa local	46.50	47.00	55.00	71.00	77.00	3.25	6.85	15.00	14.50	12.65	12.80	0.23	20.85
C152	91.50	48.00	52.00	66.00	74.00	3.70	8.50	13.50	12.50	10.50	12.20	0.22	14.80
Bailhongal local	76.50	47.00	59.00	75.00	77.00	3.50	11.60	16.50	13.00	10.60	10.40	0.24	18.95
V118	66.50	50.00	50.00	63.00	65.50	4.00	8.50	12.50	14.50	10.00	12.40	0.16	11.75
EC394767	85.00	37.50	57.50	70.00	74.00	4.90	8.00	12.50	10.50	8.50	12.15	0.22	16.15
EC 394691	86.50	51.50	59.50	73.50	82.50	4.90	12.50	14.50	14.00	13.50	14.10	0.22	17.50
EC394823	77.00	42.50	60.50	76.00	83.00	3.50	7.50	10.50	12.00	8.00	15.75	0.15	9.90
EC394740	57.00	50.00	52.50	73.00	80.50	5.00	8.00	11.50	12.00	9.50	22.30	0.20	13.35
EC394855	80.50	49.00	59.50	72.50	79.00	4.50	7.00	10.00	12.50	12.00	13.75	0.19	12.05
EC394805	76.50	40.00	61.50	69.00	79.50	4.10	7.00	12.00	14.50	8.50	19.60	0.20	12.90
EC394753	90.00	50.00	61.50	73.50	84.00	3.50	8.00	10.50	9.00	13.50	11.05	0.20	14.30
EC394745	88.00	42.00	50.00	75.00	82.00	4.80	8.00	11.50	14.50	12.50	11.60	0.22	14.85
IC97764	69.50	39.50	59.50	72.50	83.00	4.50	8.50	12.00	13.00	10.50	11.50	0.14	8.80
IC257437	46.50	36.00	58.50	78.50	82.50	5.00	12.50	13.00	11.50	11.00	12.30	0.23	19.50
IC257447	75.00	39.50	59.50	79.50	85.00	4.00	6.50	8.50	13.00	11.00	13.90	0.16	6.90
GC3	84.00	54.00	61.50	76.50	85.50	4.50	11.50	12.50	12.50	11.50	14.00	0.19	13.80

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

Appendix II: Mean values of different traits in cowpea during Summer 2005

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
IC257410	84.00	37.00	61.00	74.00	76.50	3.70	11.00	16.60	12.20	11.20	8.17	0.24	16.75
IC257411	97.50	45.28	64.00	76.50	81.50	4.00	12.50	14.25	12.40	11.50	8.07	0.22	19.12
IC257420	92.50	42.55	60.00	72.00	74.00	5.00	13.00	24.60	10.85	9.95	8.26	0.28	25.02
IC257422	99.00	48.35	60.00	70.50	72.50	4.40	13.00	19.00	11.75	11.10	6.26	0.28	24.04
IC97767	82.50	36.85	61.00	72.00	74.00	4.50	15.00	22.00	10.50	9.80	13.97	0.27	21.06
IC97787	98.00	46.40	62.50	74.50	76.00	4.75	13.70	22.25	14.75	12.80	9.85	0.28	23.82
IC97806	96.00	43.75	63.50	75.00	76.00	4.50	12.65	22.10	16.96	16.01	9.18	0.18	14.39
IC97806	86.00	36.40	65.00	80.50	81.50	4.35	15.50	23.10	15.08	13.52	10.55	0.23	20.82
IC97829	37.50	34.65	59.00	70.50	72.50	4.10	13.00	24.00	15.72	13.09	10.85	0.28	21.21
IC97830	73.00	39.30	64.00	76.00	79.00	4.45	12.70	17.50	17.75	15.90	10.64	0.28	23.86
IC97830	47.50	40.85	62.50	75.50	78.00	4.15	11.50	23.55	13.23	12.60	10.30	0.27	24.53
IC97834	78.00	39.35	62.50	75.00	77.00	4.80	15.10	28.55	14.07	13.05	9.75	0.22	14.85
IC97838	77.50	42.10	58.50	71.50	73.00	4.30	15.35	26.95	13.99	12.30	7.30	0.28	25.80
IC97856	50.00	46.20	62.00	74.00	79.00	4.90	13.20	27.75	14.28	13.20	8.61	0.28	23.50
IC15567	95.00	40.55	66.00	78.00	80.00	4.15	9.70	16.85	15.85	14.70	10.90	0.19	15.15
IC91556	70.00	37.00	61.00	74.00	76.50	4.45	10.60	17.45	14.25	12.75	11.77	0.21	16.34
IC97764	87.50	45.20	59.50	73.00	75.00	3.88	10.85	16.00	13.93	12.05	10.70	0.21	14.95
IC198321	68.50	46.80	67.00	80.50	83.50	3.53	11.80	14.35	11.95	10.30	7.20	0.28	22.77
IC198323	79.00	46.75	60.50	72.00	74.00	3.90	10.05	14.85	15.90	13.85	13.50	0.19	12.78
IC198327	82.50	39.00	60.50	75.00	76.00	3.90	11.10	15.35	14.60	12.65	8.65	0.20	12.89
IC198333	81.50	43.70	68.00	79.00	81.00	4.35	10.10	17.50	15.07	12.49	10.00	0.18	13.66
IC198335	74.50	38.60	56.00	67.00	69.50	3.40	13.05	18.55	13.90	13.15	10.76	0.20	12.55
IC198342	72.50	39.95	61.00	75.50	78.00	4.25	11.95	17.35	14.22	13.04	11.11	0.18	10.50
IC198349	92.00	41.80	60.50	75.50	79.00	4.30	10.20	14.85	13.80	12.15	7.18	0.24	15.15
IC198355	79.00	45.25	58.50	76.00	79.00	3.80	7.35	16.45	15.50	14.08	10.65	0.21	15.52
IC198359	83.50	43.85	59.00	70.50	72.00	3.80	11.95	16.40	14.60	13.40	11.05	0.23	16.50
IC198361	79.00	39.75	61.50	71.50	73.00	3.70	8.00	14.00	13.18	9.22	10.45	0.19	12.28
IC199701	95.00	43.80	55.00	71.50	73.50	3.90	10.90	15.65	16.36	13.80	8.20	0.20	12.66
IC199704	92.50	51.40	52.00	67.50	69.50	4.30	10.00	18.25	17.25	15.73	11.30	0.13	12.52
IC201079	94.00	41.70	58.00	71.00	74.00	4.50	13.00	22.50	15.05	13.20	11.72	0.22	17.50
IC201087	69.00	43.75	60.50	77.00	76.50	3.20	13.75	19.40	16.27	14.40	9.86	0.22	14.62
IC201095	82.50	43.33	57.00	69.00	70.50	4.80	8.38	11.88	13.65	11.48	12.06	0.25	20.75
IC201099	72.50	51.55	56.50	73.00	77.00	4.00	7.10	11.25	12.14	11.10	10.00	0.18	11.91
IC202705	96.00	46.50	55.00	67.50	70.00	3.50	8.95	16.30	14.30	13.20	11.85	0.13	10.07
IC202707	92.50	55.50	61.50	73.50	76.50	3.85	8.50	16.75	15.60	11.35	10.15	0.26	19.42
IC202709	79.00	42.62	63.50	75.00	77.00	4.55	13.05	19.20	14.20	12.77	7.30	0.28	22.31
IC202710	87.50	43.90	59.50	71.00	73.00	4.15	12.75	17.15	14.85	13.20	9.40	0.28	22.09
IC202718	98.50	46.97	61.50	73.00	74.50	3.90	11.75	17.40	14.82	13.55	9.44	0.26	22.19
IC202720	92.50	39.85	58.50	73.00	75.00	4.80	11.50	14.55	13.68	12.90	11.37	0.18	9.05
IC202730	75.00	41.35	59.00	77.00	81.00	4.15	11.65	11.40	11.75	10.80	9.25	0.19	10.44
IC202743	87.50	41.50	60.00	74.00	76.50	4.40	12.75	22.75	15.60	13.15	10.95	0.18	13.55
IC202762	83.50	47.95	57.00	71.00	74.00	4.25	8.52	12.23	16.45	15.62	11.20	0.25	17.47
IC202772	70.50	40.75	54.50	71.00	74.50	3.85	10.50	13.95	15.70	14.55	11.93	0.14	10.80
IC202775	82.00	53.35	56.50	70.50	72.50	4.60	9.10	15.90	15.00	13.75	11.69	0.19	15.11
IC202778	92.50	41.45	64.00	76.00	78.50	3.35	8.70	16.45	14.60	13.30	15.05	0.29	20.33
IC202779	70.00	43.85	63.50	79.50	82.00	3.90	9.00	18.85	15.60	14.70	20.18	0.28	23.10
IC202781	59.00	39.45	60.00	70.50	73.50	4.10	9.20	12.85	16.10	14.25	22.67	0.28	22.54
IC202782	67.50	33.35	57.00	68.50	72.00	4.20	10.85	15.15	10.64	9.74	10.02	0.29	21.75
IC202786	52.50	34.20	60.00	73.00	74.50	3.55	8.80	13.85	12.95	11.85	20.05	0.28	23.53
IC202787	47.50	40.85	62.00	74.00	77.00	3.65	12.80	17.25	15.40	13.20	22.20	0.26	20.85
IC202789	69.50	44.30	60.00	72.50	74.50	4.10	7.60	16.20	14.30	13.10	16.95	0.27	20.90
IC202791	72.00	35.10	64.50	82.50	83.50	3.40	10.00	17.95	12.74	10.77	7.18	0.22	15.94
IC202797	46.00	43.20	72.00	81.00	82.50	4.55	13.40	20.50	14.40	12.90	16.88	0.29	21.88
IC202799	63.50	49.50	63.50	78.50	81.00	5.05	8.60	11.30	12.25	11.48	5.05	0.17	10.85
IC202803	68.00	34.60	60.50	73.00	75.50	4.00	10.25	12.50	15.80	13.90	12.09	0.28	23.50
IC202804	71.50	43.30	62.00	72.00	74.50	4.60	12.50	19.50	14.50	11.32	10.40	0.24	18.96
IC202809	97.50	32.90	64.00	77.50	79.50	4.20	11.75	18.00	10.25	9.65	5.56	0.15	8.10
IC202823	71.50	57.55	59.00	74.00	75.50	4.90	13.85	17.55	17.70	14.24	9.73	0.28	21.69
IC202824	46.50	42.00	55.00	70.50	73.00	3.90	9.00	12.00	14.03	11.85	10.70	0.25	17.05

Appendix II contd…..

	×1	×2	×3	×4	×5	×6	×7	×8	×9	×10	×11	×12	×13
IC202835	84.00	46.25	53.50	65.00	68.00	3.30	7.80	14.80	15.60	13.60	10.45	0.17	13.30
IC202841	43.50	40.10	57.00	71.00	73.50	4.10	8.45	11.45	13.07	10.80	8.55	0.13	9.05
IC202846	53.50	42.56	59.00	73.00	75.50	3.90	8.45	9.05	16.85	14.75	7.34	0.18	13.36
IC202854	97.50	41.15	60.00	73.00	76.00	4.65	12.30	16.15	13.05	12.40	9.50	0.23	13.34
IC202860	84.00	40.05	62.00	72.50	73.00	4.50	10.00	16.90	13.50	12.80	6.92	0.18	12.20
IC202867	68.00	41.00	56.00	70.50	74.50	4.20	11.80	19.95	17.00	15.25	11.24	0.20	15.92
IC202868	58.00	43.95	59.00	70.50	74.00	4.20	13.75	26.55	14.50	12.80	9.90	0.12	10.86
IC202873	74.00	34.50	63.50	75.00	76.00	3.90	6.15	13.00	13.45	12.10	11.10	0.23	14.54
IC202893	47.00	41.50	61.50	72.00	73.50	4.15	11.95	11.00	13.25	11.65	14.70	0.25	18.66
IC202901	73.50	43.35	63.50	77.00	78.50	3.65	11.75	10.40	14.30	12.15	16.92	0.20	15.66
IC202924	75.00	45.35	57.00	68.50	70.00	4.25	8.80	13.90	13.90	12.35	10.96	0.12	10.65
IC202926	94.00	46.35	63.50	75.00	79.00	4.20	11.85	16.20	14.55	13.65	10.14	0.25	19.80
IC202927	68.00	44.65	62.50	73.50	77.00	4.35	9.90	17.95	13.17	10.96	7.65	0.23	14.88
IC204103	60.00	34.65	63.50	74.50	78.00	4.00	9.05	16.70	12.95	11.85	10.40	0.22	15.83
IC206240	92.50	42.05	63.50	77.50	79.00	4.70	10.00	19.85	17.70	14.40	8.23	0.29	18.65
IC207813	16.00	41.00	63.50	75.00	76.50	4.10	10.30	14.85	15.18	13.62	11.30	0.12	11.06
IC208618	97.50	35.75	50.00	67.00	70.50	4.60	8.75	11.04	15.25	13.77	10.46	0.17	15.75
IC214752	90.00	45.35	62.00	72.00	74.50	4.40	7.90	15.95	16.02	14.30	12.22	0.16	12.89
IC214759	85.00	41.70	62.00	73.00	76.00	4.50	7.90	15.70	14.95	13.25	9.94	0.21	15.21
IC214833	95.00	46.60	61.50	73.50	76.50	4.10	9.00	15.10	13.07	11.80	12.59	0.23	13.93
IC214834	43.50	37.45	59.00	74.00	76.50	4.10	8.50	15.60	14.65	13.40	9.64	0.19	15.25
IC214835	77.50	41.70	64.00	77.00	80.00	3.70	9.60	13.80	18.70	16.01	9.90	0.25	22.34
IC214836	72.50	41.20	59.50	74.00	76.50	3.70	10.00	16.60	14.08	12.85	12.35	0.29	21.14
IC215015	64.00	41.80	58.00	71.50	74.00	3.80	8.85	10.50	16.00	13.80	10.70	0.19	10.02
IC219141	81.50	35.30	57.50	73.50	77.00	4.40	8.50	13.65	13.00	11.80	9.74	0.22	14.45
IC219574	69.00	43.85	58.00	70.00	73.50	3.40	11.10	13.40	13.02	11.28	13.51	0.15	10.98
IC219592	80.50	44.30	56.50	67.00	69.00	4.20	5.75	7.90	14.00	11.87	8.62	0.08	6.85
IC219594	96.00	38.30	67.50	83.00	84.00	6.25	11.35	16.30	13.08	12.12	11.95	0.25	14.93
IC219607	96.50	45.50	57.50	68.00	69.50	3.70	11.30	15.80	16.75	15.30	10.50	0.28	22.30
IC219640	84.00	50.00	75.00	86.50	89.50	4.50	5.90	8.05	13.65	12.75	10.65	0.26	17.95
IC219872	96.00	44.10	53.00	65.50	67.00	4.70	10.15	9.70	13.58	12.29	11.70	0.16	12.98
IC243312	62.00	45.40	62.00	76.00	79.00	5.10	9.50	18.20	16.76	15.00	11.84	0.20	14.66
IC243353	68.00	35.00	62.50	74.50	76.00	4.90	15.45	29.65	13.95	12.98	10.28	0.26	21.36
IC243486	92.00	45.35	52.50	65.50	68.00	4.85	8.60	17.60	13.95	12.07	7.98	0.20	16.19
IC243489	83.50	46.45	64.50	76.00	77.50	4.50	12.50	20.10	16.15	14.17	12.90	0.11	8.44
IC243501	80.50	39.60	57.00	69.50	70.50	5.00	7.15	10.55	14.65	13.33	12.11	0.17	9.81
IC247430	39.00	51.70	62.50	74.00	76.00	6.40	13.10	25.00	14.95	13.85	6.55	0.23	13.08
IC249132	97.50	46.55	59.00	74.50	77.00	3.40	13.70	22.10	18.08	16.20	12.34	0.14	13.10
IC249133	96.00	35.30	53.50	69.00	72.00	3.75	10.00	9.05	17.45	15.52	8.44	0.19	13.92
IC249137	92.00	45.00	59.50	71.00	74.00	4.10	9.25	11.20	17.52	15.48	12.46	0.22	16.01
IC249140	93.50	41.85	62.50	73.50	76.00	4.55	8.25	9.90	14.78	12.26	9.34	0.19	13.38
IC249141	88.50	40.10	58.50	73.50	76.00	5.20	9.60	13.30	16.26	15.03	10.27	0.15	13.33
IC249583	49.00	39.50	67.00	80.00	82.00	4.05	7.60	11.40	11.75	10.85	10.90	0.13	10.46
IC249585	98.50	41.20	63.00	74.00	77.00	4.10	13.35	15.35	14.21	13.10	10.35	0.25	20.53
IC249586	100.00	38.05	74.00	87.50	90.50	3.90	11.30	17.50	16.74	14.24	11.14	0.26	23.58
IC249593	95.50	50.90	66.50	78.00	81.50	4.00	13.60	13.50	15.23	13.70	9.11	0.14	11.86
IC253181	66.00	45.20	54.00	65.00	67.50	5.20	10.50	17.00	12.13	11.61	12.81	0.14	11.69
IC253255	81.50	40.25	52.50	67.00	68.00	4.15	9.85	11.00	16.50	14.67	13.06	0.15	13.22
IC253268	63.50	45.95	53.50	68.00	71.50	4.60	12.85	16.95	14.72	13.93	12.56	0.15	13.96
IC253270	79.00	37.40	60.00	72.00	75.00	4.70	10.80	11.50	12.00	11.75	12.39	0.25	16.97
IC253275	79.00	51.75	56.00	65.50	69.00	4.60	11.10	8.50	15.40	13.25	16.60	0.25	18.66
IC253276	37.00	46.10	59.00	75.50	76.50	4.10	11.75	8.00	12.65	11.85	9.65	0.19	10.85
IC253277	81.50	43.35	58.50	69.50	73.00	4.70	12.75	5.65	13.60	11.80	10.78	0.10	7.39
IC253281	20.00	52.95	55.50	72.50	75.00	5.10	10.15	14.90	15.85	13.95	8.91	0.23	14.24
IC253288	86.50	43.10	60.50	74.00	76.00	4.80	14.50	17.50	15.65	13.52	8.78	0.25	16.65
IC257406	81.50	47.40	60.00	72.50	75.00	4.50	12.85	13.80	17.70	15.06	10.40	0.13	12.38
IC257407	100.00	45.20	56.50	70.00	73.00	4.60	8.25	11.70	8.06	6.95	9.26	0.13	9.91
IC257424	85.00	40.85	69.50	81.00	84.00	4.45	9.00	11.15	14.64	11.96	7.73	0.15	12.57
IC257425	91.50	51.00	56.00	72.50	74.00	4.70	12.80	19.70	14.05	13.09	9.00	0.22	16.62

Appendix II contd…..

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
IC257427	96.50	57.65	60.00	73.00	74.00	5.50	13.70	13.80	13.75	13.00	7.46	0.16	13.01
IC257435	79.00	52.05	59.00	71.00	74.00	4.25	9.95	17.05	11.55	11.15	10.50	0.25	17.66
IC257441	91.00	46.55	65.50	78.00	81.00	4.50	12.15	11.95	14.75	13.38	7.01	0.14	13.85
IC257445	100.00	55.65	61.00	74.00	75.50	4.60	12.40	16.95	14.35	13.80	8.80	0.27	18.43
IC257449	81.50	39.30	60.00	74.00	76.50	4.70	9.30	16.40	11.75	10.88	11.30	0.25	18.12
IC257452	73.00	40.55	78.00	93.00	95.00	5.00	12.25	14.50	12.30	10.60	9.58	0.16	12.88
IC257453	91.00	37.00	63.00	76.00	78.00	5.10	12.20	21.25	13.16	11.40	19.15	0.30	20.66
IC259058	100.00	44.50	58.00	71.00	73.50	5.50	14.00	17.40	11.53	10.90	7.56	0.27	17.78
IC259061	89.00	38.00	55.50	67.00	70.00	5.00	10.80	13.95	14.83	14.75	10.78	0.20	14.72
IC259063	100.00	46.40	59.00	70.00	74.00	4.50	8.80	11.50	16.05	13.66	9.44	0.18	14.06
IC259064	94.00	45.75	55.50	69.00	72.50	3.90	9.00	10.80	8.25	8.10	10.51	0.25	16.92
IC259069	98.50	48.60	55.00	67.00	69.00	4.90	11.00	11.95	11.40	9.65	6.49	0.14	10.80
IC259071	71.50	38.75	55.00	71.50	74.00	5.20	7.90	13.00	13.75	11.95	9.67	0.11	8.76
IC259072	79.00	53.60	51.00	65.00	68.00	4.35	8.35	16.60	13.99	12.66	10.00	0.19	11.01
IC259078	61.50	45.75	49.00	64.00	66.00	4.95	10.85	14.85	11.74	11.10	10.32	0.19	11.30
IC259081	86.50	49.70	60.00	76.00	79.00	4.60	12.85	17.62	15.89	14.20	15.53	0.28	22.36
IC259083	84.00	40.75	47.00	59.00	61.50	4.20	12.80	20.65	14.75	12.60	15.50	0.28	22.85
IC259084	97.50	48.15	46.00	58.00	61.00	4.70	12.85	21.95	14.78	12.86	13.65	0.26	21.95
IC259084	79.50	46.15	48.00	60.00	62.50	5.30	12.75	18.90	13.85	11.65	11.60	0.28	21.00
IC259085	85.50	41.00	64.00	77.00	79.00	4.88	12.95	18.75	13.32	11.23	11.88	0.26	21.04
IC259095	77.00	36.50	56.00	69.50	72.50	5.25	9.20	11.20	11.45	10.70	12.50	0.23	15.47
IC259100	53.00	34.00	62.00	75.00	77.00	4.00	8.45	13.85	11.79	10.95	13.25	0.27	20.45
IC259104	83.00	49.80	57.00	69.50	71.50	5.40	11.90	18.45	17.01	14.19	10.70	0.29	24.95
IC259105	85.50	44.20	56.00	74.00	75.50	4.50	11.30	19.40	14.40	12.80	8.75	0.30	21.70
IC259159	73.50	41.55	62.50	77.00	78.50	5.70	13.90	19.00	14.64	13.00	13.90	0.28	24.70
IC202784	87.00	46.25	60.00	76.00	77.50	5.40	13.10	19.60	18.80	14.95	22.80	0.29	22.25
IC201098	81.00	46.70	56.00	71.50	74.00	4.45	7.80	10.85	18.76	15.80	13.81	0.24	20.95
IC4506	81.50	39.80	58.00	75.50	78.00	4.70	7.40	10.80	13.86	12.60	10.94	0.22	17.15
IC5969	86.00	47.85	51.00	67.00	70.00	4.70	3.45	7.25	14.10	12.80	10.25	0.08	6.48
IC68786	41.50	44.00	56.00	69.50	72.50	4.40	12.30	21.80	13.92	12.85	10.39	0.25	20.99
IC68786	49.00	45.85	55.50	68.00	72.00	4.90	13.07	18.50	12.69	10.92	10.98	0.25	23.50
IC202702	69.50	34.40	54.00	71.00	74.00	4.50	11.23	9.80	16.78	14.74	9.86	0.23	18.85
IC202931	64.00	37.00	61.50	77.00	80.00	4.45	9.25	11.30	14.00	12.80	11.03	0.26	22.05
IC202932	62.50	59.45	64.00	76.00	78.50	4.90	10.90	15.65	12.14	11.50	12.62	0.25	16.68
IC247435	91.50	47.75	56.00	67.00	69.50	5.00	8.50	13.25	14.05	13.05	12.00	0.16	10.05
Goa local	35.00	49.50	53.50	67.50	71.00	4.90	13.80	23.95	15.65	12.60	13.25	0.28	21.68
C152	100.00	46.33	53.00	66.00	69.00	5.10	10.20	17.60	15.05	12.80	12.12	0.28	20.08
Bailhongal local	100.00	45.40	57.00	69.00	71.00	4.05	12.80	18.70	14.85	13.85	11.10	0.30	20.57
V118	73.50	39.50	63.00	78.50	80.00	4.65	10.80	18.15	13.70	12.85	12.27	0.27	18.39
EC394767	44.00	44.95	59.00	72.00	74.50	5.40	9.10	13.25	13.60	12.80	12.48	0.28	19.12
EC 394691	79.00	46.65	59.50	73.00	72.50	5.40	12.90	17.85	12.70	12.02	14.48	0.27	23.61
EC394823	41.00	39.00	58.50	75.00	77.00	4.05	11.75	19.35	11.90	10.00	16.06	0.28	21.55
EC394740	43.00	51.85	60.00	73.00	75.00	5.50	9.85	13.10	14.83	12.57	22.63	0.19	18.26
EC394855	34.00	44.40	61.50	73.00	76.00	5.00	14.25	19.50	16.70	14.89	13.90	0.27	21.30
EC394805	62.00	40.00	64.00	76.00	78.50	4.70	9.10	10.90	16.27	14.00	20.37	0.26	20.35
EC394753	86.00	45.25	58.00	73.00	76.00	4.10	8.50	11.30	16.30	13.76	11.36	0.25	18.19
EC394745	72.00	41.65	59.00	74.50	77.50	4.90	10.85	17.10	13.36	11.90	11.76	0.29	21.71
IC97764	46.00	48.85	67.50	80.00	82.50	4.90	9.30	17.90	17.90	15.75	12.05	0.27	22.80
IC257437	74.00	43.00	62.00	74.50	76.50	5.45	13.15	20.55	16.85	14.40	12.67	0.22	21.73
IC257447	60.00	46.00	65.00	79.50	82.00	4.30	9.85	11.00	14.10	12.70	14.00	0.25	18.02
GC3	70.00	41.25	60.00	72.50	76.00	5.40	13.05	18.60	13.30	11.70	14.20	0.28	21.55

X1 = Germination percentage
X2 = Plant height
X3 = Days to flower initiation
X4 = Days to flower termination
X5 = Days to physiological maturity
X6 = Number of branches per plant
X7 = Number of clusters per plant
X8 = Number of pods per plant
X9 = Pod length
X10 = Seeds per pod
X11 = Hundred seed weight
X12 = Harvest index
X13 = Seed yield per plant

Appendix III: Monthly meteorological data for experimental year (2004) and average of past 54 years (1950-2004) of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Months	Rainfall (mm)			Temperature (^0C)						Relative humidity (%)		
				Mean maximum			Mean minimum					
	2004	2005	1950-2004	2004	2005	1950-2004	2004	2005	1950-2004	2004	2005	1950-2004
January	Traces	Traces	0.086	29.6	29.9	29.15	14.7	15.0	19.23	54	55	63.37
February	Traces	Traces	1.161	32.5	34.0	34.52	16.4	16.8	16.02	53	50	51.18
March	Traces	Traces	0.147	36.5	35.3	35.73	19.6	18.5	18.81	49	45	56.47
April	24.4		48.45	37.4		37.00	19.8		21.32	51		76.98
May	61.1		81.40	33.6		36.52	21.4		21.48	66		66.71
June	43.8		109.14	28.8		29.50	21.5		21.21	80		81.69
July	24.8		150.77	29.2		22.06	21.0		20.95	79		87.46
August	160.7		95.30	27.0		22.01	20.3		20.62	83		86.51
September	222.1		100.54	28.6		28.75	19.9		20.16	77		82.40
October	64.6		130.99	30.1		30.12	18.4		19.30	65		76.44
November	0.6		32.04	30.2		29.46	15.9		15.50	52		68.13
December	0.0		54.50	29.4		29.18	12.5		13.44	45		63.81
Total	**602.10**		**750.52**									

CHARACTERIZATION AND EVALUATION OF COWPEA (*Vigna unguiculata* (L.) Walp) GERMPLASM

WITHANAGE DON LESLY 2005 Dr. M. S. UMA
Major Advisor

ABSTRACT

The extent of genetic variability for quantitative traits and disease resistance was assessed in 169 genotypes of cowpea along with nature and magnitude of association between seed yield and its component traits. Also, the magnitude of genetic divergence of genotypes was assessed.

The genotypes revealed high significant variability for the traits; germination percentage, plant height, days to flower initiation, days to flower termination, days to physiological maturity, branches/plant, clusters/plant, number of pods/plant, pod length, seeds/pod, hundred seed weight, harvest index and seed yield per plant. High PCV and GCV values were recorded by seed yield/plant, hundred seed weight, harvest index, number of pods/plant and germination percentage. All the characters showed high heritability except seeds /pod, pod length and number of branches /plant. High genetic advance was recorded by plant height, number of clusters /plant, number of pods/plant, hundred seed weight, harvest index and seed yield /plant.

Number of clusters /plant, number of pods/plant, harvest index and hundred seed weight were significantly correlated with seed yield both at genotypic and phenotypic levels. Number of clusters/plant and pods/plant significantly associated with harvest index both at genotypic and phenotypic levels.

The highest direct effect recorded by harvest index and higher indirect effect of number of clusters/plant and number of pods/plant through harvest index was exhibited in both the seasons (*kharif* 2004 and summer 2005) at genotypic and phenotypic level. GxE interaction was highly significant for all characters except branches per plant.

The highest contribution to the diversity was recorded by number of pods per plant in both the seasons. Genotypes were grouped into 51 and 46 clusters, among them the most divergent clusters were 12:47 and 11:42 in both the seasons respectively. Promising lines for high yield (IC257420, IC257422 and IC202803), disease resistance (IC198333 and IC97787) and early maturity (IC259071 and IC259084) were identified.