VARIABILITY AND HETEROSIS IN BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* (L) Walp.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled '**Variability and heterosis in bush type vegetable cowpea [*Vigna unguiculata* (L.) Walp.]**' is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **'Variability and heterosis in bush type vegetable cowpea [*Vigna unguiculata* (L.) Walp.]'** is a record of research work done independently by **Miss.P.P.Sobha** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Miss.P.P.Sobha** a candidate for the degree of Master of Science in Horticulture with major in Olericulture, agree that the thesis entitled **'Variability and heterosis in bush type vegetable cowpea [*Vigna unguiculata* (L.) Walp.]'** may be submitted by Miss.P.P.Sobha in partial fulfilment of the requirements for the degree.

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Dedicated to
my loving parents

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Introduction

INTRODUCTION

Legumes are important sources of human food, next only to cereals. They are richer in protein materials than any other vegetable product, besides possessing high energy, fair contents of minerals and vitamins. They are an absolute necessity in the diet of the vegetarians or in countries where little meat is eaten. They also improve soil nutrition through biological fixation of nitrogen. With an annual global production of 156 million metric tonnes, legumes rank third among the food crops, topped only by root and tuber crops and cereals (FAO, 1980).

The genus *Vigna* include more than 100 species distributed in tropical and subtropical areas. Cowpea [*Vigna unguiculata* (L.) Walp.] is a common vegetable grown throughout the country, a rich and inexpensive source of vegetable protein. Cowpea is known by several names such as black eye pea, southern pea and lobia. Cowpea has originated in Africa (Ng and Marechal, 1985). Verdcourt (1970) considered *Vigna unguiculata* to comprise of five subspecies - two wild (dekindtiana and *mensensis*) and three cultivated *unguiculata* (L.) Walp., *cylindrica* (L.) Verdc. and *sesquipedalis* (L.) Verdc.

In an agriculture based country like India, increasing crop productivity is the key stone for overall development. Among the major reasons that have sustained a huge population in our country, is the development of varieties with high production potential and the science based agrotechnology that expresses this potential optimally are most significant. Genetic improvement for higher production and better quality of crop plants has been an effective tool, since the advent of scientific agriculture. Two components involved in crop improvement are creation of genetic variability and devicing methodologies for combining characteristics of different individuals into a superior cultivar.

Cowpea production is limited by a number of constraints. The grain output from most of the local varieties is between 100 and 300 kg/ha (IITA, 1984). Apart from the obvious genetic inadequacies such as extreme viny growth habit, compulsive photoperiodism, low flowering and pod setting abilities and low yields of so called local varieties, problems like susceptibility to insect pests, lack of resistance to viral, bacterial and fungal diseases, lack of tolerance of excessive moisture levels, weed infestation and inadequate soil nutrient supply are super imposing to its disadvantage.

Among the leguminous crops, cowpea is an important vegetable grown during rainy and summer seasons. Tender pods as well as green shelled are used as vegetable and seeds as pulse when dried. It is an important crop in Kerala grown in almost all the homesteads and in rice fallows. Despite its high economic and nutritive values, high yielding varieties of vegetable cowpea with acceptable market quality and bushy habit are lacking. Bush type vegetable cowpea do not require staking and thus reduce the cost of cultivation. There are bush types in grain cowpea, but bush type vegetable cowpeas are limited.

In vegetable cowpea,tender, green pod yield is the most important character to be considered for improvement. Hence genetic potentialities of yield contributing characters and their interrelationships should be properly assessed for their improvement. There is only limited work done on genetic variability of bush type vegetable cowpea, especially in respect of vegetable pod yield and its yield contributing characters. Since cowpea is a highly self pollinated crop, a programme of yield improvement should be based on selection and hybridization between two or more selected parents. In this programme the ability to accurately predict the parental combinations, which generate superior inbred lines, following hybridization is crucial to the success of the breeding programme.

Keeping in view the importance of crop improvement the present investigation was carried out with the following objectives.

i) To study the genetic variability in cowpea for different characters by estimating phenotypic and genotypic coefficients of variation.

ii) To estimate the heritability and genetic advance for different characters.

iii) To study the genetic divergence among different genotypes and to group them into different clusters.

iv) To study the electorphoretic pattern of protein.

v) To study the association between yield and its components by estimating phenotypic, genotypic and environmental correlation coefficients.

vi) To determine the direct and indirect effect of each component on yield by path coefficient analysis.

vii) To generate information on combining ability, and

viii) to find out the extent of heterosis for different characters in cowpea.

Review of Literature

2. REVIEW OF LITERATURE

The crop improvement work is rather scanty in cowpea in general and vegetable cowpea or green cowpea in particular. Compared to other well known pulse crops, cowpea has greatly been underresearched for many years. However some improvement works such as hybridization and selection for size, shape and colour of pods and seeds, maturity, yield and disease resistance have been carried out in the last two decades. The available literature on various aspects of crop improvement in cowpea is reviewed under the following two heads.

1. Genetic variability and divergence
2. Combining ability and heterosis

2.1 Genetic variability and divergence

2.1.1 Genetic variability, heritability and enetic advance

The extent of variability is of paramount importance in the improvement of any crop. Knowledge of available variability within the species enables the breeder to determine the method of crop improvement. Selection of superior type will be effective only when major part of the variability of the trait is genetic. Many workers studied the extent of variability in cowpea by working out the genotypic and phenotypic coefficients of variation.

Chandrika (1979) observed variability for all the important economic characters in cowpea. Except for primary branches/plant, the major portion of the variability was genetic. Among 12 varieties of cowpea wide variability was noticed for many characters (Lakshmi & Goud, 1977). The genotypic coefficient of variation was higher for plant height, grain yield, pods/plant and 100 grain weight. Heritability was very high for plant height, pod length and 100 grain weight. Pod length was associated with high genetic advance.

Ramachandran *et al.* (1980) reported variability for yield, pods/plant and internode length in cowpea. K-1552 from Karnal was the earliest and the highest yielder with more fruits per plant. Jalajakumari (1981) studied genetic variability in seventeen cowpea varieties, and reported highly significant variation for all the characters. Variability studies in eleven cowpea varieties by Jana *et al.* (1982) revealed high genotypic co-efficient of variation for vegetable yield and pods/plant. The number of primary branches/plant was positively correlated with vegetable pod yield. Heritability and genetic advance were high for 1000 grain weight and days to flower. A study on genetic variability for six traits in 40 genotypes of cowpea revealed significant differences for all the characters except pods/cluster (Pandita *et al.*, 1982). Yield per plant had the highest genotypic and phenotypic coefficient of variation. High heritability estimates and high percentage of genetic advance were also recorded for yield per plant.

Vaid and Singh (1983) reported that branch number, and yield per plant gave high values for phenotypic and genotypic coefficient of variation, heritability and expected genetic advance. Apte *et al.* (1987) observed high heritability for 100 seed weight, seeds/pod and days to maturity in cowpea. The per cent genetic gain was high for 100 seed weight, plant height, branches/plant and seeds/pod.

Patil and Baviskar (1987) observed maximum variation for seed yield/plant followed by pods/plant, pod clusters/plant and days to maturity. The genotypic and phenotypic coefficients of variation were highest for pods/plant, pod clusters/plant, seed yield and 100 seed weight. Heritability was the highest for 100 seed weight, followed by days to maturity and pod length.

Sharma *et al.* (1988) reported maximum genotypic coefficient of variation for dry matter yield followed by plant height, green forage yield, pods/plant, seed weight and green pod yield. Heritability ranged from 46.9 per cent for green pod yield to 98 per cent for days to 50 per cent maturity.

In a variability study for yield and other traits

Kandaswamy *et al.* (1989) obtained increased yield through selection for pods/plant, seeds/pod, and 100 seed weight. A study by Thiyagarajan (1989) showed high heritability and genetic advance for plant height, seeds per pod and 100 seed weight. Roquib and Patnaik (1990) also reported high heritability for these characters and for primary branches, pod length and breadth, days to 50 per cent flowering, maturity and yield in cowpea. Most of these traits exhibited high estimates of genetic advance.

Gowda *et al.* (1991) reported that an F_2 population of cowpea showed high estimate of genotypic component of variation for pods/plant and seed yield per plant followed by 100 seed weight.

Evaluation of selected bush type vegetable cowpea varieties by Abdul Wahab *et al.* (1991) for earliness, vegetative and productive characters for three seasons have identified IHR 61-B and selection 2-1 as high yielding varieties for summer and rainy seasons respectively under Kerala conditions. Savithramma (1992) reported high genotypic coefficient of variation for all characters except seeds/pod, seed weight/plant, hundred seed weight and petiole length. High heritability values were observed for plant height, pod length and 100 seed weight. High genetic advance was recorded in respect of plant height, seed weight/plant and 100 seed weight.

Evaluating sixteen strains of cowpea for six fodder characters, Gopalan and Balasubramanian (1993) reported that genetic variability was maximum for plant height followed by green fodder yield and number of leaves.

The heritability estimates were also high for plant height, green fodder yield and number of leaves.

2.1.2 Genetic divergence

A knowledge of genetic diversity, its nature and degree is useful in the improvement of any heritable character. Chandrika (1979) could group 202 varieties of cowpea into 17 clusters based on the genetic distance using Mahalanobis D^2 statistics.

Marangappanvar (1986) concluded that intercluster spatial patterns were not consistent with varietal geographic distribution following clustering studies in cowpea. Patil and Bhapkar (1987) did not obtain any relationship between genetic diversity and geographic origin. Thiyagarajan et al. (1988) reported that days to flowering, 100 seed weight and plant height contributed most to genetic divergence.

Dharmalingam and Kadambavanasundaram (1989) reported wide genetic diversity among the 13 clusters formed from 40 genotypes of cowpea. Among them CO-2 and C-5 were the widest which were identified for heterosis breeding. Based on their intracluster mean values and wide genetic diversification the types suitable for hybridization among themselves and the selection for the desirable traits have been identified. Thirty geographically diverse cowpea accessions could be grouped into four clusters by Thiyagarajan and Natarajan (1989). Pods/plant, seeds/pod and seed yield/plant gave the largest contribution to genetic divergence. They also did not obtain any relationship between geographic distribution and genetic diversity.

Hazra *et al.* (1993) studied the genetic divergence among cowpea genotypes belonging to three cultigroups *unguiculata*, biflora and sesquipedalis under two environments. Using D^2 statistics, the genotypes were grouped into four clusters in both the environments. No close correspondence was observed between geographic distribution and genetic divergence. Maximum genetic divergence was observed between the genotypes of cultigroups *sesquipedalis* and those of *biflora*.

Sudhakumari and Gopimony (1994) studied genetic divergence in cowpea using Mahalanobis D^2 technique, and reported that the intercluster distances were more than the intra cluster distances suggesting homogeneity within the clusters and heterogeneity among the clusters. The maximum divergence was observed between clusters V and VII which indicate that parents chosen from these are likely to produce better recombinants with better adaptability in hybridization works.

2.1.2.1 Electrophoresis

In recent years protein or isozymatic analysis by polyacrylamide gel electrophoresis (PAGE) has been considered as a unique and powerful technique for ascertaining gene homology at the molecular level because of its superior capability for component resolution. Further, PAGE provides a tool for species identification and delimitation and has been particularly useful in deducing somatic relationships between groups where morphological and cytological data were not corollary. In spite of this, innumerable chemotaxonomists have successfully established the phylogenetic relationships employing protein electrophoresis studies in major crops like rice, wheat, barley, soyabean, broad bean chickpea and cotton etc. (Ladizinsky and Hymovitz, 1979).

Data from protein electrophoresis seems to give more accurate information on phylogenetic relationships than isozymes. Proteins separated by electrophoretic methods are thought to undergo the process of evolution with relative slowness due to their "non essential" nature (Margoliash and Fitch, 1968) while enzymes are thought to be extremely sensitive to selection pressures in evolution and thus to the survival of the organism (Mc Daniel, 1970).

Polyacrylamide gel electrophoretic study by Lubis *et al.* (1977) has revealed that, on the basis of protein banding, samples of *Vigna unguiculata* belonging to taxonomic grouping *sesquipedalis, sinensis* and *cylindrica* were indistinguishable. So they concluded that these three belong to a single species.

Yaaska (1984) reported that electrophoretic analysis of the enzyme extracted from seedlings of *Phaseolus vulgaris, Phaseolus coccineus, Vigna mungo* and *Vigna unguiculata* revealed three main isozymes in each of the species except *P. coccineus* which had an additional isozyme. The three isozymes common to all four species differed in resistance to acidity and heat, in intracellular location, and in electrophoretic variability, indicating that they are genetically independent isoenzymes.

The advantage of using electrophoretic pattern of seed globulin is that this technique is non expensive and easy to perform in developing countries where cowpea is extensively cultivated and germplasm is collected and stored (Singh and Ntare, 1985).

Rao *et al.* (1992) analysed the seed storage proteins of ten *Vigna* species by means of SDS/PAGE and reported great variation both in number and molecular weight (MW) of the polypeptides. They also reported that proteins extracted from different accessions of the same species revealed the presence of an electrophoretic pattern typical for each species and these species specific bands, allow the identification of 10 *Vigna spp.* analysed.

Oghiakhe *et al.* (1993) has reported that no inter varietal differences existed for total protein content but water soluble seed proteins proved useful in distinguishing cultivars. A key for the classification of the fifteen cultivars into five groups was developed based on the presence or absence of three proteins following PAGE of the water soluble proteins.

Valliamcourt *et al.* (1993) compared cultivated and wild cowpea for their isozyme diversity and reported that cultivated cowpea accessions were characterised by very low genetic diversity (Ht = 0.029) with only six polymorphic loci. The cultivated groups could not be differentiated from the domesticated cowpea. Wild cowpea were highly diverse with 19 out of 26 loci polymorphic. And six wild accessions displayed identity with the cultivated cowpea.

Zope *et al.* (1992) on evaluation of the globulin fraction of two morphological mutants reported that the banding patterns of the mutants showed no correlation with morphological characters.

2.1.3 Correlation studies

Yield in any crop is a complex character determined by many component characters. Selection of specific characters result in correlated response for some other characters. Interrelationship between yield and its contributing characters have been reported by many workers in cowpea. Kumar (1976) reported that pod yield was positively associated with branches/ plant, pod length, pod thickness, days to flowering and days to maturity. Singh *et al.* (1977) reported positive and significant correlation of yield with pods/plant and seeds/pod. Hanchinal *et al.* (1979) reported that seed yield showed positive and significant correlations with plant height, branches/plant and dry pods/plant in winter, where as highly significant positive correlation was obtained with number of seeds and dry pods in summer. Very high positive correlation was noted between seed yield and dry pod yield in both the seasons. Hundred seed weight was highly correlated with number of pods and number of branches for both the seasons. Virupakshappa (1980) observed that seed yield was positively correlated with pods/plant, seeds/pod and 100 seed weight in the F_2 and with pods/plant in both back crosses. Jana *et al.* (1982) found that yield was positively and significantly associated with pods/plant. Pods/plant was also positively and significantly correlated with primary branches/plant which was negatively correlated with days to flower and pod length but positively correlated with vegetatable pod yield/plant.

A study by Jindal and Gupta (1984) revealed that plant height, inflorescence/plant, pod length and seeds/pod were significantly and positively associated with seed yield. For days to maturity the correlation was significant and negative. Senanayake and Wijarathne (1988) reported that yield was negatively correlated with the primary branches/plant and positively with 100 seed weight as well as pod length. Sharma *et al.* (1988) found that seed yield was highly and significantly correlated with pods/plant, seeds/pod, days to first flower and days to 50% maturity. Green forage yield was highly and positively correlated with pods/plant, days to first flower, seeds/pod and plant height. Tyagi and Koranne (1988) observed that branches/plant and seeds/pod were positively and significantly correlated with yield. Similar results have been obtained by Patil *et al.* (1989). Highly significant positive correlation of seed yield with inflorescences/plant, pods/plant and grains/pod was observed by Apte *et al.* (1991). However 100 grain weight and harvest index indicated significant negative genotypic correlation.

Biradar *et al.* (1991) has noted strong positive association of grain yield with pod weight, pods/plant and clusters/plant, seeds/pod and pod length. Oseni *et al.* (1992) showed that pods/plant had significant positive correlation with yield where as both days to flowering and 100 seed weight had negative correlation with grain yield. Gopalan and Balasubramanian (1993) observed positive and significant genotypic correlation of green fodder yield with plant height, number of leaves, and stem girth.

Samiullah and Imtiaz (1993) found that green pod yield/plant was significantly and positively correlated with pod number at the genotypic level only. It was suggested that the fruiting branches and days to flowering were the reliable and effective selection criteria for the improvement of pod yield in cowpea. Kandaswamy *et al.* (1993) reported positive association of pods/plant and cluster/plant with yield.

2.1.4 Path coefficient analysis

The path coefficient provides an effective means of finding out direct and indirect causes of association and allows a detailed examination of specific forces acting to produce a given correlation and measures the relative importance of each factor. A study conducted by Hanchinal (1979) in 25 genotypes of cowpea has suggested that rather than the direct effect of number of seeds and plant height, the indirect effect of seeds through branches is more important in deciding the yield.

Chauhan and Joshi (1980) has revealed that generally the negatively correlated traits pods/plant and 100 seed weight were the most important components of yield. Variability studies by Jalajakumari (1981) has shown that the yield of pods/plant, breadth of seeds, and pods/plant had high positive direct effect on seed yield/plant. But pod weight, seeds/pod, and seed thickness exhibited low and negative direct effect on seed yield/plant. Murthy (1982) observed pod number/plant as the major contributor to yield followed by pod length, seed number/pod and pod weight.

Jindal and Gupta (1984) reported plant height, inflorescence/plant, branches/plant, pod length and seeds/pod as the major components contributing directly to seed yield. Padhye *et al.* (1984) noted that pods/plant and seeds/pod had highest positive direct phenotypic and genotypic effects respectively on yield.. Obisesan (1985) revealed through path coefficient analysis that the most important yield components were pods/plant, 100 seed weight and seeds/pod. The indirect effect of peduncles/plant, mean peduncle length and a vigour index were more important than their direct effects. Biradar *et al.* (1991) found that pod weight had the highest positive direct effect on yield followed by plant height, and clusters/plant. Pod length, pods/plant and seeds/pod showed negative direct effect on yield. Pod weight/plant could be used as a reliable parameter for yield in cowpea.

Path coefficient analysis by Oseni *et al.* (1992) showed that days to flowering had the highest direct effect on grain yield followed by 100 seed weight, days to pod filling and pod length. Seeds/plant and days to maturity also had high but negative direct effect on grain yield. Gopalan and Subramanian (1993) reported that number of leaves, leaflet length, and stem girth showed high positive direct effect on green fodder yield. It was suggested that selection of plants with thick stem and more leaves will improve green fodder yield in cowpea.

Kandaswamy *et al.* (1993) reported that the clusters/plant had the highest positive direct effect of 0.886 followed by seeds/pod and 100 grain weight (0.27 and 0.226 respectively). Though pod length had a weak direct effect, its indirect effect through seeds/pod was higher.

2.2 Combining ability and heterosis

2.2.1 Combining ability

Selection of parents and hybrids on the basis of general combining ability (gca) and specific combining ability (sca) are pre-requisites to develop high yielding varieties and hybrids respectively. Singh and Jain (1972) reported the importance of both general and specific combining ability in cowpea for yield, pod length and seed weight, where as only specific combining ability variance was important for seeds/pod. Brahmappa and Singh (1977) through study on five parental diallel cross in pea revealed significant difference among genotypes for days to flowering, primary branches, pods/plant, pod weight/plant, seeds/pod and 100 seed weight. High variances due to both specific and general combining ability were found in Little Marvel and Progress where as high gca effects were observed in Progress and Burpiana for earliness of flowering and in Little Marvel x Progress for pod yield. Patil and Shete (1986) reported that combining ability was associated with good performance in both parents and hybrids in cowpea. Hebbal (1988) observed high gca variance for peduncle length, grain yield/plant and seeds/pod. Specific combining ability variance was significant for pods/plant and 100 grain weight while both sca and gca variances were important for pod weight and volume of 100 grains. Russian Giant was a good general combiner for grain yield, pod length and pod weight/plant.

Thiyagarajan *et al.* (1990) in a 6 x 6 diallel cross of cowpea for combining ability studies found that additive and non additive gene effects were important for plant height, branches/plant, clusters/plant, pods/plant, pod length, seeds/pod, 100 seed weight and yield per plant. The cultivars EC 164370, EC 170777 were the best general combiners on the basis of the gene effects. Rejatha (1992) observed that the variance due to general combining ability was significant and higher in magnitude than specific combining ability for the days to flowering, pod weight, mean pod length, seeds/pod, internode length and seed : pod ratio. Selection 104 and selection 145 were the best general combiners for most of the characters.

Thiyagarajan *et al.* (1993) reported that, the variance due to gca and sca showed that gene action was predominantly nonadditive for days to 50 per cent flowering, days to maturity, plant height, pod length, seeds/pod, 100 grain weight and yield/plant and primarily additive for primary branches/plants, clusters/plant and pods/plant. The genotypes CO 4, C 87, C 152 and COVu 4 were found to be the good general combiners. The crosses CO 3 x C 152, CO 3 x COVu 4, CO 4 x C 152, V 87 x C 152, KC 199 x KC 195 were observed to have higher sca effects for some of the yield components.

2.2.2 Heterosis

Manifestation of heterosis was recorded by several workers for yield and other traits in several grain legumes. Information on heterosis and combining ability is meagre in cowpea especially in respect of vegetable types. As early as 1972 Singh and Jain reported that heterosis in yield was influenced by heterosis in pod length and seeds/pod. The best hybrid combination for grain yield showed heterosis to the extent of 39 per cent. Kherdnam *et al.* (1975) studied heterosis in cowpea and pointed out greatest heterosis over mid parent for seed yield and the lowest for number of branches. Intervarietal hybridization by Inasi (1980) revealed significant heterosis for all the 16 characters. Maximum heterosis of 43.36% was exhibited by P 118 x C 152 x NE 1 for pod yield/plant. Heterosis could be observed to the same extent in both genetically related and unrelated parents.

Jain (1982) reported heterosis of 55 per cent and 39 per cent under two environments for seed yield. Non additive gene effects predominated over additive for most of the characters. Among the 41 hybrids studied by Selvaraj and Annappan (1983) ten exhibited heterosis to the extent of 243 per cent over the mid parental value, 223 per cent over the better parent and 64 per cent over the best parent. Hebbal (1988) studied heterosis in a 6 x 6 diallel cross in respect of 10 characters. Among the direct crosses pod length, clusters/plant, seeds/pod, pod weight/plant and grain yield/plant showed maximum heterosis while in reciprocal crosses maximum heterosis was noticed for days to 50 per cent flowering, pods/plant, pod length, 100 grain weight and volume of 100 grains.

Biradar et al. (1991) noticed heterosis in the F_1 of a genetically diverse cross for most of the characters.

Rejatha (1992) obtained a maximum heterosis of 118.99 per cent for fruit yield/plant. Selection 145 x Kurutholapayar and selection 145 x selection 7 had maximum relative heterosis and heterobeltiosis respectively for the character days to flowering. Selection 129 x Selection 104 had maximum relative heterosis for pods/cluster.

Materials and Methods

3. MATERIALS AND METHODS

The investigations were carried out at the Vegetable Research Farm of Department of Olericulture, College of Horticulture, Vellanikkara during 1992-94. The experimental field is located at an altitude of 22.5 M above MSL, between 70°32′ N latitude and 76°16′ E longitude. The area enjoys a warm humid tropical climate. Studies were undertaken under the following two major heads.

3.1. Genetic variability and ivergence in bush type vegetable cowpea

3.2. Development of F_1 hybrids and their evaluation for combining ability and heterosis

3.1. Genetic variability and Divergence

3.1.1. Genetic variability

3.1.1.1. Experimental materials

The materials comprised of 31 diverse genotypes of bush type vegetable cowpea collected from different parts of the country. This included genotypes varying in vegetative and productive characters (Table 1).

Table 1 Morphological characters of 31 genotypes of cowpea

Sl. No.	Genotypes	Source	Growth habit	Pod attachment to peduncle	Immature pod colour
1	2	3	4	5	6
1.	IC 38956-1	NBPGR, New Delhi	Erect	Erect	Dark green
2.	Saval De Dhule	NBPGR, New Delhi	Semi erect	Pendent	Dark green
3.	IC 91511	NBPGR, New Delhi	Semi erect	Pendent	Dark green
4.	JBT 4/103	NBPGR, New Delhi	Semi erect	Sub-erect	Light green
5.	M/D 119	NBPGR, New Delhi	Erect	Pendent	Light green
6.	IC 91499	NBPGR, New Delhi	Erect	Sub-erect	Light green
7.	EC 240715	NBPGR, New Delhi	Erect	Sub-erect	Light green
8.	BC 240712	NBPGR, New Delhi	Semi erect	Sub-erect	Light green
9.	Kanakamony	Kerala Agrl.University	Semi erect	Pendent	Dark green
10.	Pusa Dofasli	IARI, New Delhi	Erect	Erect	Light green
11.	Selection 2-1	NDUAT, Faizabad	Erect	Pendent	Light green
12.	Pusa Komal	IARI, New Delhi	Erect	Sub-erect	Light green
13.	VS 87	Kerala Agrl.University	Erect	Pendent	Dark green
14.	Arka Garima	IIHR, Bangalore	Semi erect	Pendent	Light green

contd.

Table 1 (contd.)

1	2	3	4	5	6
15.	Amb-1	Ambojogai	Erect	Pendent	Light green
16.	VS 389	IITA, Nigeria	Erect	Pendent	Light green
17.	Selection 263	PAU, Ludhiyana	Erect	Pendent	Light green
18.	VU-18	Vellanikkara	Semi erect	Pendent	Dark green
19.	IC 91456	NBPGR, New Delhi	Erect	Erect	Dark green
20.	NIC 12882	NBPGR, New Delhi	Semi erect	Pendent	Light green
21.	416 NB	NBPGR, Vellanikkara	Erect	Sub-erect	Dark green
22.	VS 479	IITA	Semi erect	Pendent	Dark green
23.	420 NB	NBPGR, Vellanikkara	Erect	Sub-erect	Dark green
24.	Local 1	Kottayam	Semi erect	Pendent	Dark green
25.	734 NB	NBPGR, Vellanikkara	Erect	Erect	Dark green
26.	34 NB	NBPGR, Vellanikkara	Erect	Erect	Dark green
27.	744 NB	NBPGR, Vellanikkara	Erect	Sub-erect	Light green
28.	VS 477	IITA	Semi erect	Pendent	Dark green
29.	221 NB	NBPGR, Vellanikkara	Erect	Erect	Dark green
30.	JBT 4/221	NBPGR, New Delhi	Erect	Erect	Dark green
31.	Local 2	Trichur	Erect	Sub-erect	Dark green

3.1.1.2. Methods

The 31 cowpea genotypes were raised in a randomised block design with three replications during September-November 1993 to find out the extent of genetic variability and to select parents for further hybridization programmes. The plot size was 2.4 m x 1.8 m with three rows of plants/genotype/replication. There were 24 plants/replication at 60 x 30 cm spacing. The crop received timely management and care as per the "Package of practices recommendations" of Kerala Agricultural University (KAU, 1993).

3.1.1.3. Observations recorded

Five plants were randomly selected from each genotype/replication. Observations were recorded on the following characters and the average worked out for further analysis.

Plant height

Plant height from the ground level to the top of the canopy was measured in cm after the final harvest of the crop.

Plant spread

Canopy spread of the plant was measured in cm using a metre scale at the full maturity of the plant.

Primary branches/plant

The number of primary branches/plant was counted at the full maturity of the plant.

Days to flowering

The number of days from sowing to the appearance of the first flower was recorded.

Days to first harvest

The days taken from sowing to the first harvest for vegetable pods in each plant was recorded.

Pod length (cm)

Length of the randomly selected pods from each observational plant was measured using an ordinary scale and recorded in cm.

Pod girth (cm)

The same pods used for length measurements were used for recording pod girth also. The mean girth of ten pods measured in cm.

Pod weight (g)

The weight of the same pods were taken in an electric balance and the average worked out in gram.

Seeds/pod

The number of seeds in the above ten pods was counted and recorded the average number of seeds/pod.

Bunches/plant

The total number of flower bunches from each plant was counted at the full flowering stage.

Pods/cluster

The total number of pods in ten clusters were counted from each plant and the average worked out.

Pods/kg

Counts on the number of pods to make one kg of vegetable cowpea was taken from each plot at the time of harvest and expressed as number of pods/kg.

100 seed weight (g)

One hundred dried seeds from each genotype were weighed using an electric precision balance and the weight recorded in gram.

Pods/plant

Pods harvested periodically from each plant were separately counted, average worked out to obtain the total number of pods/plant.

Pod yield/plant

Weight of pods from observational plants at each harvest was taken using a top loading balance and added to get the total and the average recorded in g.

3.1.1.4. Statistical methods

Data on different characters were subjected to statistical analysis at the Computer Centre, Dept. of Statistics, College of Horticulture, using Spare 1 package. The analysis of various technique suggested by Fisher (1954) was employed for the estimation of various genetic parameters. Cowpea genotypes were compared after estimating the critical differences. The extent of association among characters, was measured by correlation coefficients. Path coefficient analysis was used for estimating the direct and indirect effects.

Phenotypic, genotypic and environmental variances

The variance components were estimated using the following formula suggested by Burton (1952).

Phenotypic variance (Vp) = Vg + Ve

where (Vg) = Genotypic variance

(Ve) = Environmental variance

$$\text{Genotypic variance (Vg)} = \frac{VT - VE}{N}$$

where VT = Mean sum of squares due to treatments

VE = Mean sum of squares due to error

N = Number of replications

Environmental variance Ve = VE

where VE = Mean sum of squares due to error

Phenotypic and genotypic coefficient of variation

The phenotypic and genotype coefficient of variation were calculated by the formula suggested by Burton and Devane (1953).

$$\text{Phenotypic coefficient of variation (pcv)} = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

Where Vp = Phenotypic variance

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

$$\text{Genotypic coefficient of variation (gcv)} = \frac{\sqrt{Vg}}{\bar{X}} \times 100$$

where Vg = Genotypic variance

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

Heritability

Heritability in the broad sense was estimated by following the formula suggested by Burton and Devane (1953).

$$\text{Heritability} \quad H = \frac{Vg}{Vp} \times 100$$

where Vg = Genotypic variance

Vp = Phenotypic variance

Expected genetic advance

The expected genetic advance of the available germplasm was measured by the formula suggested by Lush (1949) and Johnson *et al.* (1955a) at five per cent selection intensity using the constant K as 2.06 given by Allard (1960).

$$\text{Expected genetic advance} \quad GA = \frac{Vg}{\sqrt{Vp}} \times K$$

Where Vg = Genotypic variance

Vp = Phenotypic variance

K = Selection differential

Genetic gain (Genetic advance as percentage of mean)

Genetic advance (GA) calculated in the above method was used for estimation of genetic gain.

$$\text{Genetic gain} \quad GG = \frac{GA}{\overline{X}} \times 100$$

Phenotypic, genotypic and environmental correlation coefficients

The phenotypic, genotypic and environmental covariances were worked out in the same way as the variance were calculated. Mean product expectations of the covariances analyses are analogous to the mean square expectations of the analyses of variance. The different covariance estimates were calculated by the method suggested by Fisher (1954).

Phenotypic covariance between two character 1 and 2 (CoVp12) = CoVg12 + CoVe12

CoVg12 = Genotypic covariance between characters 1 and 2

CoVe12 = Environmental covariance between 1 and 2

Genotypic covariance between two characters 1 and 2

$$CoVg12 = \frac{Mt_{12} - Me_{12}}{N}$$

where Mt_{12} = Mean sum of product due to treatment between characters 1 and 2

Me_{12} = Mean sum of product due to error between characters 1 and 2

N = Number of replication

The phenotypic, genotypic and environmental correlation coefficient among the various characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955b).

Phenotypic correlation coefficient between two characters 1 and 2

$$(rp12) = \frac{CoVp12}{\sqrt{Vp1\ Vp2}}$$

where CoVp12 = Phenotypic covariance between characters 1 and 2

Vp1 = Phenotypic variance of character 1

Vp2 = Phenotypic variance of character 2

Genotypic correlation coefficient between two character 1 and 2

$$(rg12) = \frac{CoVg12}{\sqrt{Vg1\ Vg2}}$$

where CoVg12 = Genotypic covariance between characters 1 and 2

Vg1 = Genotypic variance of character 1

Vg2 = Genotypic variance of character 2

Environmental correlation coefficient between two characters 1 and 2 (re12)

$$(re12) = \frac{CoVe12}{\sqrt{Ve1\ Ve2}}$$

where CoVe12 = Environmental covariance between characters 1 and 2

Ve1 = Environmental variance for character 1

Ve2 = Environmental variance for character 2

Path coefficient analysis

In path coefficient analysis the correlation among cause and effect are partitioned into direct and indirect effects of causal factors on effect factor. The principles and techniques suggested by Wright (1921) and Li (1955) for cause and effect system were adopted for the analysis using the formula given by Dewey and Lu (1959). The characters like pod length (X_1), pod girth (X_2), pod weight (X_3), pods per kg (X_4) and hundred seed weight (X_5) which showed significant correlation with yield at one per cent level of significance alone were considered for path coefficient analysis.

3.1.2.1. Assessment of genetic divergence and grouping of genotypes

The genetic distances among 31 cowpea genotypes were assessed by determining Mahalanobis D^2 (Mahalanobis, 1928), values between every pair using 15 quantitative characters.

Grouping of genotypes into clusters were done by Tocher's method (Rao, 1952).

3.1.2.2. Electrophoretic studies

Genetic variability among the 31 genotypes were studied by eletrophoretic analysis (Harborne, 1973).

3.1.2.2.1. Materials

The seeds of thirty one genotypes included in the variability studies were used for electrophoretic studies.

1. Protein estimation

To standardise the concentration of protein solution to be applied, protein per cent in cowpea seeds were estimated by Lawrys method. The reagents used were

A. 2% Na_2CO_3 in 0.1N NaOH

B. 0.5% $CuSO_4.5H_2O$ in one per cent sodium potassium tartarate

C. Alkaline $CuSO_4.5H_2O$ solution. Mixed 50 ml of reagent A with 1 ml of reagent B

D. Dilute Follen's reagent

2. Electrophoresis

1) Extracting buffer containing the following chemicals were used for proteins extraction

   a) Hydroxy methyl auxine methane - 35 μm

   b) Citric acid - 2.5 μm

   c) Ascorbic acid - 6 μm

   d) L-cystein hydrochloride - 6 μm

   e) Sucrose - 0.5 m

2) Solution for staining:

For staining proteins, bromophenol blue 0.5% in ethanol was used. 1 g of stain dissolved in 100 ml of distilled water.

Amido black - 1 g Amido Black and 10 ml acetic acid dissolved in 100 ml of methanol. 10 ml of this stain was diluted to 50 ml.

Destaining solution: 7 % acetic acid was used.

3. Stocks for electrophoresis

A.(1) To 48 ml of 1 M HCl 36.6 g of Tris and 0.46 ml of Temed was added and made upto 100 ml with distilled water. The pH was adjusted to 8.9.

A.(2) To 30 g of acrylamide 0.8 g bisacrylamide was added and made upto 100 ml with distilled water.

A.(3) To 18.0 g of acrylamide 0.47 g of bis-acrylamide was added and made upto 100 ml with distilled water.

A.(4) 0.14 g of Ammonium persulfate was dissolved in 100 ml distilled water. Prepared fresh at the time of gel casting.

Preparation of running gel

One part of A1 was mixed with two parts of A2, one part distilled water, and 4 part of A4. Applied the gel to the tubes for setting. Kept it as such for setting for 15-30 minutes. Applied few drops of distilled water on the top. Removed the water from top before applying the sample.

Electrophoresis buffer

To 30.3 g of Tris, 142.6 g of glycine was added and made upto five litres with distilled water, the pH was adjusted to 8.3.

3.1.2.2. Methods

1. Protein estimation

Seed samples are ground with sand to fine powder. Extracted the protein in Tris buffer (pH 7.0) and precipitated in 5 per cent TCA, and centrifuged. Removed excess TCA by repeated washing. Dissolved the protein in 0.1N NaOH for estimation. To 1 ml of protein solution added 5 ml of reagent C. Mixed well and allowed to stand at room temperature for 10 minutes. To this added 0.5 ml of reagent D. and mixed thoroughly. After 30 minutes the OD was measured at 500 nm.

Prepared standards of 100, 200, 300, 500 and 700 μg/ml of protein in 0.1N NaOH from stock solution of Borine serum albumin. Amount of protein in seeds was found out using standard curve and diluted the protein solution to the range of 2-3 microgram/ml.

Electrophoresis

Hundred milligrams of sample (seed after removing seed coat) was ground to fine powder with equal quantity of sand. Added 10 drops of extracting buffer to produce a thick slurry. Kept it as such for one hour and centrifuged at 3000 rpm for 10 minutes. Took 20 μl of supernatant containing 2-3% of protein for electrophoresis.

Gel tubes were transferred to the electrophoretic apparatus and applied 20 μl of sample and a few drops of bromophenol blue solution. Filled the upper and lower tank with running buffer of pH 8.3. Initially 2 mA current was applied per tube and gradually the current was increased to a level of 4 mA/tube. Running was continued for 4 hours. Removed the gel tubes and stained in dilute amido-black solution for one to two minutes. Then destaining was continued for cleaning the protein bands. The number of bands were counted and the variation in protein banding pattern was observed among the 31 genotypes.

3.2. Development of F_1 hybrids and their evaluation for combining ability and heterosis

3.2.1.1. Experimental materials

Ten parents, viz. Pusa Komal, Selection 2-1, VS 389, Kanakamoni, Selection 263, Vu-18, Amb-1, Arka Garima, JBT 4/221 and Pusa Dofasli which were originally included in the variability studies were selected based on genetic divergence. These diverse parental lines were selfed for one generation and crossed in all possible combinations in a 10 x 10 diallel to develop 45 F_1 hybrids. The 45 F_1 hybrids and their ten parents were grown in a randomised block design with two replications during March-June 1994. The plot size was 2.4 x 1.8 m^2 with 24 plants/plot for each genotypes. Seeds were sown at a spacing of 60 cm between rows and 30 cm within rows. All cultural and management practices were adopted as per package of practices recommendations 1993 of Kerala Agricultural University (KAU, 1993).

3.2.1.3. Observations

In all the 45 F_1 hybrids and ten parents, five plants each were marked at random. Observations were recorded on plant height (cm), plant spread (cm), primary branches/plant, days to first flowering, days to first harvest, pod length (cm), pod weight (g), pod girth (cm), pods/cluster, bunches/plant, pods/plant, pods/kg, seeds/pod, 100 seed weight (g) and yield/plant (g). Average of five plants was worked out for statistical analysis.

3.2.2. Statistical analysis

3.2.2.1. Analysis for combining ability

The mean values of F_1 hybrids and parents for all the characters were analysed for combining ability using the method suggested by Griffing (1956) as given in Table.

3.2.2.2. Heterosis

The mean values of parents and hybrids of both the replications for each characters was taken for the estimation of heterosis in terms of three parameters, Heterosis over mid parent (Relative heterosis, RH), better parent (Heterobeltiosis (HB) and Standard parent (Standard Heterosis (SH) were worked out as suggested by Briggle (1963) and Hayes (1965). For calculating the standard heterosis the genotype, Arka Garima was taken as the standard parent. It has been proved to be superior for the last six years at Vellanikkara conditions through AICVIP trials (Abdul Wahab *et al.* 1991).

Relative heterosis is the deviation of hybrid mean from the mid parents value (RH) =

$$\frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Heterobeltiosis is the deviation of hybrid mean from the better parent value (HB) =

$$\frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Heterosis over the standard variety (SH) =

$$\frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

For each character the average value of the two parents in each cross was taken as the mid parental value (MP) and that of the superior parent as the better parent value (BP).

To test the significance of difference of F_1 mean over mid and better parent, critical difference (CD) was calculated from their standard error of difference as given below (Briggle,1963).

To test the significance over mid parent

$$CD\ (0.05) = te'_{(0.05)} \times \frac{\sqrt{3\ MSE}}{2r}$$

$$= te'_{(0.05)} \times SE$$

To test the significance over better parent and standard parent

$$CD\ (0.05) = te'_{(0.05)} \times \frac{\sqrt{2\ MSE}}{r}$$

$$= te'_{(0.05)} \times SE$$

where

e = error degrees of freedom

MSE = error variance

r = number of replications

SE = standard error of difference between two means

Results

4. RESULTS

4.1. Genetic variability and divergence in cowpea

4.1.1. Variability, heritability and genetic advance

General analysis of variance showed significant differences among the 31 genotypes of cowpea for all the 15 characters studied (Table 2). The population mean range, genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic advance as per cent of mean (genetic gain) for all the 15 characters are given in Table 3. The mean values are given in appendix I.

Plant height

Plant height ranged from 27.2 to 53.1 cm with a general mean of 40.3 cm. JBT 4/103 was the shortest (27.2 cm) while EC 240715 recorded the maximum height (53.1 cm). It had a pcv of 17.2 and gcv 19.2. This character had comparatively low heritability (0.79) and genetic advance as per cent of mean (31.6).

plant spread

Significant difference among the genotypes was observed for plant spread. It ranged from 38.3 cm in JBT 4/221 to 64.2 cm in Saval De Dhule. The mean was 50.1 cm. The gcv was 15.5 and pcv was 16.8. Heritabillity was 0.85

eral analysis of variance for 15 characters in cowpea (31 genotypes)

Mean Squares														
Plant spread	Primary branches	Days to flower-ing	Days to first harvest	Pod length	Pod girth	Pod weight	Flower bunch no.	Pods/ cluster	Pods/ plant	Pods/ kg	Seeds/ pod	100 seed weight	Yield/ plant
27.8	0.05	1.96	0.40	0.56	0.01	0.35	1.3	0.00	12.8	295.8	0.50	0.43	1110.0
90.6**	1.3	25.5**	385.6**	104.96**	0.95**	21.9**	300.7**	1.75**	616.2**	76865.3**	29.5**	22.5**	20456.4**
10.6	0.22	0.95	0.36	1.10	0.01	0.57	9.1	0.04	14.5	919.3	0.43	0.22	283.6

** Significant at 1% level.

Table 3. Range, mean, pcv, gcv, heritability, genetic advance and genetic advance as per cent of mean for 15 characters in cowpea

	Characters	Range	Mean ± SE	gcv	pcv	Heritability	Genetic advance	Genetic gain
1.	Plant height (cm)	27.2 - 53.1	40.3 ± 2.90	17.2	19.2	0.79	12.7	31.6
2.	Plant spread (cm)	38.3 - 64.2	50.1 ± 2.6	15.5	16.8	0.85	14.7	29.4
3.	Primary branches	2.5 - 6.1	4.5 ± 0.40	20.0	22.6	0.78	1.6	36.4
4.	Days to flowering	33.5 - 44.1	40.9 ± 0.80	7.0	7.4	0.90	5.6	13.6
5.	Days to 1st harvest	45.0 - 57.0	52.5 ± 0.50	6.8	6.9	0.97	7.3	13.8
6.	Pod length (cm)	8.8 - 32.4	18.7 ± 0.9	31.3	31.8	0.97	11.9	63.8
7.	Pod girth (cm)	0.70 - 3.8	2.4 ± 0.1	22.9	23.4	0.96	1.1	23.2
8.	Pod weight (g)	1.4 - 13.1	4.9 ± 0.61	54.6	56.7	0.93	5.3	108.1
9.	Flower bunch number	18.4 - 57.6	30.5 ± 2.5	32.3	33.8	0.91	19.4	63.7
10.	Pods/Cluster	1.4 - 3.8	2.4 ± 0.17	30.9	32.0	0.93	1.5	61.5
11.	Pods/Plant	15.0 - 90.8	34.5 ± 3.1	41.2	42.5	0.93	28.2	81.6
12.	Pods/Kg	76.7 - 716.3	27.8 ± 24.8	57.2	58.3	0.97	322.0	115.8
13.	Seeds/Pods	6.6 - 20.7	13.4 ± 0.54	23.3	23.8	0.96	6.3	46.9
14.	100 seed weight (g)	6.2 - 16.0	10.8 ± 0.38	25.3	25.7	0.97	5.5	51.6
15.	Yield/Plant (g)	56.0 - 457.3	154.3 ± 13.8	53.1	54.2	0.96	165.5	107.2

and genetic advance as per cent of mean was moderate (29.4).

Primary branches/plant

The primary branches ranged from 2.5 in JBT 4/103 to 6.1 in M/D 119, with a general mean of 4.5. This character had a comparatively low estimate of heritability (0.78) and genetic advance as per cent of mean (36.4).

Days to flowering

Among the 31 genotypes there was significant variation for days to flowering. It ranged from 33.5 days in IC 38956-1 to 44.1 days in VS 477 with a general mean of 40.9 days. Pcv was 7.4 and gcv 7.0. It showed a high estimate of heritability (0.90). But the genetic gain was low (13.6).

Days to first harvest

The days taken for the first vegetable pod harvest ranged from 45 days in IC 38956-1 and Selection 263 to 57 days in Saval De Dhule; with a general mean of 52.5 days. It recorded a pcv of 6.9 and gcv of 6.8. Though heritability was very high for this trait (0.97), estimate for genetic advance as per cent of mean was low (13.8).

Pod length

The length of pods in different genotypes showed significant variation (Plate 1). It ranged from 8.8 cm in 420 NB to 32.4 cm in Selection 2-1 (Plate 2) with an over all mean of 18.7 cm. The phenotypic and genotypic coefficients of variation were 31.8 and 31.3 respectively. The estimate of heritability was 0.97 and that of genetic gain was 63.8.

Pod girth

Pod girth ranged widely from 0.70 cm (Pusa Dofasli) to 3.81 cm (Arka Garima) with a general mean of 2.4 cm. It recorded pcv of 23.4 and gcv of 22.9. It recorded high heritability (0.96) with low values of genetic gain (23.2).

Pod weight

Pod weight exhibited a wide range from 1.4 g in 734 NB to 13.1 g in Arka Garima (Plate 3) with a general mean of 4.9 g. Phenotypic coefficient of variation was 56.7 while genotypic coefficient of variation was 54.6. It showed high estimate of heritability (0.92) and genetic gain (108.1).

Flower bunch number

The genotype EC 240712 had the lowest number of bunches/plant (18.4) while IC 38956-1 showed the maximum (57.6). The general mean was 30.5. This trait exhibited a pcv of 33.8 and gcv 32.3, resulting in high estimates of heritability (0.91) and genetic gain (63.7).

Plate 1. Variability for pod length in 31 cowpea genotypes

Plate 2. Selection 2-1 with maximum pod length

Plate 3. Arka Garima which recorded highest pod weight

Pods/cluster

Pods/cluster ranged from 1.4 in Local 2 to 3.8 in Pusa Dofasli (Plate 4). It had a general mean of 2.4. Phenotypic coefficient of variation was 32.0 while genotypic coefficient of variation was 30.9. It showed high estimate of heritability (0.93) and low genetic gain (61.5).

Pods/plant

Pods/plant ranged widely from 15.0 in VS 479 to 90.8 in IC 91456 (Plate 5) with a general mean of 34.5. Pod number showed high pcv and gcv (41.2 and 42.5 respectively) and high values of heritability (0.93) and genetic advance as per cent of mean (81.6).

Pods/kg

Number of pods to make 1 kg ranged from 76.7 (Arka Garima) to 716.3 (734 NB). The general mean was 278.0. This character showed a pcv of 58.3 and gcv of 57.2 and also exhibited very high estimates of heritability (0.97) and genetic advance as per cent of mean (115.8).

Seeds/pod

Seeds/pod ranged widely from 6.6 (34 NB) to 20.7 (VS 477) with an average of 13.4. It recorded pcv of 23.8

Plate 4. Pusa Dofasli with more number of pods/cluster

Plate 5. IC 91456 with maximum number of pods/plant

Plate 6. Electrophoretic pattern of protein in cowpea genotypes
(IC 91511, NIC 12882, VS 389, EC 240712, Pusa Dofasli, VS 87, IC 91499, Local-2, 416 NB, IC 91456, VU 18, 744 NB)

and gcv of 23.3. It also exhibited very high estimate of heritability (0.96) and moderate value of genetic advance as per cent of mean (46.9).

100 seed weight

100 seed weight ranged from 6.2 g (734 NB) to 16.0 g (Selection 2-1) with a general mean of 10.8 g. The heritable variation was higher for this character (pcv, 25.7; gcv, 25.3), resulting in high heritability (0.97) and genetic advance as per cent of mean (51.6).

Yield/plant (g)

Wide variation existed among genotypes for yield/plant. Lowest yielder was Saval De Dhule (56.0 g) and highest yield was recorded in Arka Garima (457.3 g). The average yield was 154.3 g. Phenotypic coefficient of variation was 54.2 and gcv 53.1. It also indicated very high heritability (0.96) and genetic gain (107.2).

4.1.2. Genetic divergence among 31 genotypes of cowpea

4.1.2.1. D^2 analysis

The 31 cowpea genotypes were grouped into six clusters (Rao, 1952). The clustering pattern is given in Table 4.

The clusters III and V were the largest both having nine genotypes each followed by II, IV and VI all

Table 4. Clustering pattern in 31 cowpea genotypes

Cluster Number	Number of genotypes in each cluster	Genotypes
I	1	Arka Garima
II	4	IC 38956-1, Pusa Komal, IC 91456, JBT 4/221.
III	9	Saval De Dhule, EC 240715, EC 240712, NIC 12882, 416 NB, 420 NB, 744 B, VS 477, Local 1.
IV	4	Pusa Dofasli, 734 NB, 34 NB, 221 NB
V	9	IC 91511, M/D 119, IC 91499, Kanakamony, VS 87, VS 389, Vu 18, VS 479, Local 2.
VI	4	JBT 4/103, Selection 2-1, Amb 1, Selection 263.

having four genotypes each. Cluster I was smallest with only a single genotype.

The cluster I was unique with a single genotype Arka Garima, the highest yielder with highest pod weight. The cluster II contained moderate yielders (Pusa Komal, JBT 4/221), early yielders (IC 38956-1, JBT 4/221), and those with more number of pods/plant (IC 91456). The genotypes in cluster III were economically poor yielders, and most of them had semi erect or slight trailing habit. The cluster IV contained genotypes with more number of pods/cluster and less pod weight (Pusa Dofasli). The cluster V included moderate yielding, dual purpose genotypes like Kanakamony and determinate types with many podded clusters like VS 389, VU 18 etc. along with profuse branching M/D 119. Cluster VI contained high and early yielders like Selection 2-1, Selection 263 and Amb-1 with desirable morphological and economic characters.

The intra and inter cluster D^2 values are presented in Table 5. The intra cluster distance (D^2) was highest in cluster II (460.5) followed by cluster IV (346.6) and VI (262.3). The inter cluster distance was maximum between cluster I and IV (2336.5) followed by clusters IV and VI (1525.7) and I and II (14.10.2).

The genetic distance between cluster III and V was minimum (394.0). With the help of average inter cluster D^2

Table 5. Inter and Intra D^2 values among six clusters of genotypes in cowpea.

Cluster	I	II	III	IV	V	VI
I	0.00					
II	1410.2	460.5				
III	1326.3	774.4	251.7			
IV	2336.5	874.7	625.4	346.6		
V	636.7	734.7	394.0	1142.4	196.3	
VI	695.97	572.2	889.6	1525.70	485.37	262.3

values, cluster diagram showing the inter relationship has been prepared (Fig. 1).

Based on D^2 values and morphological observations ten genotypes were selected from these six clusters for developing 45 F_1 hybrids to study the nature of combining ability and heterosis. The parents selected were Arka Garima (cluster I), Pusa Komal, JBT 4/221 (cluster II), Pusa Dofasli (cluster IV), Kanakamony, VS 389 and VU-18 (cluster V) and Selection 2-1, Amb-1 and Selection 263 (cluster VI).

4.1.2.2. Electrophoretic studies

The electrophoretic pattern of seed proteins of 31 cowpea genotypes have been outlined in the form of Electrophorograms (Fig. 2). Rf values are given in appendix II. The maximum number of bands obtained in a genotype was five. The Rf values varied from 0.06 to 0.69 indicating that proteins of different nature are present in the genotype (Plates 6, 7 and 8).

Based on the Rf values the protein bands were grouped into three, Rf values ranging from (1) 0 to 0.2. (2) 0.21 to 0.51 and (3) more than 0.51.

In general protein bands was more dominant in the range of Rf value 0.21 to 0.51. The bands at Rf 0.06 to 0.2 are common to genotypes 2, 3, 9, 15, 21, 23, 25 and 26. The bands at the second range are common to all the

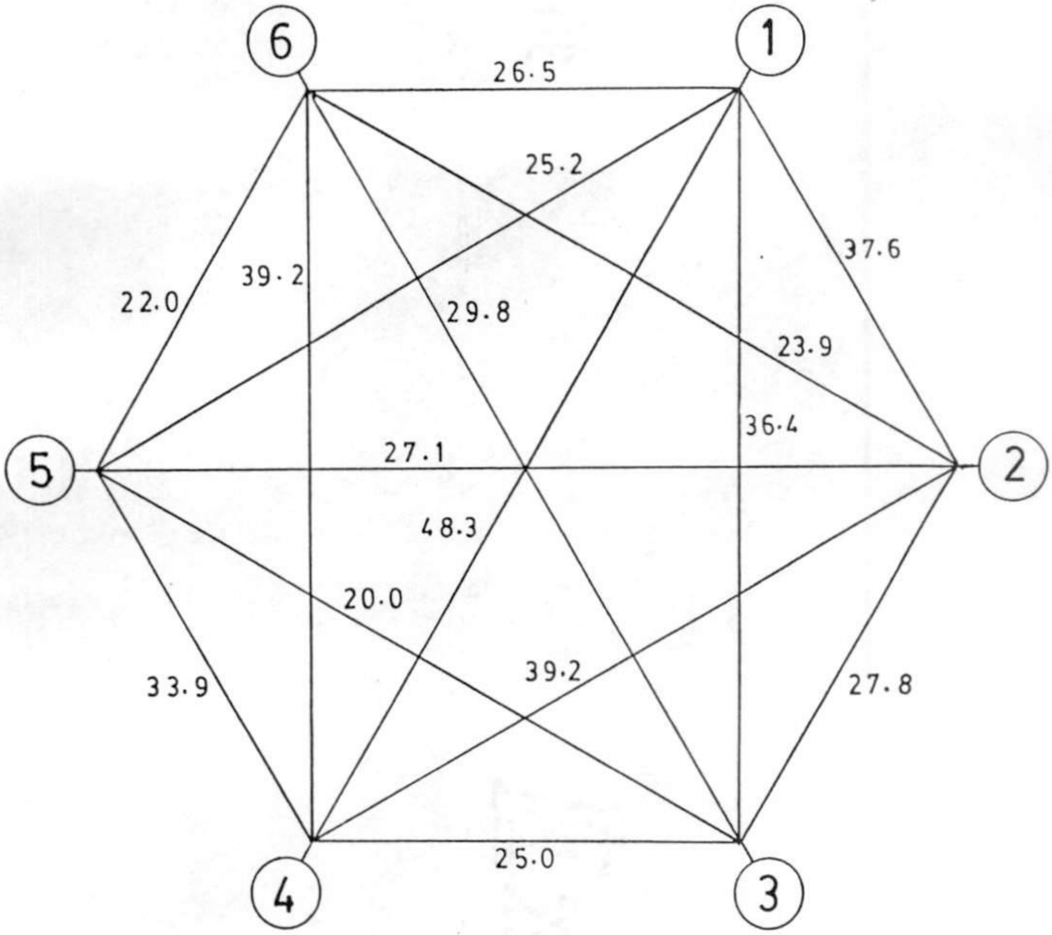


FIG.1 DIAGRAMATIC REPRESENTATION OF CLUSTERING OF 31 GENOTYPES OF COWPEA

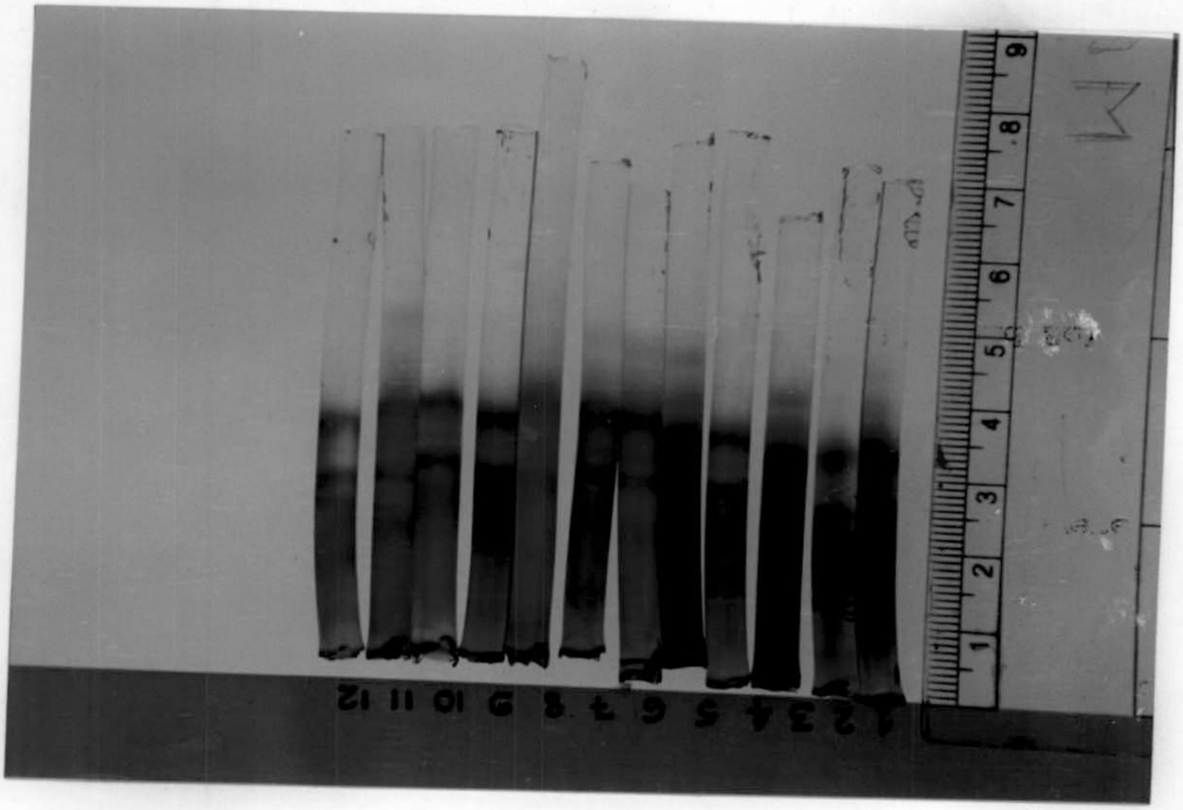

1 2 3 4 5 6 7 8 9 10 11 12

Plate 7. Electrophoretic pattern of protein in cowpea genotypes
(IC 38956-1, Amb-1, 420 NB, JBT 4/103, VS 477, Arka Garima, JBT 4/221, EC 240715, Saval De Dhule, Local-1, 734 NB

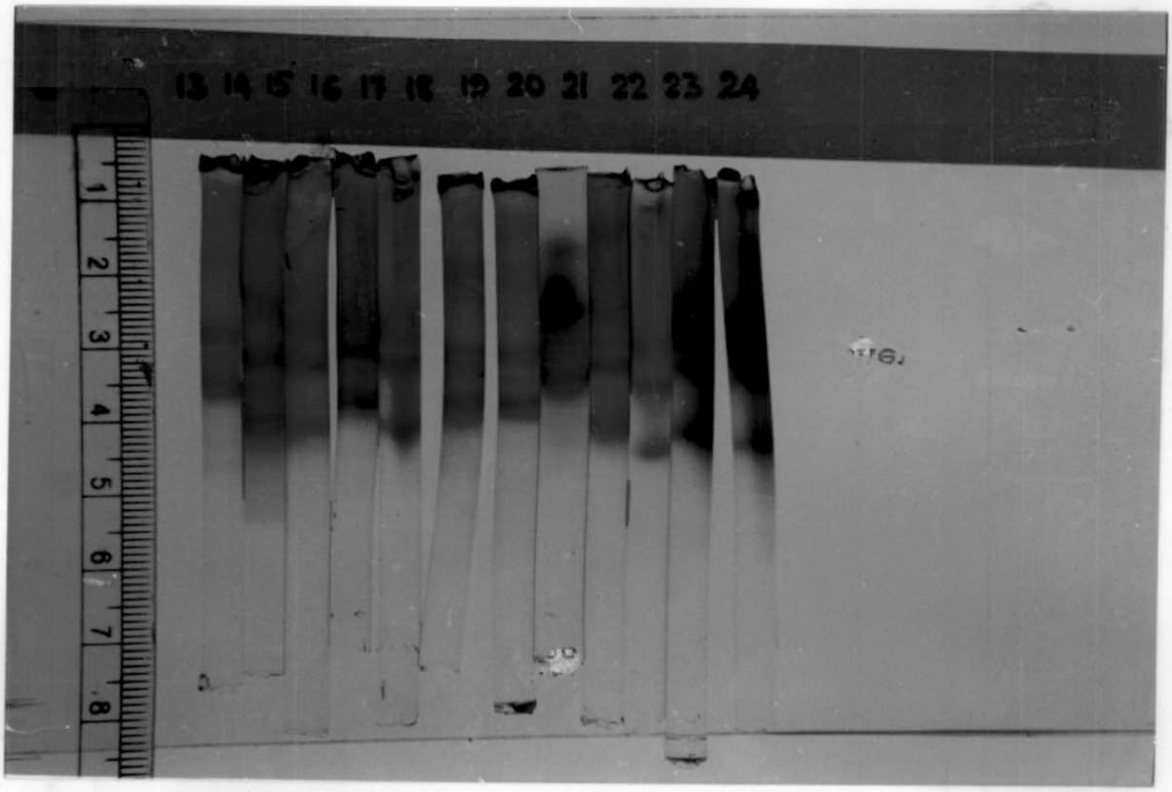
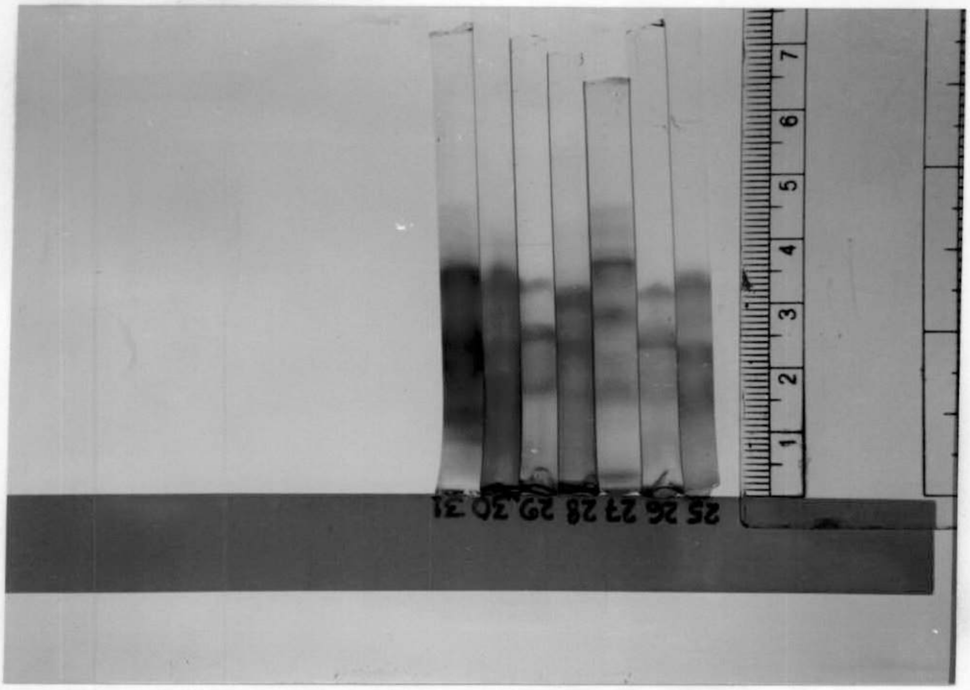

13 14 15 16 17 18 19 20 21 22 23 24

Plate 8. Electrophoretic pattern of protein in cowpea genotypes
(VS 479, Selection 2-1, Selection 263, Pusa Komal, 34 NB, Kanakamony, 221 NB)


25 26 27 28 29 30 31
1 2 3 4 5 6 7

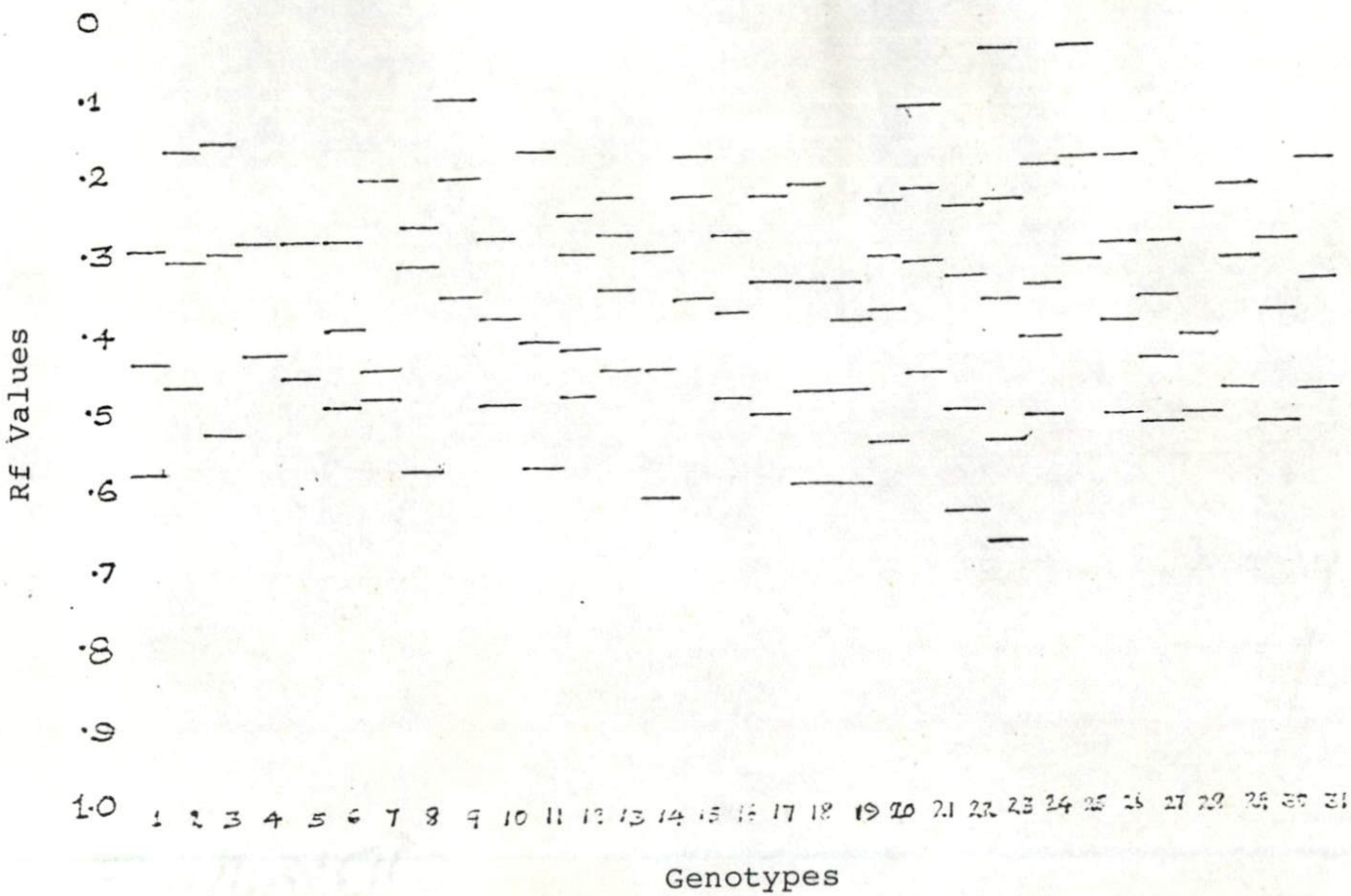


Fig. 2 Electrophorograms of seed proteins of <u>Vigna</u> <u>unguiculata</u> accessions

accession studied. The bands at the third range are found in genotypes 1, 3, 8, 11, 16, 17, 18, 19, 20, 22, 23, 24, 26, 27, 28.

A grouping of the genotypes into different clusters were attempted based on Rf values. Cluster I included the following accessions where the first band was at a range of Rf 0.25 to 0.30, second band at 0.35 to 0.45 and third at a range of 0.50 to 0.65. They were genotypes 1, 6, 10, 12, 13, 14, 16, 28, 29 and 30. Cluster II included the following two accessions with only 2 clear bands at Rf 0.29 and 0.49 to 0.46. Cluster III contained genotypes with clear bands (12, 17, 18, 20, 22, 24, 26 and 27) where Rf ranged from 0.21 to 0.25 for first band, 0.29 to 0.35 for the second band and from 0.36 to 0.52 for the third and 0.46 to 0.61 for the fourth. Cluster IV contained genotype 22 with Rf values 0.26, 0.35, 0.52 and 0.65 respectively. The cluster V contained the genotypes 2, 3, 9, 11, 15, 21 and 26. Where the Rf value at first band ranged from 0.11 to 0.20. The second from 0.21 to 0.31 and the third from 0.33 to 0.58. The cluster VI contained the genotypes 23 and 25 with bands at Rf 0.06, 0.2 to 0.25 and 0.33 to 0.38. This classification is not in strict confirmity with statistical divergence studies. However there is a close proximity.

4.1.3. Correlation studies

The genotypic, phenotypic and environmental correlations among yield and its components have been worked out and the results are presented in Tables 6, 7 and 8. The genotypic correlation coefficients were high for all the characters studied.

The characters which significantly contributed to yield were days to first harvest, pod length, pod girth, pod weight, pods/kg, seeds/pod and 100 seed weight. Pod weight exhibited the highest positive and significant association with pod yield (rp = 0.79, rg = 0.83, re = 0.29), followed by pod length (rp = 0.61, rg = 0.64, re = 0.06) and pod girth (rp = 0.60, rg = 0.63, re = -0.06) and 100 seed weight (rp = 0.51, rg = 0.53 and re = 0.14). The character pods/kg exhibited significant negative association with yield (rp = -0.61, rg -0.62 and re = -0.27), followed by days to first harvest (rp = 0.25, rg = 0.26, re = 0.16).

Intercorrelation among yield components

Plant height exhibited significant association with yield through pods/cluster and pods/plant (rp = 0.30 and 0.26 respectively). Plant spread exhibited significant association with yield through days to flowering, days to harvest, pod length, pod weight, seeds/pod and 100 seed

Table 6. Phenotypic correlation coefficients (r_p) among yield and its components in cowpea

	Plant spread	Primary branches	Days to flowering	Days to harvest	Pod length	Pod girth	Pod weight	Bunches/plant	Pods/cluster	Pods/plant	Pods/kg	Seeds/pod	100seed weight	Yield
Plant height	-0.29*	0.12	-0.14	-0.19	-0.03	0.15	0.00	0.13	0.25	0.23	-0.01	-0.11	-0.13	0.21
Plant spread		0.05	0.58**	0.54**	0.24	0.13	0.32*	-0.47**	-0.60**	-0.48**	-0.30*	0.29*	0.31	0.03
Primary branches			0.22	0.27*	-0.17	-0.37**	-0.26*	0.28*	0.02	0.29*	0.34**	-0.11	-0.41	-0.08
Days to flowering				0.88**	-0.09	-0.19	0.04	-0.45**	-0.55**	-0.31*	0.05	0.01	-0.07	-0.20
Days to 1st harvest					-0.16	-0.30*	-0.03	-0.35**	-0.51**	-0.32*	0.09	-0.04	-0.16	-0.25*
Pod length						0.56**	0.73**	-0.39**	-0.24	-0.32*	-0.68**	0.70**	0.64**	0.61**
Pod girth							0.62**	-0.29*	-0.29*	-0.24	-0.61**	0.25*	0.57**	0.60**
Pod weight								-0.43**	-0.35**	-0.42**	-0.80**	0.46**	0.70**	0.79**
Bunch/plant									0.47**	0.44**	0.55**	-0.42**	-0.44**	-0.21
Pods/cluster										0.64**	0.36**	-0.13	-0.34**	0.00
Pods/plant											0.49**	-0.30*	-0.44**	0.10
Pods/kg												-0.57**	-0.77**	-0.61**
Seeds/pod													0.32*	0.29*
100 seeds weight														0.51**

*Significant at 5% level
**Significant at 1% level

Table 7. Genotypic correlation coefficients (r_g) among yield and its components in cowpea

	Plant spread	Primary branches	Days to flowering	Days to harvest	Pod length	Pod girth	Pod weight	Bunches/plant	Pods/cluster	Pods/plant	Pods/kg	Seeds/pod	100seed weight	Yield
Plant height	-0.35**	0.10	-0.16	-0.19	-0.03	0.17	-0.00	0.16	0.30*	0.26**	0.01	-0.18	-0.14	0.23
Plant spread		0.03	0.66**	0.60**	0.27*	0.16	0.36**	-0.52**	-0.67**	-0.54**	-0.33**	0.31*	0.34**	0.05
Primary branches			0.25*	0.33**	-0.19	-0.42**	-0.31*	0.29*	0.06	0.34**	0.39**	-0.13	-0.47**	-0.10
Days to flowering				0.94**	0.10	-0.20	0.04	-0.50**	-0.59**	-0.35**	0.06	0.01	-0.10	-0.21
Days to 1st harvest					-0.17	-0.30	-0.03	-0.37*	-0.53**	-0.34**	0.09	-0.03	-0.17	-0.26*
Pod length						0.58**	0.77**	-0.41**	-0.25*	-0.34**	-0.70**	0.72**	0.66**	0.64**
Pod girth							0.68**	-0.33**	-0.32*	-0.27*	-0.64**	0.26*	0.59**	0.63**
Pod weight								-0.46**	-0.38**	-0.42**	-0.82**	0.49**	0.74**	0.83**
Bunches/plant									0.52**	0.46**	-0.58**	0.44**	-0.46**	-0.22**
Pods/cluster										0.68**	0.39**	-0.15	-0.37**	0.00
Pods/plant											0.49**	-0.33**	-0.46**	0.10
Pods/kg												-0.59**	-0.79**	-0.62**
Seeds/pod													0.34**	0.31*
100 seeds weight														0.53**

*Significant at 5% level

**Significant at 1% level.

Table 8. Environmental correlation coefficients (r_e) among yield and its components in cowpea

	Plant spread	Primary branches	Days to flowering	Days to harvest	Pod length	Pod girth	Pod weight	Bunches/plant	Pods/cluster	Pods/plant	Pods/kg	Seeds/pod	100seed weight	Yield/plant
Plant height	-0.05	0.20	-0.02	-0.27	-0.11	0.04	0.06	-0.05	-0.05	0.05	-0.03	0.25	-0.13	0.13
Plant spread		0.15	-0.03	-0.07	-0.12	-0.20	0.06	-0.07	0.05	0.20	0.01	0.09	-0.04	0.21
Primary bunches			0.03	-0.23	-0.02	-0.11	0.02	0.25	-0.23	0.01	0.10	.08	-0.07	0.03
Days to flowering				0.05	-0.22	-0.10	0.11	0.08	-0.06	0.18	0.05	-0.01	0.38	0.01
Days to 1st harvest					0.12	-0.06	-0.07	-0.04	0.14	0.13	0.05	-0.27	0.21	0.16
Pod length						0.13	-0.01	-0.04	0.05	-0.04	0.10	0.14	-0.01	0.06
Pod girth							0.36	0.24	0.20	0.16	0.19	-0.01	0.11	-0.06
Pod weight								-0.06	-0.07	-.47	-0.54	0.06	-0.00	0.29*
Bunches/plant									-0.10	0.11	0.19	-0.00	-0.08	-0.07
Pods/cluster										0.15	-0.10	0.11	-0.13	-0.01
Pods/plant											0.64	0.11	0.06	0.09
Pods/kg												-0.03	-0.06	-0.27*
Seeds/pod													-0.08	-0.08
100 seeds weight														0.14

*Significant at 5% level

weight (rg = 0.66, 0.60, 0.27, 0.36, 0.31 and 0.34 respectively). Significant negative association was observed among bunches/plant, pods/cluster, pods/plant and pods/kg (rg = -0.52, -0.67, -0.54 and -0.33 respectively). Primary branches exhibited positive association with days to flowering (rg = 0.25), days to first harvest (rg = 0.33), bunches/plant (0.29), pods/plant (0.34) and pods/kg (rg = 0.39). Days to flowering exhibited a significant negative association with yield through bunches /plant (-0.50), pods/cluster (-0.59) and pods/plant (-0.35). Significant positive association was recorded with days to harvest (0.94).

Days to first harvest exhibited a significant negative correlation with bunches/plant (-0.37), pods/cluster (-0.53), pods/plant (-0.34) and pods/kg (-0.70). Pod length exhibited positive association with pod girth (rg = 0.58), pod weight (0.77), seeds/pod (0.72), 100 seed weight (0.66) and yield. Pod length exhibited negative association between bunches/plant (-0.41), pods/cluster (-0.25), pods/plant (-0.34) and pods/kg (-0.70).

Pod girth was positively correlated with pod weight (0.68) and 100 seed weight (0.59) and seeds/pod (0.26). Significant negative association was noticed between pod girth (-0.33) and bunches/plant (-0.27), pods/cluster (-0.32), pods/plant and pods/kg (-0.64). Pod weight exhibited significant positive association with bunches/plant (-0.46), pods/cluster (-0.38) and pods/plant (-0.42).

Bunches/plant exhibited significant positive association with seeds/pod (0.44), pods/plant (0.46), pods/cluster (0.52), pods/kg (0.58). Pods/cluster was found to be highly correlated with pods/plant (0.68) and pods/kg (0.39). Pods/plant was positively associated with pods/kg (0.49) and negatively associated with seeds/pod (-0.33) and 100 seed weight (-0.46). Pods/kg was negatively associated with seeds/pod (-0.59) and 100 seed weight (-0.79). Seed/pod exhibited a positive significant association with 100 seed weight (0.34).

4.1.4. Path coefficient analysis

The genotypic correlations among yield and its component characters were partitioned into different components to find out the direct and indirect contribution of each character on pod yield (Table 9, Fig. 3). The characters like pod length (x_1), pod girth (x_2), pod weight (x_3), pods/kg (x_4) and 100 seed weight (x_5) which showed significant correlation with yield at 1 per cent level of significance alone were selected for path coefficient analysis.

The path analysis revealed that the pod weight exerted the maximum positive direct effect on pod yield

Table 9. Direct and indirect effects of yield components on pod yield in cowpea.

Characters	Pod length	Pod girth	Pod weight	Pods/Kg	100 seed weight	Genotypic correlation with yield
Pod length	0.081	0.121	0.550	-0.162	-0.077	0.614
Pod girth	0.046	0.215	0.466	-0.056	-0.068	0.602
Pod weight	0.059	0.132	0.758	-0.073	-0.084	0.790
Pods/Kg	-0.055	-0.131	-0.60	0.091	0.092	-0.61
100 seed weight	0.052	0.122	0.530	-0.070	-0.120	0.514

Residual 0.34

(The underlined, diagonal values indicate direct effects)

(0.758), followed by pod girth (0.215). Pods/kg and pod length also exerted positive direct effect on yield (0.091 and 0.081 respectively). 100 seed weight showed a negative significant direct effect on pod yield.

Though the direct effect of pod length on yield was negligible, the indirect effects of pod length through pod girth and pod weight was positive and high (0.121 and 0.55 respectively). Pod length exerted a negative indirect effect (-0.162 and -0.077) through pods/kg and 100 seed weight, respectively. The indirect effect of pod girth through pod weight was positive and high (0.466). However, the indirect effect through pods/kg and 100 seed weight were quite low and negative and that through pod length was positive but low.

Pod weight exerted a positive indirect effect through pod girth (0.132). The indirect effect through other characters were negligible. The negative correlation between pods/kg and yield (rg = -0.61) resulted from the high negative indirect effect through pod weight (-0.61). Though the direct effect of pods/kg on yield was negligible, its indirect effect through 100 seed weight was positive (0.092). 100 seed weight exerted positive indirect effect through pod weight (0.53), pod girth (0.122) and pod length (0.052). It exerted a negative indirect effect through pods/kg (-0.07).

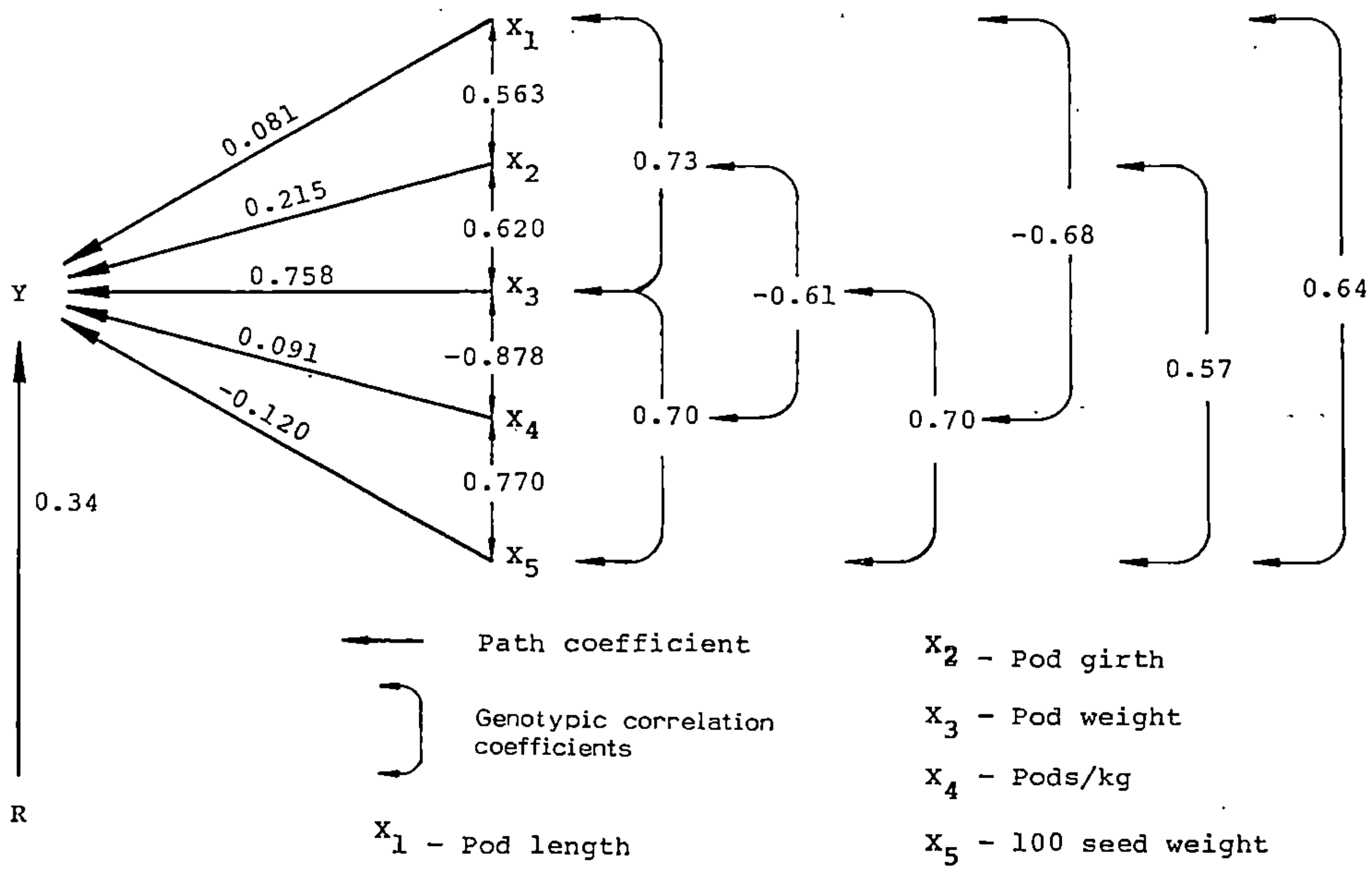


FIG.3 PATH DIAGRAM SHOWING DIRECT AND INDIRECT EFFECT OF THE COMPONENTS ON YIELD

The residual effect due to the unknown causal factors influencing yield was 0.34, thus indicating that the five characters considered in path analysis contributed to about sixty six per cent of the yield.

4.2. Combining ability and Heterosis

4.2.1. Combining ability analysis

General analysis of variance showed significant differences among 55 genotypes for all the fifteen characters (Table 10). Analysis of variance for different characters had shown that the variance due to gca and sca were significant for all the traits (Table 11). Estimate of gca effect of parents and sca effect of hybrid combinations are presented in Tables 12 and 13 respectively.

Plant height

The gca and sca variances were highly significant for plant height. Positive values of gca indicated increase and negative values decrease in plant height. VU-18 had the maximum value of gca effect (2.93) and Selection 263 the lowest. The crosses Pusa Komal x Kanakamony showed highest value for sca effect (13.61) followed by Amb-1 x Pusa Dofasli (13.44) and VS 389 x Selection 263 (9.65).

Plant spread

Significant gca and sca variances were observed for this character also. Selection 263, Selection 2-1 and

Table 10. General analysis of variance for 15 characters in 55 genotypes of cowpea.

Source of variation	df	Plant height	Plant spread	Primary branches	Days to flowering	Days to first harvest	Pod length	Pod girth	Pod weight	Flower bunches	Pods/ Cluster	Pods/Plant	Pods/Kg	Seeds/Pod	100 seed weight	Yield/Plant
Replication	1	4.38	5.8	0.24	0.74	0.32	0.03	0.04	0.0	2.2	0.13	9.9	55.0	0.03	0.0	72.3
Genotypes	54	7.40**	44.3**	1.5**	6.2**	11.9**	35.1**	0.40**	5.8**	163.1**	0.71**	160.4**	3833.0**	8.5**	8.5**	5898.0**
Error	54	2.2	1.8	0.03	1.1	0.1	0.08	0.08	0.07	2.1	0.03	2.7	44.5	0.05	0.0	16.6

**Significant at 1% level.

Table 11. Analysis of variance for combining ability in a 10 x 10 diallel in cowpea

Source of variation	df	Plant height	Plant spread	Primary branches	Days to flowering	Days to first harvest	Pod length	Pod girth	Pod weight	Flower bunches	Pods/ Cluster	Pods/Plant	Pods/Kg	Seeds/Pod	100 seed weight	Yield/Plant
gca	9	85.3**	61.9**	1.4**	7.6**	13.5**	70.1**	0.52**	11.0**	176.3**	1.6**	185.2**	7217.5**	7.7**	11.0**	6442.9**
sca	45	27.3**	14.2**	0.65**	2.2**	4.5**	7.1**	0.14**	1.3**	62.6**	0.11**	59.2**	856.1**	3.4**	2.9**	2249.9**
Error	54	1.1	0.9	0.02	0.53	0.05	0.04	0.04	0.04	1.1	0.16	1.3	22.3	0.03	0.0	8.3

**Significant at 1% level

VS 389 had higher negative gca effects. Selection 2-1 x Kanakamony showed the highest negative sca effect (-7.98) followed by JBT 4/221 x Pusa Dofasli (-7.97).

Primary branches/plant

JBT 4/221 showed significant gca effect (0.62) for branches/plant followed by Pusa Dofasli (0.33). VS 389 had lowest gca effect (-0.60). Arka Garima x JBT 4/221 had highest positive sca effect (1.87).

Days to flowering

Both gca and sca variances were highly significant for days to flowering. Amb-1 possessed highest negative gca effect (-1.13) followed by Selection 263 (-0.70). Amb-1 x Arka Garima had highest negative sca effect (-3.62) followed by VU-18 x Amb-1 (-2.85) and VS 389 x Kanakamony (-2.56).

Days to harvest

Significant gca and sca variances were observed for days to harvest also. Maximum negative gca effect was recorded with Amb-1 (-1.63) followed by Selection 2-1 (-0.76) and JBT 4/221 (-0.74). The cross Selection 263 x VU 18 had maximum sca effect for days to harvest (-3.91).

Pod length

Pod length exhibited significant gca and sca variances. The genotype Selection 2-1 showed maximum gca effect (3.10) followed by Selection 263 (2.91). Maximum sca effect was in Selection 2-1 x Arka Garima (5.33). Kanakamony x Amb-1 (4.97) and Selection 263 x Pusa Dofasli (4.60) exhibited considerable values for sca.

Pod girth

Highly significant gca and sca variances were noticed for pod girth. Arka Garima had highest positive gca effect (0.45) followed by VU 18. The crosses with high positive effect were Selection 2-1 x JBT 4/221 (1.22) followed by Amb-1 x Arka Garima (0.59).

Pod weight

The gca and sca variances were highly significant for this character. Arka Garima possessed maximum gca effect (2.91) followed by VU 18 and Selection 263. Maximum sca effects were observed in Selection 263 x VU 18 (2.12) and VU 18 x Pusa Dofasli (1.88).

Bunches/plant

Highest values of gca effect was observed in Selection 2-1 and Amb-1 (5.12 and 4.60) where as highest sca values were recorded in Kanakamony x Selection 263 (15.59) and VS-389 x Kanakamony (14.90).

Pods/cluster

General combining ability and specific combining ability variances were highly significant for pods/cluster. The genotypes with maximum gca effects were JBT 4/221 (0.60) and Pusa Dofasli (0.53). The hybrids with high sca effects for pods/cluster were Kanakamony x JBT 4/221 (0.69) and Selection 263 x JBT 4/221 (0.57).

Pods/plant

Pods/plant exhibited highly significant gca and sca variances. The parents with high gca effects were Pusa Komal (6.88) followed by Kanakamony (4.04). High sca effects were shown by Pusa Komal x JBT 4/221 (14.50) and Pusa Komal x VU 18 (14.38).

Pods/kg

The gca and sca variances were highly significant. Arka Garima had maximum negative gca effect (-39.2) for pods/kg. Combination with maximum negative sca effect was VS 389 x Pusa Dofasli (-51.77).

Seeds/pod

Highly significant gca and sca variances were observed for seeds/pod. Highest gca effect was for Selection 2-1 (1.40). Larger sca effects were recorded in the

Table 12. Estimate of gca effects of 10 cowpea genotypes for 15 characters

Parental lines	Plant height	Plant spread	Primary branches	Days to flowering	Days to first harvest	Pod length	Pod girth	Pod weight	Bunches/ Plant	Pods/ cluster	Pods/ plant	Pods/Kg	Seeds/pod	100 seed weight	Yield/ plant
Pusa Komal	2.53	-1.26	-0.33	0.09	0.30	-1.3	-0.02	-0.83	-1.19	-0.03	6.88	19.9	0.12	-1.5	6.01
Selection 2-1	-0.42	-1.89	0.03	-0.84	-0.76	3.1	-0.11	0.36	5.12	-0.03	-0.98	-19.2	1.4	1.5	19.7
VS 389	-0.37	-1.58	-0.60	1.16	1.46	1.8	0.03	0.28	1.36	0.08	-3.85	-14.2	-0.51	0.34	-3.7
Kanakamony	-2.73	2.89	0.20	0.85	1.0	-2.3	-0.05	-0.36	-6.15	-0.38	4.04	4.9	-1.1	0.38	12.7
Selection 263	-4.16	-2.63	0.01	-0.70	-0.62	2.9	0.02	0.48	0.17	-0.15	-4.65	-4.8	0.46	0.11	-20.1
Vu-18	2.93	2.97	-0.10	-0.55	-0.93	0.22	0.14	0.51	-4.66	-0.44	-0.81	-14.2	0.64	0.42	10.9
Amb-1	2.64	-0.81	-0.08	-1.13	-1.63	0.07	0.09	-0.26	4.60	0.21	-0.62	1.5	0.40	0.04	-6.8
Arka Garima	1.6	3.6	-0.08	0.17	0.83	1.8	0.45	2.02	-3.36	-0.38	-4.55	-39.2	0.0	0.92	41.8
JBT 4/221	-3.5	-0.27	0.62	-0.28	-0.74	-3.95	-0.24	-0.82	3.10	0.60	0.57	16.6	-1.30	-0.87	-23.4
Pusa Dofasli	1.47	-1.01	0.33	1.04	1.09	-2.3	-0.30	-1.38	1.01	0.53	3.97	48.9	-0.13	-1.3	-37.0
Var (Gi)	0.09	0.08	0.001	0.04	0.004	0.003	0.003	0.003	0.08	0.001	0.10	1.7	0.002	0.001	0.62
Var (Gi - Gj)	0.18	0.15	0.003	0.09	0.008	0.006	0.007	0.006	0.18	0.003	0.22	3.7	0.004	0.002	1.4

Table 13. Estimate of s.c.a effects of 45 F_1 hybrids of cowpea for 15 characters

Genotypes	Plant height	Plant spread	Primary branches	Days to flowering	Days to first harvest	Pod length	Pod girth	Pod weight	Flower bunch No.	Pods/cluster	Pods/plant	Pods/Kg	Seeds/Pod	100 seed weight	Yield/plant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-2.51	-0.48	0.56	0.08	-0.90	-2.82	0.24	-0.04	-2.82	-0.17	-2.79	0.68	-1.78	1.84	-17.57
2	-3.26	-3.78	0.02	-0.67	-1.52	1.67	0.14	-0.12	10.44	-0.44	9.93	3.82	-1.64	0.98	48.41
3	13.61	1.65	-0.86	-0.37	0.50	-0.86	-0.32	0.66	4.45	0.43	2.94	3.70	0.40	2.94	9.41
4	-5.87	0.48	-0.25	-0.87	-1.26	-1.56	-0.16	-0.35	-2.62	-0.05	-0.28	-8.06	-1.70	-0.79	8.27
5	2.59	-0.26	0.69	0.59	0.27	-0.24	-0.06	-1.56	1.21	-0.09	14.38	54.69	-0.29	-0.10	3.18
6	0.83	0.92	0.66	-0.02	0.60	-0.18	-0.12	-0.19	1.95	0.29	2.19	7.19	0.95	-0.72	2.16
7	-2.63	0.79	-1.33	0.82	2.26	-3.88	0.32	1.05	6.41	-0.15	-13.37	-39.13	1.35	1.40	-33.70
8	3.97	0.12	-0.32	-1.98	-1.59	1.95	-0.07	-0.25	-6.05	0.04	14.50	-3.91	0.82	-1.81	79.24
9	-2.75	-0.85	1.26	2.45	0.75	2.61	0.06	-0.21	-5.96	-0.14	-5.90	5.29	-0.51	-1.35	-25.78
10	3.19	4.70	0.98	0.16	-0.04	1.48	-0.95	-0.51	-1.71	-0.18	8.54	-24.18	1.60	-1.00	122.37

contd.

Table 13 (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
11	-3.35	-7.98	0.01	0.61	-0.64	-2.54	-0.13	-1.86	4.38	0.14	7.25	31.95	-1.11	-1.04	-7.64
12	-1.04	4.48	0.93	0.16	0.19	-3.76	-0.29	1.60	2.81	-0.05	2.08	-13.66	2.62	0.98	30.64
13	2.27	-0.26	-0.05	0.42	-0.34	0.06	-0.11	-0.61	-12.71	0.08	-0.51	4.04	0.69	1.93	-7.00
14	2.91	0.92	0.53	-0.76	-0.97	2.71	-0.01	0.19	-0.87	0.11	-13.20	-1.76	2.69	2.25	-86.51
15	-4.27	0.79	-0.24	-0.58	-0.92	5.33	0.51	0.28	5.35	0.02	2.01	-2.67	1.41	-0.50	24.82
16	-0.63	0.12	-0.56	-0.59	2.31	-0.89	1.22	0.38	13.88	0.29	0.62	-0.10	-0.60	-4.79	0.93
17	-1.68	-0.85	0.19	-0.32	-0.52	-3.09	-0.08	-0.53	7.47	-0.14	10.16	10.34	-2.91	0.68	27.72
18	-7.28	-2.13	0.53	-2.56	1.19	-3.44	-0.06	0.42	14.90	-0.34	-3.33	26.44	3.61	0.10	-53.77
19	9.65	0.93	0.51	-0.22	1.30	2.66	0.31	-2.22	0.82	0.17	-1.99	79.19	1.14	1.38	-87.99
20	-4.82	-4.42	0.96	-0.45	0.78	0.64	0.12	1.04	-7.09	-0.03	-8.76	-21.67	-0.66	-1.93	-29.27
21	-3.52	2.04	0.81	1.67	-1.21	-2.61	-0.38	-0.42	5.15	0.32	11.82	10.44	-2.59	1.44	48.81
22	0.84	-0.65	-0.22	-0.71	-2.89	2.16	0.19	-0.43	-1.89	0.24	-3.31	1.86	1.23	-0.44	-38.88
23	5.61	4.17	-0.76	-0.47	-1.75	-1.06	-0.32	0.19	1.65	-0.07	2.36	-6.06	0.09	2.35	19.19
24	-3.11	-3.19	0.00	-1.27	-0.07	3.14	0.20	1.22	-5.02	-0.25	-10.59	-51.77	0.23	0.82	-8.73

contd.

Table 13 (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
25	-3.74	-3.29	0.82	-0.45	-0.07	-0.69	0.17	0.55	15.59	-0.12	-3.60	-25.33	1.30	1.83	10.62
26	-6.50	-2.56	-0.19	-0.23	-3.09	1.82	0.05	0.58	-3.83	-0.07	5.89	-20.79	1.28	-0.97	80.13
27	-6.12	2.14	-0.99	-1.00	-3.09	4.90	0.43	0.58	7.66	-0.22	-8.47	-21.49	0.62	0.40	-23.00
28	3.70	-2.27	0.62	-0.03	-0.05	0.42	-0.03	-1.03	0.62	0.36	8.97	6.93	-0.58	1.52	39.08
29	1.97	4.10	-0.81	2.36	0.14	-1.15	-0.38	0.33	-14.09	0.69	-2.53	-9.43	-2.42	-0.69	-0.72
30	7.17	5.67	1.14	1.02	3.31	-0.83	0.14	-0.15	-14.01	-0.71	2.11	8.76	0.27	-0.22	-1.79
31	-4.02	-2.63	-0.01	0.87	-3.91	1.07	0.20	2.12	-13.40	0.03	-12.84	-48.20	3.36	1.30	-23.59
32	-6.98	-7.59	-0.67	-1.00	0.70	-3.23	-0.02	0.37	-5.41	-0.20	3.97	27.84	-1.39	0.67	60.82
33	3.47	-0.93	-0.79	-0.67	-0.73	-4.22	-0.53	-1.25	2.67	-0.37	2.15	3.59	-0.36	-0.21	-11.99
34	5.66	-2.01	-0.08	1.71	1.17	2.79	0.18	1.37	4.34	0.57	-8.12	-47.82	0.19	1.08	8.20
35	-4.94	6.89	-0.50	0.73	1.34	4.60	0.16	0.35	-2.83	0.22	6.63	-42.09	-2.24	-1.45	80.53
36	4.88	6.89	0.72	-2.85	-3.22	1.93	0.21	0.32	-1.83	0.35	-1.46	-13.90	-1.15	0.36	10.66
37	-1.46	1.25	0.61	-0.42	-0.13	0.68	0.35	-0.02	11.88	0.43	8.19	-7.44	1.16	0.48	88.39
38	-1.90	-2.48	-0.39	2.57	4.06	0.36	0.01	0.02	-5.33	-0.54	-10.53	-8.02	0.39	2.28	-51.17

contd.

Table 13 (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
39	-2.83	-1.91	0.15	-1.46	-0.42	-0.98	-0.18	1.88	5.25	0.02	-6.59	-19.80	2.35	0.69	-17.76
40	0.96	-0.32	0.54	-3.62	-2.05	2.21	0.59	1.21	-5.63	-0.80	2.77	-19.07	1.82	1.86	48.98
41	-0.39	6.60	0.71	-0.29	-2.10	2.28	0.30	-0.80	1.16	0.06	-1.85	38.00	2.26	-1.35	-42.05
42	13.44	-1.96	0.17	0.46	-0.98	-1.73	0.07	-0.55	-2.01	0.55	5.85	24.00	1.45	-0.39	3.92
43	-0.36	1.68	1.87	-0.43	0.43	-4.00	-0.66	-2.24	-6.13	-0.13	6.26	41.58	-2.22	-1.23	-37.07
44	-1.00	4.12	-0.59	0.36	-2.40	-2.98	-0.26	-2.23	1.71	0.04	-4.30	37.30	-1.90	1.23	-83.69
45	2.60	-7.97	-0.86	-0.76	-2.45	-0.29	-0.07	-0.06	8.74	0.06	3.91	10.15	-0.18	1.03	16.46
46 Var (Sij)	0.926	0.748	0.0147	0.454	0.0409	0.0321	0.0358	0.036	0.898	0.0132	0.913	18.88	0.0217	0.0010	7.04
Var (Sij sik)	2.001	1.617	0.0138	0.981	0.0885	0.0694	0.0774	0.066	1.941	0.0286	2.455	40.80	0.0440	0.0022	15.22
Var (Sij ski)	1.819	1.47	0.0289	0.892	0.8051	0.631	0.0703	0.060	1.765	0.0260	2.232	37.10	0.0427	0.0020	13.84

* Significant at 5% level
** Significant at 1% level

hybrids VS 389 x Kanakamony (3.61), Selection 263 x VU-18 (3.36) and Selection 2-1 x Amb-1 (2.69).

100 seed weight

The gca and sca variances were significant for 100 seed weight also. The genotypes with high gca effects were Selection 2-1 (1.58) and Arka Garima (0.92). Hybrids with highest sca effects were Pusa Komal x Kanakamony (2.94) and VS 389 x JBT 4/221 (2.35).

Yield/plant

Yield of pods recorded highly significant values of gca and sca variances. Maximum gca effect was in Arka Garima (41.80), followed by Selection 2-1 (19.67). Maximum sca effect was recorded in Selection 2-1 x VS 389 (122.37). Other combinations with high sca effects were VU 18 x Arka Garima (88.9) and Selection 263 x Pusa Dofasli (80.53).

4.2.2. Heterosis in cowpea

General analysis of variance for ten parents and 45 hybrids showed significant differences among the genotypes for all the characters under study (Table 11). The relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) calculated are presented in Tables 14, 15, 16, 17 and 18.

Plant height

Significant relative heterosis was shown by 32 hybrids out of 45 F_1 hybrids. Highly significant relative heterosis was expressed by Amb-1 x Pusa Dofasli (29.68%) followed by Pusa Komal x Kanakamony (26.7%). Heterobeltiosis was maximum for Kanakamony x JBT 4/221 (27.52%) and Amb-1 x Pusa Dofasli (26.54%). Standard heterosis values of 23.75% was recorded in Amb-1 x Pusa Dofasli.

Plant spread

Relative heterosis, heterobeltiosis and standard heterosis was significant in many hybrids for plant spread. Maximum relative heterosis value of -20.83 per cent was shown by Selection 2-1 x Kanakamony. Maximum heterobeltiosis values were also observed in the same cross (-27.26%). Standard heterosis was maximum in Selection 263 x Amb-1 (-32.3) followed by JBT 4/221 x Pusa Dofasli (-28.95).

Primary branches/plant

Highly significant heterosis was observed in almost all the hybrids. Relative heterosis of 61.83 per cent observed in VS 389 x VU 18 was the highest, followed by Selection 2-1 x VS 389 (48.37%). Heterobeltiosis also was the highest in VS 389 x VU 18 (39.86%) itself. Standard heterosis observed in Arka Garima x JBT 4/221

Table 14. Heterosis for plant height, plant spread and primary branches/plant in cowpea

Genotypes parents/cross	Plant Height				Plant Spread				Primary branches/plant			
	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal	58.33				45.47				4.85			
Selection 2-1	56.95				46.40				5.16			
VS 389	55.88				45.29				3.12			
Kanakamony	50.07				55.40				6.00			
Selection 263	50.83				43.87				5.78			
Vu-18	67.00				56.83				4.29			
Amb-1	57.53				41.30				4.88			
Arka Garima	58.83				53.54				4.75			
JBT 4/221	40.00				44.83				7.58			
Pusa Dofasli	54.75				46.50				5.33			
Pusa Komal x Selection 2-1	54.85	-4.84*	-5.96*	-6.76*	43.65	-4.98*	-5.93*	-18.47**	6.00	19.82**	16.17**	26.31**
Pusa Komal x VS 389	54.15	-5.17*	-7.16*	-7.96**	40.67	-10.39**	-10.58**	-24.04**	4.83	21.13**	-0.41	-1.68
Pusa Komal x Kanakamony	68.67	26.70**	17.73**	+16.73**	50.57	-0.25	-8.73**	-5.54*	4.75	-12.44**	-20.83**	0.00
Pusa Komal x Selection 263	47.75	-12.51**	-18.13**	-18.83**	43.88	-1.78	0.02	-18.04**	5.16	-2.78**	-10.56**	8.63*

Table 14. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal x VU 18	63.30	1.02	-5.52*	7.60**	48.73	-4.74*	-14.25**	-8.98**	6.00	31.29**	23.71**	26.31**
Pusa Komal x Amb-1	61.25	5.74*	5.02	4.11	46.13	6.32*	1.44	-13.84**	5.99	23.29**	22.97**	26.10**
Pusa Komal x Arka Garima	56.75	-3.12	-3.54	-3.54	50.42	1.83	-5.84*	-5.82*	4.00	-16.67	-17.53**	-15.78**
Pusa Komal x JBT 4/221	58.25	18.49**	-0.13	-9.85**	45.88	1.60	0.88	-14.31**	5.70	-8.21**	17.63**	20.00**
Pusa Komal x Pusa Dofasli	56.50	-0.07	-3.13	-3.96	44.17	-3.96	-5.02	-17.50**	7.00	37.52**	31.33**	47.36**
Selection 2-1 x VS 389	57.65	2.19	1.23	-2.00	48.51	5.82*	4.56	-9.39**	6.15	48.37**	19.07**	29.47**
Selection 2-1 x Kanakamony	48.75	-8.89**	-14.40**	17.13**	40.30	-20.83**	-27.26**	-24.23**	5.98	7.12**	-0.33	25.89**
Selection 2-1 x Selection 263	49.62	-7.91**	-12.86**	-15.66**	47.25	4.69	1.83	-11.75**	6.70	22.58**	16.10**	41.05**
Selection 2-1 x Vu 18	60.03	-3.14	-10.40**	2.03	47.25	-8.46**	-16.86**	-11.75**	5.62	18.98**	8.91*	18.32**
Selection 2-1 x Amb-1	60.38	5.48*	4.95	2.63	44.60	1.71	-3.88	-16.70**	5.16	2.89	0.00	8.63*
Selection 2-1 x Arka Garima	52.17	-9.89**	-11.33**	-11.32**	47.21	-5.53*	-11.83**	-11.82**	5.45	10.04**	5.61	14.74**
Selection 2-1 x JBT 4/221	50.17	4.61	-10.97**	-14.72**	44.75	-1.90	-3.56	-16.42**	5.83	-8.51**	-23.09**	22.74**

Table 14. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Selection 2-1 x Pusa Dofasli	54.62	-2.19	-4.08	-7.16*	41.12	-11.46**	-11.37**	-23.20**	6.29	19.87**	18.01**	32.42**
Vs 389 x Kanakamony	44.88	-15.28**	-19.69**	23.71**	46.46	-7.73**	-16.15**	-13.20**	5.88	28.77**	-2.08	23.79**
VS 389 x Selection 263	60.38	13.16**	8.05**	2.63	44.00	-1.30	-2.85	-17.82**	5.66	27.19**	-1.99	19.16**
VS 389 x Vu 18	53.00	-13.73**	-20.90**	-9.90**	44.25	-13.34**	-22.14**	-17.35**	6.00	61.83**	39.86**	26.31**
VS 389 x Amb 1	54.00	-4.77	-6.14	-8.20**	46.92	8.38**	3.61	-12.36**	5.88	46.88**	20.51**	23.79**
VS 389 x Arka Garima	57.33	-0.04	-2.55	-2.55	48.65	-1.55	-9.13**	-9.13**	4.84	22.79**	1.79	1.89
VS 389 x JBT 4/221	57.00	18.91**	2.01	-3.11	49.60	10.08**	9.52**	-7.36**	5.00	-6.59*	-34.04**	5.26
VS 389 x Pusa Dofasli	53.25	-3.73	-2.74	-9.48**	41.50	-9.58**	-10.75**	-22.48**	5.47	28.51**	2.72	15.16**
Kanakamony x Selection 263	44.62	-11.54**	-12.21**	-24.15**	44.25	-10.84**	-20.13**	-17.35**	6.77	14.90**	12.75**	42.53**
Kanakamony x Vu 18	48.96	-16.36**	-2.22	-16.77**	50.58	-9.86	-11.00**	-5.53*	5.65	9.91**	-5.75	18.95**
Kanakamony x Amb-1	49.04	-8.84**	-2.05	-16.64**	51.50	6.51**	-7.04*	-3.81	4.88	-10.34**	-18.75**	2.73**

Table 14. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Kanakamony x Arka Garima	57.83	6.21*	15.51**	-1.69	51.50	-5.45*	-7.04*	-3.81	6.47	20.47**	7.92*	36.21**
Kanakamony x JBT 4/221	51.00	13.26**	27.52**	-13.30**	54.00	7.75**	-2.53	0.86	5.75	-15.32**	-24.14**	21.05**
Kanakamony x Pusa Dofasli	61.17	16.71**	11.72**	3.97	54.83	7.62**	-1.03**	2.4	7.41	30.89**	23.58**	56.00**
Selection 263 x Vu 18	50.00	-15.14**	-25.38**	-15.01**	45.00	-10.63**	-20.83**	-15.95**	5.64	11.97**	-2.42	18.74**
Selection 263 x Amb-1	46.75	-13.71**	-18.74**	-20.53**	36.25	-14.87**	-17.36**	-32.30**	5.00	-6.10**	-13.42**	5.26
Selection 263 x Arka Garima	56.17	2.43	-4.53	-4.52	47.33	-2.82	-11.60*	-11.60**	4.88	-7.36*	-15.58**	2.74
Selection 263 x JBT 4/221	53.25	17.26**	4.76	-9.48**	42.38	-4.45	-5.48	20.84**	6.29	-5.80*	-17.02**	32.40**
Selection 263 x Pusa Dofasli	47.62	-9.78**	-13.01**	-19.05**	50.54	11.86**	8.69**	-5.60*	5.58	0.50	-3.38	17.47**
Vu-18 x Amb-1	65.71	-5.52*	-1.93	11.69**	56.33	14.81**	-0.88	5.21*	6.29	37.26**	29.03**	32.40**
Vu-18 x Arka Garima	58.33	-7.29**	-12.94**	-0.84	55.10	-0.14	-3.04	2.91	6.16	36.39**	29.79**	29.68**
Vu-18 x JBT 4/221	52.79	-1.32**	-21.21**	-10.27**	47.50	-6.55**	-16.42**	-11.28**	5.88	-1.01	-22.49**	23.79**

Table 14. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Vu-18 x Pusa Dofasli	56.83	-6.64**	-15.18**	-3.40	47.33	-8.39**	-16.72**	-11.60**	6.12	27.34**	14.92**	28.84**
Amb-1 x Arka Garima	60.46	3.91	2.76	2.77	49.75	4.91*	-7.08*	-7.10**	6.12	27.27**	25.64**	28.84**
Amb-1 x JBT 4/221	54.00	10.74**	-6.14*	-8.21**	52.80	22.61**	17.78**	-1.38	7.00	12.40**	-7.65**	47.36**
Amb-1 x Pusa Dofasli	72.80	29.68**	26.54**	23.75**	43.50	-0.91	-6.45*	-18.75**	6.16	20.82**	15.67**	29.68**
Arka Garima x JBT 4/221	53.00	7.26*	-9.91**	-9.90**	52.30	6.33*	-2.32	-2.32	8.15	32.20**	7.52**	71.58**
Arka Garima x Pusa Dofasli	57.33	-0.95**	-2.55	-2.55	54.00	7.96**	0.86	0.86	6.58	30.56**	23.45**	38.53**
JBT 4/221 x Pusa Dofasli	55.83	17.85	1.97	-5.09	38.04	-16.70**	-18.19**	-28.95**	5.83	-9.68**	-23.09**	22.74**
SEm±	1.14	1.36	1.65	1.65	1.13	1.17	1.39	1.39	0.18	0.16	0.19	0.19
CD (0.05)	2.29	2.73	3.31	3.31	2.77	2.35	2.79	2.79	0.36	0.32	0.38	0.38
CD (0.01)	3.04	3.63	4.40	4.40	3.02	3.13	3.71	3.71	0.48	0.43	0.51	0.51

* Significant at 5% level
** Significant at 1% level

(71.58%) was the largest, followed by Kanakamony x Pusa Dofasli (56.0%).

Days to flower

Significant and negative relative heterosis was observed in 17 hybrids. Highest negative relative heterosis was recorded with Amb-1 x Arka Garima (-17.57) followed by VU 18 x Amb-1 (-13.40%). Thirteen hybrids exhibited significant heterobeltiosis. The hybrids which showed high relative heterosis also exhibited high heterobeltiosis (-15.91% and -10.89% respectively). Significant standard heterosis was observed in almost all the hybrids. Maximum being recorded in Amb-1 x Arka Garima (-19.2%), followed by Selection 263 x Pusa Dofasli (-19.04%).

Days to harvest

Significant negative relative heterosis was expressed by many hybrids. A maximum relative heterosis of -16.11 per cent was exhibited by VU 18 x Amb-1. Heterobeltiosis and standard heterosis was maximum in the same hybrid (-14.57% and -20.82% respectively).

Flower bunch number

Several hybrids exhibited highly significant positive relative heterosis. Selection 2-1 x Pusa Dofasli exhibited largest value of relative heterosis (78.06%). Heterobeltiosis was high in Pusa Komal x VS 389 (44.9%) followed by Selection 2-1 x Pusa Dofasli (43.54%).

Table 15. Heterosis for days to flowering, days to first harvest and flower bunch number in cowpea.

Genotypes parents/cross	Days to flowering				Days to first harvest				Flower bunch number			
	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal	36.60				47.40				36.75			
Selection 2-1	35.55				45.75				45.00			
VS 389	41.00				51.38				36.75			
Kanakamony	38.45				49.25				22.50			
Selection 263	34.90				45.75				42.00			
Vu-18	35.80				47.50				46.75			
Amb-1	37.88				49.25				51.75			
Arka Garima	39.40				51.25				28.42			
JBT 4/221	34.80				44.75				49.75			
Pusa Dofasli	37.90				49.25				48.00			
Pusa Komal x Selection 2-1	35.95	-0.35	1.13	-8.76**	45.00	-3.38**	-1.64**	-12.20**	43.75	7.03**	-2.78	53.94**
Pusa Komal x VS 389	37.00	-4.64*	1.09	-6.10**	46.60	-5.64**	-1.69**	-9.10**	53.25	44.09**	44.90**	87.40**
Pusa Komal x Kanakamony	37.00	-1.40	1.09	-6.10**	48.15	-0.36	1.58**	-6.00**	39.75	34.18**	8.16*	36.90**
Pusa Komal x Selection 263	34.95	-2.24	0.14	-11.30**	44.78	-3.86**	-3.60**	-12.60**	39.00	-0.95	-7.14*	37.20**

Table 15. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal x VU 18	36.55	0.97	2.09	-7.23**	46.00	-3.06**	-2.95**	-10.20**	38.00	-8.43**	-17.84**	33.70**
Pusa Komal x Amb-1	35.37	-5.03*	-3.37	-10.20**	45.62	-5.59**	-3.74**	-10.98**	48.00	8.47**	-7.25**	68.90**
Pusa Komal x Arka Garima	37.50	-1.32	2.46	4.82*	49.75	0.86	4.96**	-2.90**	44.50	36.58**	21.09**	56.60**
Pusa Komal x JBT 4/221	34.25	-4.06	-1.58	-13.10**	44.33	-3.79**	-0.94	-13.50**	38.50	19.98**	-22.61**	35.50**
Pusa Komal x Pusa Dofasli	40.00	7.38**	9.29**	1.52	48.50	0.36	2.32*	-5.40**	36.50	-13.86**	-23.96**	28.40**
Selection 2-1 x VS 389	37.10	-3.07	4.36	-5.83**	47.01	-3.19**	2.77**	-8.30	47.42	16.00**	5.37	66.80**
Selection 2-1 x Kanakamony	37.25	0.68	4.78*	-5.50*	45.95	-3.26**	0.44	-10.30**	46.00	36.30**	2.22	61.90**
Selection 2-1 x Selection 263	35.25	0.07	1.00	-10.50**	45.17	-1.28**	-1.28	-11.86**	50.75	16.67**	12.78**	78.90**
Selection 2-1 x Vu 18	35.65	-0.07	0.28	-9.52**	44.33	-4.92**	-3.10**	-13.50**	30.40	-33.37**	-34.27**	6.97
Selection 2-1 x Amb-1	33.90	-7.66**	-4.64	-13.96**	43.00	-9.48**	-6.02**	-16.10**	51.50	6.46**	-0.48	81.20**
Selection 2-1 x Arka Garima	35.38	-5.60*	-0.49	-10.20**	45.50	-6.19**	-0.55	-11.20**	49.75	35.53**	10.56**	75.10**
Selection 2-1 x JBT 4/221	34.92	-0.74	0.33	-11.40**	47.17	4.23**	5.40**	-7.96**	64.75	36.68**	30.15**	127.80**

Table 15. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Selection 2-1 x Pusa Dofasli	36.50	-0.61	2.67	-7.40**	46.17	-2.81**	0.91	-9.91**	56.25	20.97**	17.19**	97.90**
Vs 389 x Kanakamony	35.88	-9.69**	-6.70**	-8.90**	50.00	-0.62	1.50	-2.43**	52.75	78.06**	43.54**	85.60**
VS 389 x Selection 263	36.67	-3.39	5.06*	-6.93**	48.50	-0.14	6.00	-5.40**	45.00	14.29**	7.14**	58.30**
VS 389 x Vu 18	36.58	-4.74*	2.18	-7.20**	47.67	-3.59**	0.35**	-6.98**	32.25	-22.29**	-30.27**	13.50**
VS 389 x Amb 1	38.13	-3.32	0.67	-3.20	44.97	-10.63	-8.70**	-12.30**	53.75	21.47**	3.86	89.10*
VS 389 x Arka Garima	37.04	-7.86**	-5.99**	-6.00**	45.75	-10.84**	-10.73**	-10.70**	38.75	18.93**	5.44	36.30**
VS 389 x JBT 4/221	36.83	-2.82	5.83*	-6.50**	45.33	-5.70**	1.28	-11.60**	48.75	12.72**	-2.01	7.50**
VS 389 x Pusa Dofasli	37.35	-5.32*	-1.45	-5.20*	48.83	-2.95**	-0.85	-4.70**	40.00	-5.60	-16.67**	40.70**
Kanakamony x Selection 263	36.12	-1.50	3.51	-8.30**	46.67	-1.76**	2.00	-8.90**	52.25	62.02**	24.40**	83.80**
Kanakamony x Vu 18	36.50	-1.68	1.96	-7.40**	43.33	-10.43**	-8.78**	-15.50**	28.00	-18.55**	-39.46**	-1.50
Kanakamony x Amb-1	35.15	-7.89**	-7.19**	-10.80**	42.62	-13.45**	-13.45**	-16.80**	48.75	31.31**	-5.80**	71.50**

Table 15. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Kanakamony x Arka Garima	37.42	-3.88	-2.69	-5.03*	48.12	-4.23**	-2.28**	-6.10**	33.75	32.57**	18.78**	18.80*
Kanakamony x JBT 4/221	39.35	7.44**	13.07**	-0.13	46.75	-0.53	4.47**	-8.78**	25.50	-29.41**	-48.74**	-10.20*
Kanakamony x Pusa Dofasli	39.33	3.03	3.77	-0.18	51.75	5.08**	5.08**	0.98	23.50	-33.33**	-51.04**	-17.30**
Selection 263 x Vu 18	39.05	1.98	3.30	-0.89	40.90	-12.28**	-10.60**	-20.20**	24.75	-43.91**	-46.49**	-12.90*
Selection 263 x Amb-1	33.60	-7.66**	-3.72	-14.72**	44.80	-5.68**	-2.08**	-12.60**	42.00	-10.40**	-18.84**	47.80**
Selection 263 x Arka Garima	35.22	-5.18*	0.93	-10.60**	45.83	-5.51**	0.17	-10.60**	42.12**	19.65	0.30	48.20**
Selection 263 x JBT 4/221	37.15	6.60*	6.75**	-5.71**	46.17	2.02**	3.16**	-9.90**	50.25	9.54**	1.01	76.80**
Selection 263 x Pusa Dofasli	37.50	3.02	7.45**	-4.82*	48.17	1.40*	5.28**	-6.00**	41.00	-8.89**	-14.58**	44.30**
Vu-18 x Amb-1	31.90	-13.40**	-10.89**	-19.04**	40.58	-16.11**	-14.57**	-20.82**	40.75	-16.84**	-21.26**	43.40**
Vu-18 x Arka Garima	35.62	-5.23*	-0.49	-9.60**	46.12	-6.58**	-2.88**	-10.00**	46.50	24.56**	0.54	63.60**
Vu-18 x JBT 4/221	38.17	8.12**	9.67**	-3.12**	48.75	5.69**	8.94**	-4.88**	35.75	-25.52**	-28.14**	25.80**

Table 15. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Vu-18 x Pusa Dofasli	35.45	-3.80	-0.98	-10.03**	46.10	-4.70**	-2.95**	-10.05**	44.25	-6.10**	-7.81**	55.70**
Amb-1 x Arka Garima	31.85	-17.57**	-15.91**	-19.20**	43.50	-13.43**	-11.68**	-15.10**	38.25	-4.57	-26.09**	34.60**
Amb-1 x JBT 4/221	34.73	-4.42	-0.20	-11.85**	41.88	-10.90**	-6.42**	-18.30**	51.50	1.48	-0.48	81.20**
Amb-1 x Pusa Dofasli	36.80	-2.87	-2.84	-6.60**	44.83	-8.97**	-8.97**	-12.50**	46.25	-7.27**	-10.63**	62.70**
Arka Garima x JBT 4/221	35.88	-3.30	3.09	-8.93**	46.83	-2.34**	4.75**	-8.62**	36.25	-7.25**	-27.14**	27.60**
Arka Garima x Pusa Dofasli	38.00	-1.69	0.25	-3.55	45.88	-8.71**	-6.83**	-10.50**	42.00	9.93**	-12.50**	47.80**
JBT 4/221 x Pusa Dofasli	36.42	0.18	4.64	-7.56**	44.25	-5.85**	-1.12	-13.70**	55.50	13.53**	11.56**	95.30**
SEm±	1.03	0.82	0.84	0.84	0.31	0.28	0.33	0.33	1.45	1.21	1.41	1.41
CD (0.05)	2.06	1.64	1.68	1.68	0.62	0.56	0.66	0.66	2.90	2.43	2.83	2.83
CD (0.01)	2.75	2.19	2.24	2.24	0.83	0.75	0.88	0.88	3.87	3.23	3.76	3.76

* Significant at 5% level
** Significant at 1% level

Standard heterosis upto 127.8 per cent was shown by Selection 2-1 x Amb-1.

Pod length

Twenty six hybrids showed positive relative heterosis for pod length. It was highest in Kanakamony x Amb-1 (31.76%). This hybrid had maximum heterobeltiosis also (30%). However the standard heterosis was maximum in Selection 2-1 x Arka Garima (16.3%).

Pod girth

Highly significant positive relative heterosis was expressed by Selection 2-1 x Pusa Dofasli (72.84%) and the highest heterobeltiosis was also observed in the same hybrid (70.25%). Standard heterosis recorded was maximum in Amb-1 x Arka Garima (14.38%).

Pod weight

Maximum relative heterosis was shown by Selection 263 x VU 18 (65.82%). Heterobeltiosis was the highest in the same combination (58.15). None of the hybrids showed positive significant standard heterosis for pod weight. Amb-1 x Arka Garima (-23.11%) and Selection 263 x VU 18 (-26.2%) were those nearest to the standard parent.

Seeds/pod

Relative heterosis and heterobeltiosis values were

Table 16. Heterosis for pod length, girth and weight in cowpea.

Genotypes parents/cross	Pod length				Pod girth				Pod weight			
	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal	20.75				2.47				5.03			
Selection 2-1	29.70				2.00				7.47			
VS 389	23.00				2.97				7.18			
Kanakamony	18.25				2.51				5.43			
Selection 263	28.75				2.57				5.89			
Vu-18	19.53				2.43				5.35			
Amb-1	18.75				2.18				5.33			
Arka Garima	27.50				3.20				12.63			
JBT 4/221	18.85				1.94				5.09			
Pusa Dofasli	17.00				1.92				3.63			
Pusa Komal x Selection 2-1	20.70	-17.94**	-30.30**	-24.70**	2.64	6.87	18.21	-17.50*	5.68	-9.04*	-23.84**	-55.03**
Pusa Komal x VS 389	23.88	9.14**	3.80*	-13.20**	2.68	-1.65	-9.92	-16.25*	5.53	-9.42*	-22.93**	-56.02**
Pusa Komal x Kanakamony	17.22	-11.69**	-17.01**	-37.40**	2.14	-14.14	-14.74	-33.13**	5.67	8.36	4.42	-55.10**
Pusa Komal x Selection 263	21.78	-12.00**	-24.24**	-20.80**	2.38	-7.77	-5.94	-25.62**	5.50	0.69	-6.62	-56.45**

Table 16. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal x VU 18	20.40	1.30	-1.69	-25.80**	2.60	5.05	6.12	-18.75*	4.32	-16.67**	-19.08**	-65.79**
Pusa Komal x Amb-1	20.31	2.84*	-2.12	-26.10**	2.47	0.00	6.45	-22.81**	4.92	-5.07	-7.69	-61.04**
Pusa Komal x Arka Garima	18.35	-23.94**	-33.27**	-33.30**	3.28	2.34	15.42	2.50	8.43	-4.50	-33.21**	-33.25**
Pusa Komal x JBT 4/221	18.42	6.45**	-11.25**	-33.00**	2.20	-11.11	-0.34	-31.25**	4.31	-14.96**	-15.42*	-65.87**
Pusa Komal x Pusa Dofasli	20.74	10.07**	0.12	-24.50**	2.28	-8.08	3.41	-28.75**	3.78	-12.96*	-24.83**	-70.07**
Selection 2-1 x VS 389	28.11	6.70**	-5.34**	2.21	1.50	-49.58**	-39.70**	53.13**	6.34	-13.46**	-15.14**	-49.80**
Selection 2-1 x Kanakamony	19.97	-16.73**	-32.78**	-27.40**	2.24	-10.76	-0.67	-30.00**	4.34	-32.69**	-41.86**	-65.63**
Selection 2-1 x Selection 263	24.00	-17.88**	-19.19**	-12.70**	2.16	-16.12	-5.57	-32.50**	8.64	29.39**	15.74**	-31.59**
Selection 2-1 x Vu 18	25.12	2.08	-15.40**	-8.60**	2.68	10.31	20.90	-16.25*	6.47	1.01	13.39**	-48.77**
Selection 2-1 x Amb-1	27.62	14.04**	-6.99**	0.44	2.50	14.94	19.76	-21.88**	6.49	1.52	-12.99**	-48.60**
Selection 2-1 x Arka Garima	31.98	11.80**	7.66**	16.30**	3.38	5.63	30.00**	5.25	8.86	-11.82**	-29.85**	-29.84**
Selection 2-1 x JBT 4/221	20.00	-8.15**	-32.66**	-27.30**	3.40	70.25**	72.84**	6.25	6.12	-2.43	-17.95**	-51.50**

Table 16 (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Selection 2-1 x Pusa Dofasli	19.49	-16.53**	-34.38**	-29.10**	2.05	2.50	4.46	-35.94**	4.65	-16.22**	-37.71**	-63.80**
Vs 389 x Kanakamony	17.76	-13.92**	-22.80**	-35.40**	2.45	-17.48*	-10.48	-23.44**	6.54	3.77	-8.85*	-48.22**
VS 389 x Selection 263	29.11	12.50**	1.25	5.85**	2.90	4.50	-2.52	-9.38	4.74	-27.36**	-33.87**	-62.47**
VS 389 x Vu 18	24.40	14.76**	6.09**	-11.30**	2.82	-5.04	4.63	-11.88	8.03	28.35**	11.99**	-36.42**
VS 389 x Amb 1	20.99	0.57	-8.72**	-23.40**	2.28	-11.65**	-23.53**	-28.75	5.80	-7.16	-19.09**	-54.08**
VS 389 x Arka Garima	27.50	8.91**	19.57**	0.00	3.20	0.00	3.64	0.00	8.07	-18.45**	-36.06**	-36.10**
VS 389 x JBT 4/221	18.53	0.54	-19.46**	-32.60**	2.00	-32.77	-18.62**	-37.50	5.85**	-4.61	-18.47**	-53.68**
VS 389 x Pusa Dofasli	24.42	22.08**	6.15**	-11.20**	2.47	-16.81	1.02	-22.81**	6.32	17.02**	-11.85**	-49.96**
Kanakamony x Selection 263	21.62	-7.98**	-24.78**	-21.40**	2.68	3.88	5.21	-16.25*	6.88	21.47**	16.72**	-45.53**
Kanakamony x Vu 18	21.44	13.51**	9.81**	-22.00**	2.68	6.57	8.41	-16.25*	6.94	28.82**	27.81**	-45.05**
Kanakamony x Amb-1	24.38	31.76**	30.00**	-11.30**	3.00	-19.52**	28.07*	-1.25	6.16	14.50**	13.44*	-51.22**

Table 16. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Kanakamony x Arka Garima	21.62	-5.46**	-21.36**	-21.40**	2.90	-9.37	1.58	-1.87	6.83	-24.36**	-45.92**	-45.92**
Kanakamony x JBT 4/221	14.30	-10.90**	-21.64**	-48.00**	1.87	-25.70	-16.18	-41.57**	5.36	1.81	-1.38	-57.59**
Kanakamony x Pusa Dofasli	16.31	-7.46**	-10.63**	-4.70**	2.32	-7.37	4.85	-27.50**	4.32	-4.80	-20.53**	-65.79**
Selection 263 x Vu 18	25.95	7.51**	-9.74**	-5.60**	2.90	12.62	16.00	-9.34	9.32	65.82**	58.15**	-26.20**
Selection 263 x Amb-1	21.50	-9.47**	-25.22**	-21.80**	2.62	1.94	10.53*	-18.13	6.80	21.12**	15.37**	-46.05**
Selection 263 x Arka Garima	22.25	-20.89**	-22.61**	-19.10**	2.47	-22.66	-14.29**	-22.81**	7.45	-19.55**	-41.01**	-41.07**
Selection 263 x JBT 4/221	23.50	10.33**	-18.26**	-14.50**	2.50	-2.91	10.74	-21.87**	7.24	31.79**	22.84**	-42.67**
Selection 263 x Pusa Dofasli	27.00	18.03**	-6.09**	-1.80	2.43	-5.83	7.78	-24.06**	5.65	18.74**	-3.99	-55.26**
Vu-18 x Amb-1	23.97	25.25**	22.77**	-12.80**	2.97	20.68*	29.35**	-7.18	6.78	27.03**	26.85**	-46.32**
Vu-18 x Arka Garima	24.45	3.99**	-11.09**	-11.10**	3.47	8.59	23.56**	8.43	8.72	-2.98	-30.96**	-30.95**
Vu-18 x JBT 4/221	18.38	10.11**	-5.89**	-33.20**	2.45	1.03	12.26	-23.44**	5.91	13.37**	10.66	-53.20**

Table 16. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Vu-18 x Pusa Dofasli	18.73	2.53	-4.10**	-31.90**	2.20	-9.28	1.15	-31.25**	7.22	60.80**	35.08**	-42.83**
Amb-1 x Arka Garima	25.83	11.70**	-6.07**	-6.07**	3.66	14.38**	36.19	14.38	9.17	2.12	-27.40**	-23.11**
Amb-1 x JBT 4/221	20.15	23.62**	7.47**	-26.70**	2.68	22.99*	30.01**	-16.25	4.33	-16.89**	-18.76**	-65.71**
Amb-1 x Pusa Dofasli	17.83	-0.25	-4.91*	-35.20*	2.40	10.34	17.07	-0.25	4.02	-10.43	-24.67**	-68.17**
Arka Garima x JBT 4/221	15.60	-24.55**	-43.27**	-43.30**	2.07	-35.16**	-19.26*	-35.31**	5.16	-41.70**	-59.11**	-59.14**
Arka Garima x Pusa Dofasli	18.31	-17.71**	-33.42**	-33.4**	2.43	-24.22**	-5.37	-24.06**	4.51	-44.54**	-64.29**	-62.43**
JBT 4/221 x Pusa Dofasli	15.24	-1.17	-10.32**	-44.60**	1.92	-0.77	-0.39	-40.00**	3.95	-9.46	-22.40**	-68.72**
SEm±	0.27	0.26	0.33	0.33	0.29	0.23	0.23	0.23	0.26	0.24	0.30	0.30
CD (0.05)	0.54	0.52	0.66	0.66	0.58	0.46	0.46	0.46	0.52	0.48	0.60	0.60
CD (0.01)	0.72	0.72	0.88	0.88	0.77	0.61	0.61	0.61	0.72	0.64	0.80	0.80

* Significant at 5% level
** Significant at 1% level

significant for most of the hybrids. A maximum percentage of RH was exhibited by VS 389 x Kanakamony (45.76%) followed by Selection 263 x VU 18 (44.76%). Heterobeltiosis values were also highest in VS 389 x Kanakamony (38.17). Highest standard heterosis was noticed in Selection 2-1 x Selection 263 and Selection 263 x VU 18 both having 40 per cent standard heterosis.

Pods/cluster

Relative heterosis of 39.53 per cent observed in Kanakamony x JBT 4/221 was the highest. Heterobeltiosis of 10.47 per cent was observed in Pusa Komal x Amb-1. Selection 2-1 x JBT 4/221 showed 78.6 per cent standard heterosis.

Pods/kg

Significant relative and standard heterosis and heterobeltiosis was observed in many of the hybrids. Highest relative heterosis was in Arka Garima x JBT 4/221 (35.69%). Upto 161.38 per cent heterobeltiosis was recorded in Arka Garima x Pusa Dofasli. Standard heterosis of 195.05 per cent was observed in JBT 4/221 x Pusa Dofasli.

100 seed weight

Most of the hybrids showed positive significant relative heterosis. Maximum recorded was in Pusa Komal x

Table 17. Heterosis for seeds/pod, pods/cluster and pods/kg in cowpea

Genotypes parents/cross	Seeds/Pod				Pods/Cluster				Pods/Kg			
	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal	15.98				2.29				202.25			
Selection 2-1	16.00				2.12				138.85			
VS 389	12.00				2.83				137.15			
Kanakamony	10.75				1.57				184.05			
Selection 263	14.00				2.00				230.15			
Vu-18	12.25				1.41				186.80			
Amb-1	13.00				2.58				179.75			
Arka Garima	13.57				1.82				84.80			
JBT 4/221	12.75				3.16				200.55			
Pusa Dofasli	16.00				3.68				281.23			
Pusa Komal x Selection 2-1	14.25	-10.87**	-10.94**	4.77**	2.50	13.25	9.17	37.40**	175.95	4.70	31.45**	107.48**
Pusa Komal x VS 389	12.50	-10.63**	-21.75**	-7.88**	2.00	-21.87**	-29.33**	9.89	184.10	8.49*	34.23**	117.09**
Pusa Komal x Kanakamony	14.00	4.77**	-12.36**	3.17	2.41	25.29**	5.46	32.41**	203.10	5.15	10.35**	139.50**
Pusa Komal x Selection 263	13.41	-10.49**	-16.03**	-1.18	2.16	0.93	-5.46	18.68**	181.65	-15.98**	-21.07**	114.21**

Table 17. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal x VU 18	15.00	6.29**	-6.10**	10.54**	1.83	-1.21	-20.09**	5.49	235.00	20.81**	25.80**	177.12**
Pusa Komal x Amb-1	16.00	10.44**	0.16	17.91**	2.85	17.04**	10.47	56.60**	203.15	6.36*	13.02**	139.56**
Pusa Komal x Arka Garima	16.00	8.29**	0.16	17.91**	1.83	-10.84	-20.09**	5.49	116.20	19.04**	-42.55**	37.02**
Pusa Komal x JBT 4/221	14.16	-1.38**	-11.33**	4.35*	3.00	9.95	-5.21	65.00**	207.15	2.86	3.29	144.28**
Pusa Komal x Pusa Dofasli	14.01	-12.37**	-12.44**	3.24	2.75	-7.87	-25.27**	51.00**	248.65	2.86	22.94**	193.20**
Selection 2-1 x VS 389	17.00	21.43**	6.25**	25.28**	2.26	-8.58	-19.96**	24.20*	117.00	-13.65**	-12.59*	37.97**
Selection 2-1 x Kanakamony	13.75	2.80	-14.06**	1.33	2.12	15.18	0.00	16.50	192.25	20.95**	43.63**	126.70**
Selection 2-1 x Selection 263	19.00	26.67**	18.75**	40.00**	2.16	4.97	1.88	18.68*	136.94	-24.76**	2.31	61.48
Selection 2-1 x Vu 18	17.25	22.12**	7.81**	27.12**	2.00	12.99	-5.88	9.89	145.25	-9.40*	8.52	71.28**
Selection 2-1 x Amb-1	19.00	31.03**	18.75**	40.00**	2.68	13.92*	3.88	47.30**	155.10	-1.08	15.88**	82.90**
Selection 2-1 x Arka Garima	17.33	17.16**	8.28**	27.71**	2.00	1.52	-5.88	9.89	113.56	3.87	33.92**	33.91**
Selection 2-1 x JBT 4/221	14.00	-2.61	-12.50**	3.17	3.25	22.87**	2.69	78.60**	171.86	2.79	28.40**	102.66**

Table 17. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Selection 2-1 x Pusa Dofasli	12.88	-19.53**	-19.53**	-5.00**	2.75	-5.25	-25.27**	51.00**	214.60	3.40	60.33**	153.06**
Vs 389 x Kanakamony	16.58	45.76**	38.17**	22.18**	1.75	-20.36**	-38.16**	-3.85	191.75	19.40**	39.81**	126.12**
VS 389 x Selection 263	15.62	20.19**	11.61**	15.11**	2.50	3.52	-11.66**	37.40**	234.80	27.85**	71.20**	176.88**
VS 389 x Vu 18	14.00	15.46**	14.29**	3.17	2.00	-5.77**	-29.33	9.89	124.55	-23.11**	-9.19	46.87**
VS 389 x Amb 1	11.83	-5.36**	-9.00**	-12.82**	3.00	10.91	6.01	65.0**	172.30	8.74*	25.63**	103.18**
VS 389 x Arka Garima	15.25	19.26**	12.34**	12.38**	2.33	0.32	-17.67**	28.02**	123.10	10.93*	45.17**	45.16**
VS 389 x JBT 4/221	12.80	3.43*	0.39**	-5.67**	3.00	0.08	-5.21	65.00**	170.90	1.22	24.61**	101.53**
VS 389 x Pusa Dofasli	14.12	0.89	-11.72**	4.05**	2.75	-15.51**	-15.27**	51.00**	157.50	-24.71**	14.86**	85.73**
Kanakamony x Selection 263	15.25	23.23**	8.93**	12.38**	1.75	-1.82	-12.50**	-3.85	149.40	-27.86**	-18.83**	76.17**
Kanakamony x Vu 18	15.40	33.91**	25.71**	13.49**	1.50	0.67	-4.15	-17.6	144.55	-22.04**	-21.46**	70.46**
Kanakamony x Amb-1	14.49	22.06**	11.50**	6.78**	2.00	-3.50	-22.48**	9.89	159.50	-12.31**	-11.27**	88.09**

Table 17. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Kanakamony x Arka Garima	12.9	6.06**	-4.97**	-4.9**	2.00	18.34*	10.19	9.89	147.29	9.57**	73.69**	73.69**
Kanakamony x JBT 4/221	9.75	-17.02**	-23.53**	-28.15**	3.30	39.53**	4.27	81.3**	186.66	-2.93	1.42	120.12**
Kanakamony x Pusa Dofasli	13.62	1.87**	-14.84**	0.37	1.83	-30.22**	-50.27**	5.49	237.15	1.94	28.85**	179.65**
Selection 263 x Vu 18	19.00	44.76**	35.71*	40.00**	1.83	7.17	-8.50	5.49	107.45	-48.46**	-42.48**	26.70**
Selection 263 x Amb-1	14.00	3.70*	0.00	3.17	2.25	-1.75	-12.79*	23.63	143.45	-30.01**	-20.19**	69.16**
Selection 263 x Arka Garima	14.63	6.11**	4.50*	7.81**	1.50	-21.36**	-25.00**	17.60	134.25	-14.75**	58.31**	58.31**
Selection 263 x JBT 4/221	13.88	3.74*	-0.89	2.28	3.41	32.24**	7.90	87.36*	138.58	-35.65**	-30.90**	63.41**
Selection 263 x Pusa Dofasli	12.62	-15.83**	-21.09**	-7.00**	3.00	5.63	-18.48**	65.00**	176.00	-30.93**	-23.27**	108.25**
Vu-18 x Amb-1	14.41	14.18**	10.88**	6.19**	2.50	25.16**	-3.10	37.40**	148.00	-19.25**	-17.66**	74.53**
Vu-18 x Arka Garima	16.33	26.47**	20.29**	20.34**	2.00	23.84	10.19	9.89	113.83	-16.18**	34.23**	34.23**
Vu-18 x JBT 4/221	14.25	14.00**	11.76**	4.77**	2.00	-12.66	-36.81**	9.89	168.98	-12.75**	-9.54*	99.26**

Table 17. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Vu-18 x Pusa Dofasli	17.40	23.19**	8.75**	28.20**	2.50	-1.86	-32.07**	37.40**	189.49	-19.02**	1.44	123.45**
Amb-1 x Arka Garima	16.75	26.06**	23.39**	23.40**	1.41	-35.61**	-45.16**	22.50**	117.85	-10.91*	38.97**	38.97**
Amb-1 x JBT 4/221	15.88	23.30**	22.62**	17.02**	3.25	13.14*	2.69	78.60**	230.65	21.30**	28.32**	171.99**
Amb-1 x Pusa Dofasli	16.25	12.07**	1.56	19.75**	3.68	17.57**	0.00	102.20**	248.95	8.01**	38.50**	193.57**
Arka Garima x JBT 4/221	11.00	-16.43**	-13.73	-18.94**	2.47	-0.60	-21.80**	35.70**	193.60	35.69**	128.30**	128.30**
Arka Garima x Pusa Dofasli	12.50	-15.47**	-21.88**	-7.88**	2.58	-6.10	-29.89**	41.88**	221.65	21.11**	161.38**	161.37**
JBT 4/221 x Pusa Dofasli	12.91	-10.16**	-19.28**	-4.86*	3.45	0.95	9.16	89.60**	250.20	3.86	24.76**	195.05**
SEm±	0.22	0.20	0.24	0.24	0.17	0.15	0.17	0.17	1.66	5.90	7.02	7.02
CD (0.05)	0.44	0.40	0.48	0.48	0.34	0.30	0.34	0.34	3.33	11.83	14.08	14.08
CD (0.01)	0.59	0.53	0.64	0.64	0.45	0.40	0.45	0.45	4.43	15.75	18.74	18.74

* Significant at 5% level
** Significant at 1% level

Kanakamony (42.86%). Out of 45 hybrids 41 showed significant heterobeltiosis maximum being in Selection 263 x Amb-1 (36.36%). A maximum standard heterosis values of 30.76 per cent was observed in Selection 2-1 x VU 18 and Selection 2-1 x JBT 4/221.

Pods/plant

Significant relative heterosis was observed in 34 hybrids. The highest value was recorded by Pusa Komal x JBT 4/221 (50.83%). Significant heterobeltiosis for pods/plant was observed in 28 hybrids. Selection 2-1 x Kanakamony (61.43%) possessed maximum heterobeltiosis. Standard heterosis was significant in 38 hybrids. Pusa Komal x JBT 4/221 recorded highest standard heterosis also (133.6%) followed by Pusa Komal x Vu 18 (128.0%) and Pusa Komal x Kanakamony (103.4%).

Yield/plant

Positive and significant relative heterosis for yield per plant was recorded in many hybrids. Highest values for RH was observed in Selection 2-1 x VS 389 (65.28%) followed by VU 18 x Amb-1 (58.49%). Significant heterobeltiosis was observed in 38 hybrids. Same hybrids which are relatively heterotic expressed larger values for heterobeltiosis also. Selection 2-1 x VS 389 showed highest heterobeltiosis (60.73). Significant positive standard heterosis was shown only by a few hybrids. The

Table 18. Heterosis for 100 seed weight, pods/plant and yield/plant in cowpea.

Genotypes parents/cross	100 seed weight				Pods/plant				Yield/plant			
	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)	Mean	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal	9.00				43.50				215.00			
Selection 2-1	16.00				31.50				235.25			
VS 389	12.00				30.50				222.30			
Kanakamony	12.00				44.00				239.00			
Selection 263	11.00				37.25				161.83			
Vu-18	12.00				45.04				234.79			
Amb-1	11.00				38.50				214.21			
Arka Garima	13.00				26.75				325.41			
JBT 4/221	13.00				39.38				196.50			
Pusa Dofasli	10.00				47.85				170.30			
Pusa Komal x Selection 2-1	15.00	20.00**	-6.25**	15.38**	43.65	16.40**	0.34	63.20**	247.90	10.12**	5.38**	-23.82**
Pusa Komal x VS 389	13.00	23.81**	8.33**	0.00	53.50	44.59**	22.99**	100.00**	290.50	32.86**	30.68**	-10.73
Pusa Komal x Kanakamony	15.00	42.86**	25.00**	15.38**	54.40	24.34**	23.64**	103.40**	267.90	18.02**	12.09**	-17.67**
Pusa Komal x Selection 263	11.00	10.00**	0.00	-15.38**	42.50	5.26	-2.30	58.90**	233.98	24.18**	8.83**	-28.96**

Table 18. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Pusa Komal x VU 18	12.00	14.29**	0.00	-7.69**	61.00	37.79**	35.44**	128.00**	259.88	15.55**	10.68**	-20.76**
Pusa Komal x Amb-1	11.00	10.00**	0.00	-15.38**	49.00	19.51	12.64**	83.20**	241.11**	12.35**	12.15**	-25.90**
Pusa Komal x Arka Garima	14.00	27.27**	7.69**	7.69**	29.50	-16.01**	-32.18**	8.41	253.90**	-6.04**	-21.98**	-21.97**
Pusa Komal x JBT 4/221	9.00	-18.88**	-30.77**	-30.76**	62.50	50.83**	43.68**	133.60**	301.65	46.61**	40.30**	-7.30**
Pusa Komal x Pusa Dofasli	9.00	-5.26**	-10.00**	-30.76**	45.50	-0.38	-4.91	70.10**	183.0	-5.01**	-14.88**	-43.76**
Selection 2-1 x VS 389	14.00	0.00	-12.50**	7.69**	44.25	42.74**	40.48**	65.40**	378.12	65.28**	60.73**	16.19**
Selection 2-1 x Kanakamony	14.00	0.00	-12.50**	7.69**	50.85	34.70**	61.43**	90.10**	264.50	11.54**	10.67**	-18.71**
Selection 2-1 x Selection 263	15.75	16.67**	-1.56**	21.15**	37.00	7.64	17.46**	38.30**	270.00	35.99**	14.77**	-17.02**
Selection 2-1 x Vu 18	17.00	21.43**	6.25**	30.76**	38.25	-0.05	21.43**	43.00**	263.35	12.05**	11.94**	-23.56**
Selection 2-1 x Amb-1	16.95	25.56**	5.94**	30.40**	25.75	-26.43	-18.25**	-3.73	166.10	-26.09**	-29.39**	-48.96**
Selection 2-1 x Arka Garima	15.00	3.45**	-6.25**	15.38**	37.03	27.12**	38.41**	38.40**	326.08	16.32**	0.20	0.20
Selection 2-1 x JBT 4/221	9.00	-37.93**	-43.75**	30.76**	40.75	14.99**	3.49	52.30**	237.00	39.79**	0.74*	-27.17**

Table 18. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Selection 2-1 x Pusa Dofasli	14.00	7.69**	-12.50**	7.69**	53.70	35.35**	12.23**	100.70**	250.15	23.36**	6.33**	-23.13**
Vs 389 x Kanakamony	14.00	16.67**	16.67**	7.69**	37.40	0.40	-15.00**	39.80**	195.00	-15.46**	-18.41**	-40.07**
VS 389 x Selection 263	15.00	30.43**	25.00**	15.38**	30.05	-11.29**	-19.33**	12.30**	128.00	-33.36**	-42.42**	-60.66**
VS 389 x Vu 18	12.00	0.00	0.00	-7.69**	27.12	-28.18**	-39.78**	1.38	217.71	-4.74**	-2.07	-33.09**
VS 389 x Amb 1	15.0	30.43**	25.00**	15.38**	47.90	38.84**	24.42**	79.10**	278.05	27.40**	25.08**	-14.42**
VS 389 x Arka Garima	14.00	12.00**	7.69**	7.69**	28.83	0.72	-5.48	7.78	239.00	-12.73**	-26.56**	-26.55**
VS 389 x JBT 4/221	15.00	20.00**	15.38**	15.38**	39.62	13.42**	0.63	48.10**	231.88	10.73**	4.31**	-28.74**
VS 389 x Pusa Dofasli	13.00	18.18**	8.33**	0.00	30.08	-23.22**	-37.14**	12.45**	190.33	-3.04	-14.38**	-41.51**
Kanakamony x Selection 263	15.50	34.78**	29.17**	19.23**	36.33	-10.57**	-17.43**	35.80**	243.00	21.25**	1.67	-25.32**
Kanakamony x Vu 18	13.00	8.33**	8.33**	0.00	49.67	11.56**	10.27**	85.70**	343.50	45.00**	43.72**	2.48**
Kanakamony x Amb-1	14.00	21.74**	16.67**	7.69**	35.50	-13.94**	-19.32**	32.70**	222.62	-1.76**	-6.85**	-31.59**

Table 18. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Kanakamony x Arka Garima	16.00	28.00**	23.08**	23.07**	49.00	38.52**	11.36**	83.00**	333.35	18.12**	2.44	-2.43
Kanakamony x JBT 4/221	12.00	-4.00**	-7.69**	-7.69**	42.62	2.25	-3.12	59.30**	228.36	4.87**	-4.45**	29.82**
Kanakamony x Pusa Dofasli	12.00	9.09**	0.00**	-7.69	50.67	10.32**	5.88	89.40**	213.67	4.41**	-10.60**	-34.34**
Selection 263 x Vu 18	15.00	30.43**	36.36**	15.38**	22.25	-45.92**	-50.60**	-16.80**	207.00	4.38**	-11.84**	-36.39**
Selection 263 x Amb-1	14.00	27.27**	27.27**	7.69**	39.25	3.64	1.96	46.70**	273.66	45.55**	27.76**	-15.90**
Selection 263 x Arka Garima	14.00	16.67**	27.27**	7.69**	33.50	4.69	-10.07	25.20**	249.50	2.41	-23.33**	-23.30**
Selection 263 x JBT 4/221	13.50	12.50**	22.73**	3.84**	28.35	-26.00**	-28.00**	5.98	204.50	14.14**	4.07**	-37.16**
Selection 263 x Pusa Dofasli	10.50	0.00**	5.00**	-19.23	46.50	9.28**	-2.82	73.80**	263.20	58.49**	54.55**	-19.12**
Vu-18 x Amb-1	14.00	27.74**	16.67**	7.69**	37.67	-9.83**	-16.37**	40.80**	254.50	13.36**	8.39**	-21.79**
Vu-18 x Arka Garima	15.00	20.00**	15.38**	15.38**	43.38	20.84**	-3.70	62.20**	380.88	35.98**	17.05**	17.05**
Vu-18 x JBT 4/221	15.0	20.00**	15.38**	15.38**	29.77	-29.46**	-33.89**	11.30	176.12	-18.33**	-24.99**	-45.87**

Table 18. (contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Vu-18 x Pusa Dofasli	12.95	17.33**	7.92**	0.38	37.12	-20.07**	-22.41**	38.80**	195.90	-3.28	-16.56**	-39.79**
Amb-1 x Arka Garima	16.00	33.33**	23.08**	23.07**	38.15	16.93**	-0.91	42.60**	323.70	19.98**	-0.52	-0.50**
Amb-1 x JBT 4/221	11.00	-8.33**	-15.38**	-15.38**	38.65	-0.74	-1.84	44.50**	167.50	-18.43**	-21.80**	-48.53**
Amb-1 x Pusa Dofasli	11.50	9.52**	4.55**	-11.54**	49.75	15.23**	3.97	86.00**	199.83	3.94*	-6.71**	-38.59**
Arka Garima x JBT 4/221	12.00	-7.69**	-7.69**	-7.69**	42.83	29.53**	8.76	60.10**	221.12	-15.26**	-32.05**	-32.05**
Arka Garima x Pusa Dofasli	14.00	21.74**	7.69**	7.69**	35.67	-4.38	-25.46**	33.30**	160.88	-35.09**	-50.56**	-50.56**
JBT 4/221 x Pusa Dofasli	12.00	4.35**	-7.69**	-7.69**	49.00	12.35**	2.40	83.20**	195.83	6.78**	-0.34**	-39.82**
SEm±	0.05	0.04	0.04	0.04	1.16	1.38	1.56	1.56	1.40	3.50	3.97	3.97
CD (0.05)	1.00	0.08	0.08	0.08	2.33	2.77	3.13	3.13	2.80	7.02	7.96	7.96
CD (0.01)	0.13	0.11	0.11	0.11	3.09	3.68	4.16	4.16	3.74	9.34	10.60	10.60

* Significant at 5% level
**Significant at 1% level

superior hybrids observed were VU 18 x Arka Garima (17.05) and Selection 2-1 x VS 389 (16.19).

Discussion

DISCUSSION

Cowpea (*Vigna unguiculata* L.) Walp is a multipurpose legume vegetable of tropical and subtropical areas of the world. In Kerala, it is cultivated in almost all the homesteads and in rice fallows. It is consumed in many forms such as dry seeds, green seeds, green pods and tender green leaves. It also provides highly nutritious and palatable green fodder for cattle and is used as a quick growing cover crop under a wide range of conditions. It is highly acceptable too. However very little attention has been paid towards the improvement of this crop. The present low production and productivity could be attributed to lack of genetic information relating to crop improvement. Genetic informations such as variability, heritability, genetic advance and correlation among yield and other components are essential pre-requisites for any meaningful attempts in this direction.

Crop improvement largely depends on the magnitude of the genetic variability and the extent to which the desirable characters are heritable. Attempts were made to study the various aspects of crop improvement in cowpea. The present investigation was carried out mainly with the objectives of studying genetic variability, genetic divergence; correlation among yield and yield contributing characters, combining ability and heterosis and identifying F_1 hybrids heterotic for various economic characters.

5.1. Genetic variability and divergence

5.1.1. Genetic variability

Information on genetic variability and divergence are of vital importance in any successful crop improvement programme. Estimate of heritability coupled with genetic advance are more useful than any one of the two alone, in the choice of proper selection methods (Johnson *et al.*, 1955a).

Many workers have reported the existence of very high variability in respect of several vegetative, productive and qualitative characters in cowpea. The components of variation due to phenotype and genotype were studied in the present investigation.

Significant differences, were observed among the 31 cowpea genotypes investigated for all the fifteen characters, viz. plant height, plant spread, primary branches, days to flower, days to first harvest, pod length, pod girth, pod weight, bunches/plant, pods/cluster, pods/kg, seeds/pod, 100 seed weight and yield/plant. The existence of considerable variation indicated enough scope for improving the population. The investigations by Lakshmi *et al.* (1977), Chandrika (1979), Ramachandran *et al.* (1980), Jalajakumari (1981) and Savithramma (1992) have shown a wide range of variability for most of the characters in cowpea.

Pod yield/plant was maximum is Arka Garima (457.3 g). The highest number of fruits/plant was in IC 91456. IC 38956-1 (33.5 days) was the earliest flowering genotype.

The genotypic coefficient of variation (gcv) resulting in high heritability was of higher magnitude for pods/kg, pod weight and yield/plant. This indicated low impact of environment on the expression of these characters. Ramachandran *et al.* (1980), Jalajakumari (1981) and Pandita *et al.* (1982) have also reported high gcv with high heritability for all the characters studied in cowpea. Primary branches and plant height had the lowest values of gcv and heritability indicating greater impact of environment on these characters.

Heritability along with genetic advance should be considered for effective selection of genotypes. In the present study high heritability along with high genetic gain was also observed for the above traits. This revealed that variation for the above characters was mainly due to action of additive genes and these traits can be improved by selection. This confirms the earlier findings of Pandita *et al.* (1982) and Vaid and Singh (1983). Though heritability was high for days to flowering and days to harvest, the genetic gain was of low magnitude, indicating the action of non additive genes for expression of these characters. Thus it implies that high heritability is not always an indication of high genetic gain (Johnson *et al.,* 1955a). Hence straight selection has limited scope for improving these traits.

Genetic divergence

Genetic divergence studies based on D^2 values permits precise comparison among all possible pairs of population in any group.

Following Tocher's method, 31 cowpea genotypes were grouped into six clusters. The clustering pattern did not show any strict parallalism with the geographic source or origin. In the present study maximum distance (D = 48.3) existed between clusters I and IV. Theoretically maximum heterosis would be expected in crosses involving parents belonging to these clusters.

The clustering pattern revealed that genetic diversity was not related to geographic diversity which supports earlier observations of Marangappanvar (1986). It appeared that geographic isolation may not be the only determining factor for genetic divergence in the cowpea materials tested. Other factors such as genetic drift and selection in different environments could cause greater genetic diversity than geographical distance.

Electrophoretic studies

The storage proteins of seeds of 31 cowpea genotypes analysed by PAGE showed marked variation in banding pattern. Proteins extracted from different genotypes of *Vigna unguiculata* revealed the presence of an electrophoretic pattern typical for the species (first band). It was possible to distinguish among the varieties through groups of bands which do not vary within the species and are present in all the accessions. Number of bands cannot be releated with the yield of different cowpea genotypes. The mobility of the second protein varied considerably with the yield. Those genotypes with Rf value of second band at a range of 0.46 to 0.42 gave an yield ranging from 250 to 460 g, whereas genotypes with Rf value 0.31 to 0.36 gave an yield of less than 250 g. The mobility of protein is mainly determined by the exposed aminoacid groups which are directly responsible for the variation in yield.

The trend of changing pod length can be related to the number of bands of the seed protein where minimum number of bands (2) was for shorter pods. Length of the pod was found to be decreasing with increase in number of bands. This is an indication of the specific nature of different protein for other physiological characters.

The characters plant height, pod weight, number of days to flowering, flower bunch number, pods/cluster and

100 seed weight hadn't expressed much influence on the number of protein bands. Difference in banding pattern of specific protein is the true nature and expression of inherent character of each genotype which may or may not be expressed phenotypically. Cultural practices and environmental factors may influence the phenotypic expression where as the protein banding remains the same.

Correlation studies

A knowledge of the relationship of yield and its component characters is essential for the simultaneous improvement of yield components and in turn yield, to be effective. In the present investigation, days to harvest, pod length, pod girth, pod weight, seeds/pod and 100 seed weight were the characters which exerted the highest positive and significant association with yield (Tables 6,7 and 8). Pods/kg exerted significant negative association with yield. Kumar (1976) has observed significant positive correlation of yield with pod length, pod girth and days to maturity. Virupakshappa (1980) observed positive association of pod yield with seed/pod and 100 seed weight. Similar findings were also made by Biradar *et al.* (1991) in cowpea.

In general phenotypic correlations were smaller than genotypic correlations which indicated that environment had small and similar effects on these characters.

Path coefficient analysis

The path coefficient analysis indicated maximum direct positive effect of pod weight (0.758) on pod yield/plant. Hence pod weight is the most important component character of yield, followed by pod girth and 100 seed weight. Similar results were reported by Hanchinal (1979) and Biradar *et al.* (1991). The direct effect of 100 seed weight was negative, but the positive correlation of the trait with pod yield may be due to high positive indirect effect through pod weight. In this study the residual effect noticed was of low magnitude (0.34) indicating that almost sixty seven per cent of the variation in pod yield was attributable to factors considered in this study.

Results of the genetic variability, correlation and path analysis indicated that the characters like pod weight, pods/kg, pod length, pod girth, seeds/pod, 100 seed weight and days to first harvest are to be considered for crop improvement of cowpea.

5.2. Combining ability and heterosis

5.2.1. Assessment of combining ability of parents

In a heterosis breeding programme the breeder is often confronted with the problem of choice of parents. The common approach of selecting parents on the basis of *per se* performance does not necessarily lead to the best result in hybridisation programme (Allard, 1960). Selection of the best parents based on complete genetic information and knowledge of combining ability leads to fruitful results in the identification of promising F_1 hybrids.

In this study, ten diverse parental lines selected based on genetic divergence were used to study the combining ability, in a diallel experiment. They were crossed in all possible combinations to obtain 45 F_1 hybrids. These hybrids along with 10 parents were evaluated to obtain information on combining ability and heterosis.

The study revealed significant variances due to gca and sca for all the characters considered. The significance of general combining ability (gca) and specific combining ability (sca) variances indicated the role of additive as well as non-additive gene action in the control of most of the characters.

The mean squares for the genotypes were significant for all the vegetative and productive characters indicating the presence of adequate variability which could be exploited by selection. Significant differences among genotypes were reported by Brahmappa and Singh (1977). The magnitude of gca variance was much higher than that of sca variance. This indicated the preponderence of additive type of gene action. Thiyagarajan (1990) reported additive and nonadditive gene action for yield. The variation in the gca effect of parents can be attributed to genetic as well as geographic diversity in the material. High sca effect observed for different characters may be helpful for sorting out oustanding parents with favourable allels for the different components of yield.

It was observed that the parents showing high gca effect for yield/plant and other characters also gave good *per se* performance. Patil and Shete (1986) has reported similar findings.

Parents showing higher mean performance for a particular character were generally good combiners for that character. General combining ability studies revealed that among 10 parental lines Arka Garima and Selection 2-1 were good combiners for yield.

Selection 2-1 x VS 389 (122.37) was the best combination for yield. Others were VU 18 x Arka Garima (89.9) and Selection 263 x Pusa Dofasli (80.53). The parent Arka Garima showed high gca effect for pod length, pod girth, pod weight, 100 seed weight and yield. Amb-1 x Arka Garima, VU 18 x Amb-1 and VS 389 x Kanakamony flowered significantly earlier. This may be because of

Amb-1 which was a good general combiner for days to flowering.

It was observed that when parents possessing high gca effect were crossed, the F_1 hybrids, gave best performance.

The present study revealed the importance of both additive and non additive gene effects in the inheritance of majority of the characters. Since both additive and nonadditive gene action are seen in most of the characters, reciprocal recurrent selection would be the most appropriate method of crop improvement.

5.2.2. Heterosis

Extent of heterosis was estimated for yield, and its 14 components in the diallel experiment. Significant differences were observed among the genotypes for all the characters studied.

Significant relative heterosis, heterobeltiosis and standard heterosis was reported for plant height in many hybrids. High relative heterosis expressed by Amb-1 x Pusa Dofasli and Pusa Komal x Kanakamony can be attributed to the high gca effect of one of the parents. High heterobeltiosis observed in Kanakamony x JBT 4/221 despite both parents being poor combiners could be attributed to high genetic distance, since they belonged to different clusters. Heterosis for plant height was earlier reported by Biradar *et al.* (1991).

Several hybrids exhibited negative heterosis for plant spread. Selection 2-1 x Kanakamony exhibited maximum negative relative and standard heterosis for plant spread. These combinations exhibited high sca effects for this character. This is desirable as it results in a compact growth habit.

Significant heterosis for branches/plant was observed in many hybrids. High standard heterosis was observed in Arka Garima x JBT 4/221 (0.60). They belonged to two different clusters as well.

Significant and negative relative heterosis, heterobeltiosis and standard heterosis for days to flowering were exhibited by 17 hybrids. The maximum values of negative standard heterosis observed in the hybrid Amb-1 x Arka Garima and VU 18 x Amb-1 followed by Selection 2-1 x Amb-1 and Pusa Komal x JBT 4/221. This significant heterosis in these crosses is due to the involvement of a good general combiner Amb-1. Another combination selection 263 x Pusa Dofasli also exhibited high standard heterosis which may be due to the high genetic divergence between these parents. Hebbal(1988) has reported heterosis for days to 50 per cent flowering.

Many hybrids expressed heterosis for days to harvest. Maximum relative heterosis, heterobeltiosis and standard heterosis observed in the hybrid VU 18 x Amb-1 can be due to the involvement of a good general combiner Amb-1.

Heterobeltiosis for flower bunch number was observed in several hybrids. High heterobeltiosis observed in Selection 2-1 x Pusa Dofasli may be due to high gca effect of Selection 2-1. High standard heterosis in Selection 2-1 x Amb-1 is due to involvement of Amb-1 which is a good general combiner, eventhough, these two belonged to the same cluster.

Positive heterosis for pod length was exhibited by a few hybrids only. Highest standard heterosis observed in Selection 2-1 x Arka Garima may be attributed to the involvement of a good general combiner Selection 2-1 (gca 3.1). Sca effect was also highest in this combination. The *per se* performance was also high.

Several hybrids exhibited high relative and standard heterosis as well as heterobeltiosis for pod girth. Standard heterosis was maximum in Amb-1 x Arka Garima (14.38). This is due to highest gca effect of Arka Garima and maximum sca effect of its combination.

Maximum values of relative heterosis and heterobeltiosis was shown by the Selection 263 x VU 18 followed by VU 18 x Pusa Dofasli for pod weight. They were good general combiners for pod weight. This combination exhibited high sca effect also. Besides, these two belonged to two different clusters also.

Relative heterosis, heterobeltiosis and standard heterosis were significant in most of the hybrids for seeds/pod. Highest standard heterosis was noticed in Selection 2-1 x Selection 263 and Selection 263 x Vu 18. Here, Selection 2-1 was a good general combiner for this trait. The combination Selection 263 x Vu 18 had expressed high sca effect.

High relative and standard heterosis and heterobeltiosis was shown by many of the hybrids for pods/cluster. Standard heterosis of 78.6 per cent observed in Selection 2-1 x JBT 4/221 may be attributed to high gca effect observed in the parent JBT 4/221.

Negative heterosis for pods/kg indicate less number of pods to form one kg. This is advantageous in reducing the picking time especially in a commercial scale where once over harvest is prefered. Significant negative relative and standard heterosis and heterobeltiosis was observed in the hybrid Selection 263 x Vu 18. This may be due to very high negative gca effect of Vu 18. Also they belonged to two different clusters.

Most of the hybrids showed significant relative and standard heterosis as well as heterobeltiosis for seed weight. Maximum standard heterosis values observed in Selection 2-1 x VU 18 and Selection 2-1 x JBT 4/221 may be attributed to high gca effect of the parent Selection 2-1. Hebbal (1988) observed heterosis for 100 seed weight in cowpea.

Pods/plant

Significant relative heterosis, heterobeltiosis and standard heterosis was observed in many hybrids for pods/plant. Pusa Komal x JBT 4/221 recorded highest relative and standard heterosis. This can be due to very high gca effect of Pusa Komal for this trait (6.88). Heterosis for pods/plant has been reported earlier by Hebbal (1988) and Biradar *et al.* (1991).

Yield/plant

Yield/plant was found to be significantly higher over the mid parent and better parent in several combinations. Selection 2-1 x VS 389 followed by VU 18 x Amb-1 showed highest values for relative heterosis and heterobeltiosis. In these combinations one of the parent was a good general combiner for yield. Selection 2-1 and VU 18 were having high gca effect. Also they belonged to two different clusters as well. Highest standard heterosis observed in combination VU 18 x Arka Garima and Selection 2-1 x VS 389. Arka Garima and Selection 2-1 were good general combiners for yield. These combinations had high values of sca. Their *per se* performance was also high. They belonged two different clusters also. Heterosis for pod yield have been reported by Hebbal (1988), Biradar (1991) and Rejatha (1992).

The results reveal that the use of good combining genotypes viz. Arka Garima and Selection 2-1 can be exploited for hybridization programme and the selection desirable segregants from the segregating generations by adopting progeny selection technique for exploiting additive genetic variance would lead to rapid improvement in cowpea. In cowpea improvement all aspects such as genetic divergence, *per se* performance, gca of parents and sca effects of crosses should be considered for an effective breeding programme.

Summary

SUMMARY

The present investigation 'Variability and Heterosis in bush type vegetable cowpea [*Vigna unguiculata* (L.) Walp.]' was conducted at the Vegetable Research Farm, College of Horticulture, Vellanikkara during 1992-94. The objectives of the study were estimation of genetic variability and divergence; studying the association among yield and its components; assessing the direct and indirect effects of the component characters on yield by path coefficient analysis and identification of heterobeltiotic F_1 hybrids in bush type of vegetable cowpea.

The extent of genetic variability in 31 genotypes were assessed. From these genotypes, ten diverse parents were selected and 45 F_1 hybrids were developed. These hybrids were evaluated along with the ten parents for the estimation of combining ability and heterosis.

The 31 accessions showed significant differences for all the characters studied viz. plant height, plant spread, primary branches/plant, days to flowering, days to harvest, pod length, pod girth, pod weight, bunches/plant, pods/cluster, pods/plant, seeds/pod, 100 seed weight and yield/plant.

Pod yield/plant was maximum in Arka Garima (457.3 g). IC 38956-1 was the earliest flowering genotype (33.5 days).

The genotypic coefficient of variation resulting in high heritability along with genetic gain was of high magnitude for pods/kg, pod weight and yield/plant. Days to flowering and days to harvest though had high heritability values, showed only low genetic gain.

The 31 cowpea genotypes were grouped into six clusters based on D^2 analysis. There was no strict parallelism between genetic diversity and geographic distribution. Inter cluster distance was higher than intra cluster distance suggesting homogeneity within the clusters and heterogeneity between the clusters.

The storage proteins of cowpea seeds analysed by PAGE showed marked variation in banding pattern. It was possible to distinguish among the varieties through groups of bands which do not vary within the species and are present in all the accessions.

In general phenotypic correlations were smaller than genotypic correlations. The characters like days to harvest, pod length, pod girth, pod weight, pods/kg, seeds/pod and 100 seed weight were highly correlated with yield. Pod weight exerted the maximum direct positive effect on yield, followed by pod girth and 100 seed weight.

Ten diverse parental cowpea lines were crossed in all possible combinations to develop 45 F_1 hybrids. These hybrids were evaluated along with their ten parents to study the combining ability and heterosis. Analysis of variance for combining ability showed significant gca and sca variances for all the characters, indicating the role of both additive and nonadditive gene action for the control of most of the characters.

It was noted that the parents showing good *per se* performance posses good gca effects also for yield/plant and other characters . Among ten parental lines Arka Garima and Selection 2-1 were the good general combiners for yield. The hybrids VU 18 x Arka Garima and Selection 2-1 x VS 389 posessed high sca effects.

Several hybrids recorded significant negative relative heterosis, heterobeltiosis and standard heterosis for days to flowering. Amb-1 x Arka Garima and VU 18 x Amb-1 flowered significantly earlier than the standard variety Arka Garima.

Heterobeltiosis and relative heterosis were observed in several hybrids for yield/plant. But only few of them exceeded the standard parent. Selection 2-1 x VS 389 and Vu 18 x Amb-1 were the hybrids which exhibited highest relative heterosis as well as heterobeltiosis. VU 18 x Arka Garima and Selection 2-1 x VS 389 were the only hybrids which exceeded the standard variety Arka Garima for yield/plant.

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Appendices

APPENDIX-I

Mean value of 15 biometric characters for 31 cowpea genotypes

Genotypes	Plant height (cm)	Plant spread (cm)	Primary branches	Days to flowering	Days to 1st harvest	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Bunches/ plant	Pods/ cluster	Pods/ plant	Pods/ kg	Seeds/ pod	100 seed weight (g)	Yield/ plant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. IC 38956-1	37.3	41.6	4.2	33.5	45.0	14.7	2.4	3.2	57.6	3.6	42.3	314.8	12.6	11.7	136.8
2. Sava De Dhule	30.0	74.4	4.0	44.0	57.0	17.2	2.4	3.4	23.3	2.0	16.5	288.5	13.2	10.1	56.0
3. IC 91511	27.7	57.1	3.9	41.8	55.0	24.5	2.7	7.8	21.1	1.6	18.5	129.0	14.9	15.7	144.0
4. JBT 4/103	27.2	46.2	2.5	37.9	48.2	16.1	3.0	4.7	22.3	2.3	27.9	216.1	11.2	13.0	129.7
5. M/D 119	36.7	48.5	6.1	41.3	53.6	21.5	3.1	6.3	34.8	1.5	35.4	161.4	12.6	11.0	219.3
6. IC 91499	43.7	50.8	3.4	42.7	55.0	19.1	2.4	5.6	26.2	2.0	37.5	181.5	12.3	11.0	208.3
7. EC 240715	53.1	57.7	5.4	44.1	55.0	18.3	2.2	4.3	24.2	2.0	23.3	233.3	11.0	13.7	100.7
8. EC 240712	30.1	54.0	4.8	43.1	55.0	12.5	2.0	3.2	18.4	2.0	25.2	286.5	11.0	11.2	78.9
9. Kanakamony	40.4	64.2	4.8	42.9	55.0	17.4	2.4	5.2	24.5	2.0	38.2	194.1	16.2	11.3	197.8
10. Pusa Dofasli	37.5	40.7	5.7	39.2	55.0	14.4	0.7	2.8	42.0	3.8	37.5	364.8	13.8	6.7	110.3
11. Selection 2-1	45.4	48.5	4.5	37.0	48.0	32.4	3.0	6.7	30.8	2.7	40.5	152.1	15.5	16.0	267.3
12. Pusa Komal	51.9	45.3	4.5	39.3	50.7	21.3	2.6	3.7	31.1	3.7	52.9	277.9	16.6	8.3	133.7

Contd.

Appendix-I. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13. VS 87	43.6	42.2	2.6	41.0	51.2	17.8	2.9	6.5	21.5	2.5	20.3	154 9	15.4	11.0	130.1
14. Arka Garima	47.5	56.6	4.3	40.1	51.0	27.2	3.8	13.1	23.6	2.4	32.1	76.7	15.1	13.7	457.3
15. Amb-1	45.9	42.7	3.2	36.9	45.0	22.1	2.7	4.8	26.3	3.7	38.1	209.4	15.2	11.3	181.7
16. VS 389	46.9	42.9	5.0	41.5	53.7	21.7	2.9	7.1	27.1	3.4	38.2	141.7	11.3	12.6	274.6
17. Selection 263	39.6	44.9	4.5	35.6	45.0	27.9	3.0	6.3	31.7	2.1	33.3	159.4	15.2	11.0	208.9
18. VU 18	49.9	51.7	3.9	41.2	52.5	21.80	2.9	7.5	27.7	1.99	24.7	137.7	14.9	11.3	190.2
19. IC 91456	37.0	41.9	5.5	39.3	50.0	11.8	1.7	2.2	34.2	3.8	90.8	453.8	11.6	7.3	202.1
20. NIC 12882	35.4	53.1	5.3	43.7	55.0	22.6	2.2	4.8	27.1	2.1	22.4	281.3	17.8	8.7	125.3
21. 416 NB	45.5	46.4	3.4	42.8	55.0	15.2	2.5	3.2	25.8	2.6	43.6	315.4	11.8	10.7	148.7
22. VS 479	31.9	58.5	3.5	43.1	55.0	28.8	2.3	10.1	25.2	1.7	15.0	101.4	18.4	13.3	200.3
23. 420 NB	44.0	48.8	4.1	42.8	55.0	8.8	2.2	3.7	33.3	1.5	24.8	274.4	8.3	10.0	90.4
24. Local 2	31.2	63.1	4.4	44.0	55.2	23.4	2.6	9.1	22.6	1.4	23.1	112.8	15.6	15.8	209.0
25. 734 NB	42.1	45.3	5.6	41.8	51.0	8.8	1.5	1.4	55.8	3.6	53.4	716.3	7.3	6.2	74.9
26. 34 NB	38.5	44.6	4.7	43.2	55.0	14.4	1.9	1.5	36.2	2.1	43.7	689.8	6.6	7.5	63.6
27. 744 B	46.5	50.7	5.7	41.40	55.0	12.8	2.8	2.4	47.1	1.9	37.2	417.4	10.4	6.5	89.1
28. VS 477	31.9	54.6	5.0	44.1	55.0	24.7	2.4	3.3	25.0	2.0	27.4	303.8	20.7	10.3	91.2

Contd

Appendix-1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
29. 221 NB	37.4	47.5	4.6	41.3	55.0	14.0	2.2	1.7	34.2	3.0	37.5	580.1	12.2	6.8	64.5
30. JBT 4/221	44.6	38.3	3.4	34.5	46.0	14.8	2.5	3.0	46.0	3.2	36.8	338.7	12.0	12.0	108.8
31. Local 1	47.3	49.8	5.8	42.1	54.0	14.0	1.9	2.9	19.1	2.0	30.9	352.1	14.7	8.2	90.8
SEm±	1.28	1.26	0.38	0.79	0.49	0.86	0.096	0.61	1.25	0.17	1.31	24.75	0.54	0.38	13.7
CD (0.05)	2.56	2.52	0.76	1.58	0.98	1.72	0.192	1.22	2.50	0.34	2.62	49.52	1.18	0.76	27.4
CD (0.01)	3.40	3.35	1.01	2.10	1.30	2.30	0.26	1.62	3.33	0.45	3.48	65.84	1.44	1.01	36.4

APPENDIX-II

Rf values of protein banding in cowpea genotypes

Genotypes	Rf_1	Rf_2	Rf_3	Rf_4	Rf_5
1. IC 38956-1	0.30	0.44	0.58		
2. Sava De Dhule	0.17	0.31	0.47		
3. IC 91511	0.16	0.30	0.53		
4. JBT 4/103	0.20	0.43			
5. M/D 119	0.29	0.46			
6. IC 91499	0.29	0.40	0.50		
7. EC 240715	0.21	0.45	0.49		
8. EC 240712	0.27	0.32	0.58		
9. Kanakamony	0.11	0.21	0.36		
10. Pusa Dofasli	0.20	0.39	0.50		
11. Selection 2-1	0.18	0.42	0.58		
12. Pusa Komal	0.26	0.31	0.43	0.49	
13. VS 87	0.24	0.35	0.52		
14. Arka Garima	0.31	0.46	0.62		
15. Amb-1	0.19	0.24	0.37		
16. VS 389	0.29	0.39	0.50		
17. Selection 263	0.24	0.29	0.36	0.46	
18. VU 18	0.23	0.35	0.49	0.61	
19. IC 91456	0.35	0.45	0.49	0.61	
20. NIC 12882	0.25	0.32	0.39	0.56	
21. 416 NB	0.13	0.24	0.33	0.47	
22. VS 479	0.26	0.35	0.52	0.65	
23. 420 NB	0.06	0.25	0.38	0.56	0 69
24. Local 2	0.21	0.36	0.43	0.53	
25. 734 NB	0.06	0.20	0.33		
26. 34 NB	0.20	0.31	0.41	0.53	
27. 744 B	0.31	0.38	0.46	0.54	
28. VS 477	0.27	0.43	0.53		
29. 221 NB	0.24	0.33	0.50		
30. JBT 4/221	0.24	0.33	0.50		
31. Local 1	0.21	0.36	0.50		

ABSTRACT

The present investigation on 'Variability and heterosis in bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.)' was conducted at the College of Horticulture, Vellanikkara, Thrissur during 1992-94. Thirty one genotypes of cowpea collected from different parts of the country were grown in a randomised block design with three replications to assess the extent of genetic variability for fifteen characters viz. plant height, spread, primary branches, days to flowering, days to harvest, pod length, pod girth, pod weight, seeds/pod, flower bunches, pods/cluster, pods/kg, 100 seed weight, pods/plant, and yield/plant. The genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic gain were estimated. Based on D^2 analysis and morphological observations, ten parents were selected and crossed in all possible combinations in a 10 x 10 diallel to produce 45 F_1 hybrids. These F_1 hybrids were evaluated along with their parents to derive information on general and specific combining ability effects and heterosis.

Significant differences were observed among the 31 genotypes for all the fifteen characters studied. The highest genotypic coefficient of variation was observed for pods/kg, pod weight and yield. High heritability coupled with high genetic gain was observed for these traits. Days to harvest, pod length, pod girth, pod

weight and yield. High heritability coupled with high genetic gain was observed for these traits. Days to harvest, pod length, pod girth, pod weight, pods/kg, seeds/pod and 100 seed weight were highly correlated with yield. Pod weight exerted the maximum direct effect on yield. Based on genetic divergence the 31 genotypes were grouped into six clusters.

Polyacrylamide gel electrophoresis of cowpea seed proteins showed marked variation in banding pattern. Different cowpea varieties could be distinguished by the species specific bands.

Significant gca and sca variances were observed for all the traits. Amb-1, selection 263 and selection 2-1 were the best general combiners for earliness. Hybrids resulted from Amb-1 x Arka Garima and Vu-18 x Amb-1 recorded high sca effects for earliness. Arka Garima and selection 2-1 were the best general combiners for yield. The hybrids Vu 18 x Arka Garima and Selection 2-1 x VS 389 evinced high sca effects for yield.

Significant heterosis were observed for all the traits in many hybrids. Several hybrids recorded significant negative relative heterosis, heterobeltiosis and standard heterosis for earliness. Amb-1 x Arka Garima and Vu - 18 x Amb-1 were significantly early to flower compared to standard variety, Arka Garima.

Relative heterosis and heterobeltiosis were observed in many hybrids for yield/plant. Selection 2-1 x VS 389 and Vu-18 x Amb-1 showed high relative heterosis as well as heterobeltiosis. Vu-18 x Arka Garima and Selection 2-1 x VS 389 were the promising hybrids which exceeded the standard variety Arka Garima for yield/plant.