

**PHENOTYPIC CHARACTERIZATION, ASSESSMENT OF  
GENETIC DIVERSITY, SCREENING FOR PROTEIN  
CONTENT AND BRUCHID INFESTATION IN COWPEA  
[*Vigna unguiculata* ( L.) Walp.] GENOTYPES**

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# 1. INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is one of the most important pulse crops, native of West Africa (Vavilov, 1951) but Steele (1976) suggested Ethiopia as the primary and Africa as the secondary centre of diversity. Cowpea belongs to the order *Rosales*, family *Leguminosae*, sub family *Fabaceae* and the genus *Vigna*. It is a diploid species with somatic chromosome number  $2n=22$  (Darlington and Wylie, 1955). After successfully achieving the food security by way of increased production and comfortable levels of buffer stock nutritional security continue to be a cause for serious concern. Pulses occupy a unique position in the world agriculture by virtue of their high seed protein content. Cowpea is called as poor man's meat or vegetable meat due to its high amount of seed protein with better biological value on dry weight basis. Cowpea grain contains 23.4 per cent protein, 1.8 per cent fat and 60.3 per cent carbohydrates and also it is a good source of vitamins and phosphorus (Venkatesan *et al.*, 2003).

It is widely adapted and capable of producing seeds even in low land and semi arid regions. However, grain yield of this legume varies widely when grown at different locations. It can be grown in a wide range of soil types and environmental conditions. As a pulse crop, it plays a key role in maintaining soil health and sustainability in the production from different cropping systems as they fix atmospheric nitrogen in their root nodules. On an average, the grain legumes fix 250-312 kg nitrogen per ha per year. In case of cowpea it fixes about 70-240 kg of nitrogen per ha per year. This ensures the soil fertility as well as reduces the financial burden on poor farmers. It is a most versatile pulse crop because of its smothering nature, drought tolerant characters and soil restoring properties.

In spite of much importance of pulses as per FAO (Anon., 2004), the per capita availability of pulses in India has decreased from 41 g in 1990 to 21 g in 2004. This is an alarming trend with respect to nutritional security is concerned, one of the possible ways to meet the needs of an ever increasing population is to go for modern method of plant breeding techniques which helps to evolve new varieties which could solve the above problem.

Among the different pulses grown in the world, cowpea is grown in 10.1 million ha with a production of 4.99 million tonnes and the productivity of 494 kg per ha (Anon., 2008). In India, the cowpea is grown in an area of about 3.9 million ha with the production of 2.2 million tonnes having a productivity of 567 kg per ha, which is above the average productivity of world. In Karnataka, cowpea is grown in an area of 0.77 lakh ha with the production of 0.34 lakh tonnes (Anon., 2009a). The productivity potential of the crop in Karnataka is low (437 kg per ha) as compared to the national productivity of 567 kg per ha. This clearly indicates the necessity to identify the reasons for such a low productivity in Karnataka.

In countries, having plant breeder's right in operation, a new variety is registered only if it is '**distinct**' from other varieties, '**uniform**' in its characteristics and genetically '**stable**'. Therefore, description of characters for the assessment of varietal purity and identity are essential for seed production and certification programme of any given crop variety. In order to maintain genuineness (true to type) and quality of seed careful attention is needed at every stage of seed production of a variety. The proper variety identification serves the important goals of seed production. It ensures whether the seed being produced or offered for sale is of the variety ought to be; whether it is pure or any kind of nature; to know what to rogue out or what not to rogue out during seed production.

Exchange of seeds is essential for plant breeder to improve genetic variability of available germplasm for recombination and selection of desired traits. Characterization and identification of plant varieties are thus, fundamental to the development, release and popularization of the crop varieties. In this context, varietal description for identification of crop variation has attained a critical importance in national and international seed programmes and there is considerable need for the development of reliable methods and identifiable characters for identification purpose.

Hence, morphological descriptors have traditional significance and one immediately accessible on the spot without the need of equipment. All though this has been universally adopted as classical taxonomic approach, above to its limitations like environmental influence and time consuming. However, there is limited information on characterization of cowpea

germplasm and also they are pre-requisite for the granting of plant variety protection and utility patents and therefore, it is necessary to allow seed technologists and breeders to identify germplasm and monitor for protection. National and international registration of the variety needs to pass the criteria of distinctness/uniformity/stability (DUS) tests. Varietal identification and purity are the critical elements in assessing seed entering factories and seed production *etc.*, for checking the sample to identify and investigate the origin of off types and distinguishing closely related species. In order to fulfill these requirements, variety description must be discriminatory free from environmental effects, interpretable in genetic terms and respective of pedigree and genetic constitution.

The  $D^2$  technique based on multivariate analysis developed by Mahalanobis (1936) is the most effective method for quantifying the degree of genetic diversity among genotypes, which helps in selecting the parents for hybridization. It is generally accepted that genetically diverse parents when crossed will show maximum heterosis and offer the maximum chance of isolating transgressive segregants.

It is an important source of protein in many tropical and subtropical countries and is a rich source of lysine. This compensates for low lysine content of cereals along with which they are usually eaten. Significant variability in seed protein exists among the varieties. Besides the yield potential, chemical composition from nutritional point of view is very important. It is necessary to assess the nutritional value, seed protein content of available cowpea germplasm lines/genotypes before they involved in breeding programme.

Numbers of insects have been found to infest cowpea seed/grain both in the field as well as in the seed storages. Among the storage pests, bruchids are known to cause considerable loss. There are more than 100 species of bruchids belonging to 56 genera in five sub families (Southgate, 1979). In India, 117 species belongs to 11 genera have been recorded (Arora, 1977). The genus *Callosobruchus*, includes a number of economically important species that attack stored pulses throughout the world. But, *Callosobruchus maculatus* (Fabricus), *Callosobruchus chinensis* (Linnaeus) and *Callosobruchus analis* (Fabricus) are the important species in India. Among them *Callosobruchus maculatus* (F) is the most important and the common pest of cowpea.

It is evident that all pulses in general and cowpea in particular are susceptible for storage pests due to which the qualitative and quantitative losses during storage are increased. Especially the cowpea bruchid (*Callosobruchus maculatus* (F)) cause considerable loss to cowpea seeds during storage.

In the task of future breeding programmes of producing resistant varieties against insect pests can be made feasible primary by identifying various factors that elicit such resistance.

In part considerable amount of work on relative susceptibility and extent of damage to different pulse varieties by bruchids has done in India. But practically, no information is available on susceptibility of different cowpea genotypes to true to combat it.

Therefore, morphological characterization of germplasm lines of cowpea thus will be realized to the important tool towards identification of genotypes, maintenance of genetic purity, mitigating legal claims and confirming intellectual property rights.

Keeping in view all above facts, the present investigation entitled "Phenotypic characterization, assessment of genetic diversity, screening for protein content and bruchid infestation in cowpea genotypes" was taken up to characterize, assessment of genetic diversity, screening against bruchids and estimation of protein content of the selected cowpea genotypes with the following objectives.

- i. To identify the stable diagnostic characteristics of seed, seedling and plant morphological traits of cowpea genotypes and also to assessment of genetic diversity.
- ii. To evaluate of cowpea genotypes for seed protein content and
- iii. Screening of cowpea genotypes for their relative response to bruchid infestation and seed quality.

## 2. REVIEW OF LITERATURE

Variety identification and varietal purity assessment are very important for varieties, hybrids and their parents. This is most essential for maintenance, multiplication and seed certification.

The development of new and improved plant varieties or hybrids is a continuous process. It is of critical importance for sustained increase in agricultural productivity. Under the New Seed Policy 2001, all the new varieties have to be registered based on the criteria of novelty, distinctness, uniformity and stability (DUS).

Cowpea is called poor man's meat due to its high protein content. It is evident that all pulses in general and cowpea in particular are susceptible for storage pests especially the cowpea bruchid [*C. maculatus* (F.)]. Hence, there is a need to identify the morphological characters, assess, protein content and screening of cowpea genotypes for resistance to pulse beetle.

The literature on identification of crops through morphological characteristics, seed protein content and screening of cowpea genotypes against pulse beetle has been reviewed and presented briefly under the following headings.

2.1 Morphological characters

2.2 Genetic divergence studies

2.3 Protein content

2.4 Screening of cowpea genotypes for their relative response to bruchid infestation and seed quality

### 2.1 Morphological characters

Seeds, seedlings and plants of various cultivars exhibit a wide range of morphological distinctness which is helpful in varietal identification and genetic purity testing. Continuous usage of morphological data to describe cultivars indicated that these data retain popularity as morphological descriptors.

#### 2.1.1 Seed morphology

Morphological characters of seeds are useful traits for varietal identification of a number of crops based on seed coat colour, hilum colour, shape, size and test weight.

Elsaeed (1967) reported varietal differences in Beladi and Rebaya-34 of broad beans, based on seed weight which was 192.7g and 317.1g, respectively per 500 seeds.

Villalobos and Fournier (1978) studied 13 important characters *viz.*, colour of the seed coat, hilum and 100 seed weight *etc.*, for identification of soybean.

Tiwari *et al.* (1978) grouped 21 soybean varieties based on 100 seed weight into three groups *viz.*, small, medium and bold.

Payne and Koszykowski (1979) grouped 18 soybean cultivars based on seed size for cultivar differentiation.

Srikantaradya (1980) classified 60 varieties of soybean based on the seed coat colour. Among them, 13 varieties were found black, three varieties were brown to brick red and rests of the 44 varieties were cream to dull white.

Albina Musil (1980) reported that the seed coat colour varied from black, brown, yellow and green whereas hilum colour of the seed varied from yellow, black and grey or brown. Seed shape varied from round, oval oblong and flattened. Similarly seed size was also grouped into small, large and intermediate.

Wagner and McDonald (1982) characterized 36 soybean cultivars based on hilum colour of the seed.

Paramesh (1983) classified 24 soybean genotypes based on the number of seeds per pod, 100 seed weight and seed size. They were separated into small, medium and large seeded groups based on the test weight.

Koszykowski and Burgoon (1983) grouped 64 soybean cultivars on the basis of hilum colour of the seed.

Williams *et al.* (1984) recorded the platte soybean morphological characters as yellow seed coat with shiny luster and yellow hilum.

Modesta and Cabral (1987) evaluated 11 soybean lines based on the seed coat colour, hilum colour, seed shape and 100 seed weight.

Chakrabarthy and Agrawal (1989a) developed seed keys for the identification of 16 black gram varieties on the basis of seed size and colour of the seeds.

Agrawal and Anil Pawar (1990) given seed keys for the identification of 13 soybean cultivars on the basis of seed size, colour and hilum colour.

Sun and Chang (1990) analysed for the characteristics of green soybean in China based on 100 seed weight, seed shape and size.

Charjan and Tarar (1991) reported the influence of soybean seed size on germination, seedling length, 100 seed weight and other seed quality parameters. All seed quality parameters were increased with seed size.

Venkatareddy (1991) reported that 100 seed weight differed significantly among the soybean genotypes. Bragg recorded the highest 100 seed weight (20.35 g) followed by Hardee (19.53g) and PK471 (19.75 g) while the least (18.89 g) was recorded by Monetta.

Fourty four chickpea cultivars collected from the different sites of Uttar Pradesh were grouped based on their variation in seed size (small, medium to large), seed shape (round and wrinkled), seed colour (light to dark brown, yellow, pink and white), (Anon., 1992a).

Twenty two pea cultivars were grouped based on their variation in seed size (Small, medium and large) seed colour (white, pale green, mottled green and grey) and seed shape (round and flattened) (Anon., 1992b).

Mohanrao (1993) reported that 100 seed weight was highest (20.50 g) in PK-472 followed by Bragg, KB-60 and Hardee soybean genotypes. Whereas, the lowest (14.24 g) was in KHSb-2.

Copeland and McDonald (1997) identified soybean cultivars of chippewa-64 can easily distinguished from other varieties that do not have black hilum. Sophisticated techniques must be used for distinguishing the varieties with black hilum.

Sridhara *et al.* (1997) grouped 10 soybean genotypes based on their seed coat colour and 100 seed weight.

Among all characters at seed level, seed shape, hilum shape, seed coat colour and lusture on seed are most stable, uniform and distinguishing characters in green gram (Jain and Khare, 2002a).

Arunkumar *et al.* (2004) reported that 45 cultivars of pearl millet including 14 hybrids and their parental lines were characterized using qualitative morphological characters of seed (seed colour as green, grey, grey brown and brown), seedling characters and plant morphological characters.

Karivartharaju (2005) presented a list of seed characters *viz.*, fuzz colour, seed size, 100 seed weight, density of fuzz and fibre characters like colour, strength, fineness, uniformity, maturity and ginning per cent in cotton for identification of varieties.

Nkouannessi (2005) characterized 20 cowpea genotypes from different countries *viz.*, Cameroon, South Africa, Kenya and characterized them based on seed shape, seed testa texture, hundred seed weight.

Ashok *et al.* (2008) grouped seven french bean varieties based on seed coat colour, hilum colour and seed shape.

Naima *et al.* (2009) studied 20 landraces of cowpea and characterized based on seed morphological characters like seed colour, eye colour, shape, texture and weight of hundred seeds.

Cupic *et al.* (2009) analyzed European pea (*Pisum sativum* L.) germplasm to estimate genetic variability using seed shape, colour of hilum and texta.

Lingaraj (2009) assessed genetic diversity based on hundred seed weight in 80 cowpea genotypes.

### 2.1.2 Seedling characteristics

Lirindae (1986) and Terao (1986) classified the rice genotypes based on seedling characters *viz.*, seedling length, coleoptile and sheath colour and mesocotyl colour.

Chakrabarthy and Agrawal (1989b) developed seed keys for identification of 16 blackgram genotypes using seedling characters like pigmentation (strong, moderate, weak), stem hairiness (glabrous, pubescent), leaflet shape (lanceolate, obovate), hypocotyl and radicle length.

Eighteen soybean genotypes were classified based on morphological characters, pigmentation colour and presence of pubescence on seedling (Anon., 1995).

Ashok *et al.* (2008) characterized seven french bean varieties based seedling characters *viz.*, hypocotyl colour, seedling cotyledon colour and pubescence on hypocotyl.

### 2.1.3 Plant morphological characteristics

According to Kooistra (1964) the morphological characters of plant *viz.*, shape of leaflets, leaf serration, and number of tendrils, shape of flower, pod size and pod shape could be used for distinguishing pea varieties.

Edgar *et al.* (1970) studied the morphological characters for growth habit, nature of stem hairiness, flower colour and pubescence colour of soybean.

Stahi and Pandey (1981) evaluated 21 soybean varieties and grouped them on the basis of nature of maturity and number of days to 50 per cent flowering.

Agrawal (1984) classified soybean varieties based on spreading type, pubescence presence on stem, leaf shape and size, flower colour, pod colour at maturity, days to 50 per cent flowering and maturity.

Bahrenfus and Fehr (1984) observed differences in two soybean cultivars *viz.*, Cumberland and Harper. Harper has purple flower, tawny pubescence, brown pods at maturity and higher seed yield compared to Cumberland. But both cultivars were similar in days to maturity and plant height.

Bhagat *et al.* (1985) evaluated groundnut germplasm collection of 4030 accessions for nine morphological characters. At maturity 191 accessions of var. *vulgaris*, 128 of var. *fastigiata*, 831 of var. *hypogaea* (bunch) and 1061 accessions of var. *hypogaea* (runner), had no stem pigmentation. While, 1099 accessions of var. *vulgaris*, 523 of var. *fastigiata*, 209 of var. *hypogaea* (bunch) and 33 of var. *hypogaea* (runner) showed stem pigmentation.

From the french bean varietal trial, ten cultivars were grouped based on morphological characters *viz.*, plant height, number of branches and leaves per plant, seeds per pod, 100 seed weight and pod length (Anon., 1985)

Tunwar and Singh (1985) recorded salient features of 31 improved soybean varieties based on seed and plant morphological characteristics.

Diazcarrasco *et al.* (1986) grouped 17 soybean varieties based on days to maturity, plant height and seed yield per plant.

Rasaily *et al.* (1986) tabulated 20 soybean genotype characters based on plant height, number of branches, pods per plant and seed yield per plant.

Sisodia (1987) recorded influence of different size of large, medium and indeterminate seed sized gave seed yields of 2.87, 8.52, 2.04 t per ha, respectively.

Harville *et al.* (1988) compared soybean cultivar of Braxton with Gregg. Gregg has purple flower, tawny pubescence on pod, determinate growth habit, one day early maturity and 5 cm shorter in mature plant height than Braxton.

Kenworthy (1988) compared soybean cultivars of Sparks with Morgan. Morgan has white flower, tawny pubescence on pod and 5 cm shorter in mature plant height than Sparks.

Awasthi *et al.* (1989) studied on biochemical composition of ten important cowpea genotypes grown during summer. Freshly harvested edible immature pods of these cowpea genotypes were analysed for various physical parameters. Variability values for pod length, pod diameter, pod weight, pod yield were observed to range from 10.68-36.75 cm per pod,

0.18- 0.25 cm per pod, 2.2 1-3.80 g per pod, 65-98 g per plant, respectively. Faizabad and Sel-2 recorded highest pod yield.

Observations recorded from 3175 soybean accessions with the help of following identification characters *viz.*, days to flowering, plant height, days to maturity and number of seeds per pod (Anon., 1989).

Reddy *et al.* (1989) recorded 5 soybean cultivar variation for days to maturity, period from flower initiation to maturity, plant height, seeds per plant and yield per plant.

Boerma *et al.* (1990) reported soybean cultivar of Colquitt based on morphological characters of determinate growth habit, purple flower, tawny pubescence on pod walls and matured 3 days later than Gorden and one day earlier than Thomas cultivar.

Bowers *et al.* (1990) compared soybean cultivars of Dowling with Crockett. Crockett has purple flower, Tawny pubescence on pod walls at maturity, one day later maturity and 8cm taller than Dowling.

From 150 soybean germplasm accessions based on useful characters *viz.*, plant height, days to flower, days to maturity, pods per plant, seeds per pod, number of branches per plant and seed yield per plant and other varietal identification characters were recorded (Anon., 1990).

Vahab *et al.* (1991) studied on evaluation of selected varieties of vegetable cowpea with the objective of identifying high yielding good quality vegetable types suitable for both rainy and summer seasons. Seven selected varieties of cowpea *viz.*, IIHR 61-B (Bangalore) Sel-263 (Ludhiana), Kanakamani (Kerala), Pusakomal (IARI), VS-389 (Kerala), Sel-2-1 (Faizabad), VS-87 (Kerala) were taken for the study. Varieties differed significantly for plant height and spread in all the three seasons as well as the mean values pooled over the seasons. VS-389 was the tallest in all the seasons, with the mean value of 60 cm and Sel-263 the shortest with a mean value of 44 cm. The maximum spreading varieties were IIHR 61-B in rainy and Sel-2-1 in summer season. Sel-263 had the minimum spread in both the seasons. In all the three seasons, IIHR 61-B had maximum pod weight. Sel-2-1 had the longest pods and seeds per pod were also maximum.

From different locations of Utter Pradesh 44 chickpea cultivars were collected and all cultivars were exhibited variation for seeds per pod (1-3) foliage colour ( green, purple and half green or half purple), plant height (20-55 cm) and branches per plant (4-10) were varied (Anon., 1992a).

Aghora *et al.* (1994) studied an evaluation of vegetable cowpea for earliness and green pod yield. Nineteen diverse vegetable cowpea varieties were evaluated for their earliness and green pod yield. The study showed that IIHR Sel-11 and IIHR Sel-16 were found to be superior genotypes in terms of earliness and green pod yield.

Bonetti *et al.* (1995) reported that 17 bean cultivars were grouped based on leaf colour (very light green, light green, medium green, dark green, very dark green), pod length (very short, short, medium, long, very long), maturity (early, medium, late) and time of flowering (early, medium and late).

Excellent work was done for the 18 soybean genotypes and classified based on diagnostic characteristics such as growth habit, plant height, stem pattern, leaf surface, foliage, pigmentation on stem, stem hairiness, colour of the hair, days to flowering, flower colour, pod shape, pod hairiness, pod colour at maturity, pod hair colour at maturity and days to maturity (Anon., 1995).

Mudzana *et al.* (1995) reported that the morphological characters such as plant height, foliage colour, number of days to 50 per cent flowering, flower length, pod length, pod breadth and number of seeds per pod could be used for variety identification of faba beans.

Surendra Prakash and Singhal (1997) reported that seven grain and six vegetable pea cultivars were grouped based on plant height (short, medium, tall, very tall), leaf length (short, medium, long), time of flowering (early, medium) pod length (short, medium, long) and leaf colour (yellow green, blue green, green).

Jain and Khare (2002b) characterized 15 green gram varieties based on morphological characteristics and reported that variation in pigmentation on hypocotyls, stem, petiole, leaf, leaf midrib and ventral suture of pod and immature and mature pod colour were most stable and uniform distinguishing characters. Density of hairiness on stem, raceme position, growth habit, pod constriction and pod curvature can be used to identify the mung bean varieties effectively. Days to flowering, days to maturity and plant height were the uniform characters but their expression is varied under different environments.

Sankrapandian (2002) reported that four cowpea varieties were grouped based on pod shape, seed colour and leaf shape.

Suryawanshi *et al.* (2002) characterized seven soybean cultivars based on morphological characteristics and reported that the pigmentation on seedling, foliage colour, pubescence on leaf and stem. Flower colour, pod hairiness and pod colour at maturity were observed to be the most stable diagnostic characters and these are much helpful for identifying the genotypes at flowering and maturity stage.

Upadhyaya *et al.* (2002) evaluated 1956 chickpea accessions for flower colour (white, light flower), plant colour, seed colour (orange, yellow orange) and other characteristics.

Yadav and Shrivasthava (2002) characterized chickpea varieties based on seed colour (brown, light brown, dark brown, reddish brown, light green), seed size (bold, medium, small), stem pigmentation (strong, medium and absent), flower colour (white, deep pink, pink, light pink), foliage colour (dark green, light green), plant height (tall, medium, dwarf), podding habit (single, double), pod number per plant (low, medium, high), number of locules per pod (one, two, three) and duration (early, medium and late).

Tarasatyavathi *et al.* (2004) reported that 75 released soybean varieties were characterized based on leaf shape (lanceolate, pointed ovate, rounded ovate, triangular), leaf colour intensity (light, medium, dark), flower colour (white, violet), pod pubescence (absent, present), plant height (short, medium, tall), days to flowering (early, medium and late) and days to maturity (early, medium, late).

Nkouannessi (2005) grouped 20 cowpea genotypes from different countries *viz.*, Cameroon, South Africa and Kenya. Based on plant morphological characteristics such as growth pattern, plant pigmentation, plant hairiness, raceme position, pod attachment to peduncle, immature pod pigmentation, leaf colour, flower colour, number of main branches, number of pods per peduncle, number of pods per plant, pod length, number of seeds per pod and plant height were employed for characterization.

Mate and Shelar (2006) characterized 16 sorghum hybrids based on plant height (very short, very tall), days to 50 per cent flowering (early, late) anther colour, stigma anthocyanin, colour of straw and glume colour at maturity.

Sarutayophat *et al.* (2007) characterized 13 cowpea accession based growth habit, days to 50 per cent flowering, pod colour, pod length, number of pods per plant, seed yield per plant.

Ashok *et al.* (2008) grouped seven french bean varieties using flower colour and constriction on pod.

Cupic *et al.* (2009) analysed European pea (*Pisum sativum* L.) germplasm, to determine differences between *P. sativum* var. *arvense* and *P. sativum* ssp. *sativum* groups, and to estimate genetic variability among and within 18 *P. sativum* accessions. Sixteen morphological traits (shape of seed, colour of hilum, shape of grain starch, unwrinkled seed and simple starch grain, colour of testa, colour of cotyledons, plant height, colour of foliage, anthocyanin, type of node, stipule length, colour of flower, maximum number of flowers per node, days to flowering, pod-shape of distal part, parchment of pod) were used to estimate genetic distances.

Naima *et al.* (2009) studied 20 landraces of cowpea and characterized based on plant morphological characters such as flower colour, seed number per pod, pod purple pigmentation, pod length, number of seeds per pod and days to 50 per cent flowering.

PPV and FRA (Anon., 2009b) published important morphological characters for the varietal identification of groundnut *viz.* Plant growth habit, leaflet colour, stem pubescence, inflorescence, pod construction, seed coat colour.

Lingaraj (2009) assessed the genetic diversity based on plant height, days to 50 per cent flowering, number of pods per plant, pod length, number of seeds per pod and seed yield per plant characteristics in cowpea.

## 2.2 Genetic divergence studies

The magnitude of divergence between two groups under consideration is provided by  $D^2$  statistic developed by Mahalanobis (1936). It considers the variation produced by any character and their consequent effect that it bears on other characters.

The technique in the form of generalized distance was first used by Mahalanobis in an anthropometric survey of the united province in India. For the first time  $D^2$  statistic was applied for biological population by Nair and Mukharjee (1960) to classify the natural and plantation teak tree types. Its application was extended later to taxonomic studies. Murthy and Pavate (1962) observed that  $D^2$  analysis could be extended to the situations where overlapping species need to be discriminated and also when the discrimination at sub species level is needed.

Dharmalingam and Kadambavanasundaram (1989) presented a data on 8 yield components measured in 40 genotypes was subjected to multivariate analysis ( $D^2$ ). Wide genetic diversity was present among the 13 clusters formed. The genotypes Co2 and G5, belonging to the two most divergent clusters, were recommended as suitable for inclusion in heterosis breeding programmes.

Renganayaki and Rangaswamy (1992) analyzed the mungbean, blackgram and cowpea using the Mahalanobis  $D^2$  value and revealed that the genotypes of mungbean, blackgram and cowpea were grouped in seven, five and four clusters, respectively and also concluded that hundred seed weight, pod length and seed yield contributed most towards genetic divergence.

Mahalanobis'  $D^2$  statistic was used (Rewale *et al.*, 1996) to estimate genetic divergence of 12 yield related characters evaluated in 70 genotypes of *V. unguiculata subsp. cylindrica*. Multivariate analysis grouped the genotypes into 19 clusters, of which 11 had only one genotype each. Days to initiation of flowering, 50 per cent flowering and maturity, number of inflorescences and pods per plant, pod length, hundred seed weight, seed yield per plant and harvest index made the largest contribution to the total divergence. It is proposed that high yielding genotypes with early maturity and high harvest index could be selected as parents for hybridization.

Santos *et al.* (1997) reported genetic divergence of cowpea under two different environments using Mahalanobis  $D^2$  statistics that length of main branch, hundred seed weight and pod length were the most important characters to affect the divergence. Sharma and Mishra (1997) revealed that days to 50 per cent flowering, plant height, pods per peduncle and harvest index contributed the most towards the genetic divergence and seed yield had a high positive phenotypic correlation with pods per peduncle, number of seeds per pod and harvest index.

Backiyarani *et al.* (2000) concluded that genetic divergence for physiological traits like single plant yield, harvest index and earliness in flowering together accounted for 80 per cent of the total divergence in cowpea. Usha Kumari *et al.* (2000) reported that contribution towards genetic divergence was recorded for plant height (22.69%), number of branches (16.82%), number of pods per cluster (15.27%) and pod length (13.47%) in cowpea. Borah and Khan (2002) revealed on genetic divergence in fodder cowpea, sixty fodder cowpea cultivars were grouped in to 10 clusters. Dry matter yield, green fodder yield and plant height were recorded the highest contribution to total genetic divergence. These traits could be good criterion for selection of parents in hybridization programme.

Narayanankutty *et al.* (2003) Studied genetic variability and divergence on thirty seven genotypes of vegetable cowpea revealed significant differences for all the characters under study. The thirty-seven genotypes were grouped into eleven clusters using Mahalanobis  $D^2$  statistics. In general, the intercluster distances were higher than intracluster distances. The maximum intercluster distance was between clusters VIII and X, followed by clusters VI and X and clusters VIII and IX, respectively. The intracluster distance was maximum in cluster VII.

The nature of magnitude of genetic diversity was studied in a set of 45 cowpea (*Vigna unguiculata*) genotypes from indigenous and exotic sources (Nigude *et al.* 2004). The genotypes were grouped into five clusters using Mahalanobis  $D^2$  statistics. Cluster-I was the largest with 28 genotypes followed by cluster-II with eleven genotypes and cluster-III with four genotypes. The clusters IV and V were monogenotypic. The maximum inter-cluster distance was observed between clusters III and V followed by distance between clusters II and III. Clusters I and III exhibited the minimum inter-cluster distance. The number of branches per plant, test weight, biomass (dry weight) at harvesting and number of pods per plant had contributed considerably toward divergence.

Venkatesan *et al.* (2004) reported that clusters per plant, pods per cluster, and pods per plant and seed yield per plant had the maximum contribution towards total divergence. And in another report by Kumawat and Raje (2005) also showed seed yield per plant had the highest contribution towards the total genetic divergence; followed by seeds per pod, days to 50 per cent flowering, plant height and reproductive period. Sulnathi *et al.* (2007) assessed genetic divergence in 56 genotypes of cowpea using  $D^2$  statistics for 13 yield contributing characters showed grouping of genotypes into 9 clusters. Cluster I had the maximum number of genotypes. The characters days to maturity, 100-seed weight and days to flowering were the highest contributors to  $D^2$  values.

Indradeo Pandey (2007) evaluated 44 grain cowpea for 13 characters to quantify the genetic diversity existing among them by using Mahalanobis  $D^2$  statistics. The genotypes fell into 9 clusters. Cluster strength varied from single genotype (Cluster IV to IX) to 31 genotypes (cluster I). Cluster III had minimum days to first flower opening, days to 50 per cent flowering and seed yield per plant in addition to maximum number of pod per plant and primary branches. Cluster II, V, VII had maximum yield per plant, 100-seed weight; pod length and number of seeds per pod, respectively. Cluster II had minimum days to maturity, while cluster VII showed maximum days to maturity.

Suganthi and Murugan (2007) evaluated 30 genotypes of cowpea for 10 characters to quantify the genetic diversity existing among them by using Mahalanobis  $D^2$  statistics. These genotypes were grouped into 11 clusters. Cluster strength varied from single genotype (Cluster VI, IX and XI) to 7 genotypes (cluster III). Cluster VI had maximum seed yield per plant, number of pods per cluster, pod length, number of seeds per pod and number of pods per plant followed by cluster III. Cluster IX had maximum test weight.

## 2.3 Protein content

Selvaraj *et al.* (1986) studied on a new high yielding drought tolerant cowpea varieties named CO-4. The protein content was highest in this variety. It was around 30.0 per cent (dry matter) as against the CO-3, C-152, KM.1 in which protein content was 28.59, 27.81 and 28.90 per cent (dry matter), respectively.

Awasthi *et al.* (1989) studied biochemical composition and nutritional quality of ten important cowpea genotypes grown during summer, 1987. Freshly harvested edible immature pods of these cowpea genotypes were analyzed for various physical and biochemical parameters. Variability values for moisture, protein, reducing sugars, total sugars, crude fibre, ash, phosphorus, sulphur, iron, vitamin C and tannin content were observed in the range from 82.5-86.5 per cent, 2.5 mg per 100g, 14-22 mg per 100g and 47.4-65 mg per 100g, respectively. Genotypes L-1552, Barilobia and EC-4209 were found to be rich source of protein, while pod yield was recorded the highest in Faizabad Sel-2 having significantly less amount of tannins among various cowpea genotypes. Nevertheless on the basis of overall performance, Barilobia emerged to be the most promising genotype followed by IC20580, Chotilobia, Faizabad Sel-1 and Faizabad Sel-2 from nutritional stand point in particular.

Aghora *et al.* (1994) studied on evaluation of vegetable cowpea for protein content: The study included the important nutritional factors responsible for the quality breeding programme of vegetable cowpea during rabi season. The study showed that IIHR Sel-11 and IIHR Sel-16 were found to be superior genotypes in terms of protein content. Protein content ranged from 2.5-5.94 per cent indicating the wide variability among the genotypes. IIHR-157, IIHR-345, IIHR-333, IIHR-353 were superior only for protein content and will be useful in breeding value added protein rich vegetable cowpea.

Singh *et al.* (1997a) studied biochemical composition and nutritional quality of edible immature pods of broad bean. Wide variability in respect of moisture, protein, true protein, crude fat, crude fibre, carbohydrate, protein digestibility, phosphorus, sulphur, iron, tryptophan and methionine content was observed among 27 genotypes of broad bean grown under mid hill conditions of Himachal Pradesh at Palampur during 1995-96 ranging from 79.34 to 88.77 per cent, 3.98 to 6.25 per cent, 3.46 to 5.68 per cent, 0.73 to 1.07 per cent, 0.065 to 0.138 per cent, 1.10 to 2.75 per cent, 3.57 to 12.46 per cent, 48.90 to 56.80 per cent, 56.34 to 98.59 g per 100 g, 34.56 to 85.08 mg per 100g, 0.51 to 1.90 mg per 100 g 0.104 to 0.148 g per 100 g protein and 0.22 to 0.5 g per 100 g protein, respectively. Based on genotypic rating done in search of multipurpose genotypes the study indicated that genotypes JV-8, JV-7, JV-6, JV-5 and EC-284368, EC-284366, DPBB-I and Palampur Local-1 emerged superior over others.

Kamble *et al.* (1998) studied on nutritional quality evaluation of newly developed varieties of pigeon pea (*Cajanus cajan* (L.) Millsp.). Six varieties of pigeon pea were evaluated for nutritional quality. Significant difference was noticed in content of protein amongst the varieties tested. The varieties Dailhana Black, PBN-54 and C-11 recorded markedly low per cent of digestibility of protein among the varieties of pigeon pea tested.

Nirmal De *et al.* (2001) conducted a field experiment during the rainy season on 20 genotypes of cowpea on diet versatility in the field to study the protein content. The pod plus seed protein content was 21.2 per cent. High protein content in both foliage and pod or seed throughout the growth stage was recorded in Pusakomal. The protein content of IIHR Sel-11 and Sel-2-1 was also statistically on par with Pusakomal. In general higher protein content was recorded in local genotypes like 'Red seeded climbing', 'Cowpea Local-1' and 'Kalajhamla' compared to other tested groups.

Naeem Ahmad and Mohammad Rahim (2007) Studies were carried out on cowpea variety Swat Kulat-1 (SK-1) at the Agriculture Research Institute (N) Mingora, Swat during the year 2002-03 and reported that the 23 per cent of seed protein content in the cowpea variety Swat Kulat-1 (SK-1).

Sebetha *et al.* (2010) evaluated two different cowpea varieties from South Africa for seed protein content and results showed 24.25 and 25.35 per cent in Pan 311 and Red Caloona variety, respectively.

## 2.4 Screening of cowpea genotypes for their relative response to bruchid infestation and seed quality

### 2.4.1 Evaluation of cowpea genotypes for resistance to *C. maculatus* (F)

Wadnerkar *et al.* (1978) studied the development of *Callosobruchus maculatus* (F.) on four varieties of Arhar and three varieties of gram. Arhar was more preferred to gram for oviposition and Arhar No. 148 was the most preferred variety. Development was significantly faster in white gram. Prabhat variety of Arhar showed maximum percentage loss in weight while, it was the lowest in white gram. Adult emergence did not differ significantly.

Dabi *et al.* (1979) evaluated the relative susceptible of the seeds of 10 varieties of cowpea against *Callosobruchus maculatus* (F) and found that RS-9 was the least susceptible and RS-118, PS-42 and NO-5-19-14-1 were the most susceptible. The weight, volume, hardness and colour of the seed had no effect on susceptibility.

Kameshwara Rao and Krishnamoorthy Rao (1982) reported life cycle of *Callosobruchus maculatus* (F) between 33 and 42 days in the pigeon pea varieties C-53 Hy-2 and PDM-1, while it extended to about 40 to 44 days in other varieties UPAS 120, ST1, Mukta and BDN- 1. Largest number (307) of adult developed in C-53, while only 50 adults developed in UPAS 120. Maximum egg laying was observed on C-53 followed by Hy-2. ST-1, BDN- 1, while on PDM-1, UPAS- 120 and Mukta significantly low number of eggs were deposited. The percentage of grain damage was the highest in C-53 while UPAS- 120 and Mukta showed least damage by the bruchid *C. maculatus*.

Satya vir (1983) reported that 24 promising varieties of cowpea *Vigna unguiculata* (Linn.) were screened for their relative resistance to *C. maculatus* Fab. Among these genotypes V.C. 5, 25/8/2/2, R.S.9, C.G.28 and Sel-1476 proved to be relatively resistant, whereas Copusa-1, V-7, Copusa-2, 26/4/1, Culture-2, 5262 and P.T.B.1 were found to be most susceptible varieties. Varieties J.C.10, K-39, Culture-1, C.G.11, V-37, C-G.69, V-16,

Copusa-3, PLS-382, H.G.22, C-152, C.G.5 showed as intermediate behaviour and none was found immune to attack of *C. maculatus* (F).

Katiyar and Khare (1983) while screening 20 genotypes of green gram for their relative susceptibility to pulse beetle *C. chinensis* observed a non significant difference in susceptibility due to variation in the seed size.

Singh *et al.* (1985) screened over 8000 germplasm lines of cowpea. Three sources of resistance to cowpea weevil have been identified *viz.*, Tyul 2027, TVul 1952 and Tyul 1953. The per cent damaged seeds ranged from 25 to 26 per cent in the resistant lines and 95 per cent for life brown susceptible line.

In AVRDC (Anon., 1986) one hundred and one mungbean breeding lines were tested for their susceptibility to bruchid in a laboratory screening. Five breeding lines *viz.*, VC1535-11-1B-1-3B, VC-2764-B-7-2Bm, VC-2764-B-7-1-B, VC- 1 209-3B-1-2-B and VC- 1482-C- 12-2-B were least damaged by the bruchids. The number of adults that emerged from these resistant entries was on par with no adult emergence from VM-2 164, the resistant check.

At AVRDC (Anon., 1988) seeds of 500 mungbean accessions were screened for resistance to *C. chinensis*. Ten accessions were classified as highly resistant. Two entries, V-2802-G and V1128B-B2 were found free from bruchid infestation; V-2802BG is a selection from a resistant accession V8202.

Ahmed *et al.* (1989) evaluated eighteen chickpea (*Cicer arietinum* L.) genotypes for their susceptibility pulse beetle, *Callosobruchus maculatus* F. (bruchidae) taking into account the number of undamaged seeds (resistance to bruchids), number of eggs oviposited (ovipositional preference) and number of emergence holes (Adult survival) per 50 seeds. Resistance to bruchids appeared to be a more heritable trait than the other two damage characters. The number of emergence holes is a better indicator of seed resistance than the number of eggs present on the seeds.

Gobindan *et al.* (1989) screened seven legume species namely sweet peas, green gram (*V. radiata*), blackgram (*V. mungo*), bengalgram (*C. arietinum*), cowpea (*V. unguiculata*), pigeon pea (*C. cajan*) and wild mung (*V. vexillata*) against *C. chinensis*. They found *V. vexillata* to be the least susceptible.

Kapila and Rajni (1989) screened seeds of 17 cultivars of *Phaseolus vulgaris* for resistance to *Zabrotus subfacicttus* in the laboratory and concluded that neither size nor colour of the seeds were important with regard to susceptibility.

Manohar and Yadav (1990) studied the extent of damage on ten commonly cultivars of cowpea *viz.*, Udaipur-1, Udaipur-2, P-1309, P-1302, P-1414, P-454-157, IC-11325, CS-152, CO-1 and Kanpur black (141.23) to pulse beetle *C. maculatus* (F) , Udaipur-1 variety suffered maximum loss of 44.97 per cent in apparent weight, while, Co-1 variety had the least loss of 16.25 per cent. The respective real weight losses were 56.78 and 20.40 per cent. The loss in seed variability ranged from 9.0 to 49.34 per cent on CO-1 and Udaipur-1 varieties. Conclusively Co-1 was relatively resistant to *C. maculatus* (F) Fab. as compared to other varieties.

Dushyant *et al.* (1991) studied comparative susceptibility of 33 genotypes of pigeon pea (*Cajanus cajan*) to pulse beetle tested in laboratory condition significant variation was found in the degree of resistance with none being completely immune.

Laboratory study conducted at AVRDC (Anon., 1991) showed that *C. chinensis* resistant mungbean (*Vigna radiata*) accessions (V2709 and V2802) and one blackgram (*V. mungo*) accession (VM2 164) were equally resistant to *C. maculatus* (F), the second most important pest of *V. radiata* seeds in storage.

AVRDC (Anon., 1992c) conducted genetic studies using a wild mungbean accession *Vigna radiata* sublobata (TC1966) and two mungbean accessions (V2709 and V12802) revealed that they were immune or highly resistant. Studies further showed that in each resistant line, resistance was controlled by a single dominant gene and these three resistance genes were not allelic.

Talekar and Lin (1992) investigated on the characteristics of resistance to *Callosobruchus chinensis* in two mungbean and one blackgram accessions in a series of lab tests. They concluded that smaller seed size of the accessions was not responsible for the

resistance. The results indicated the possible presence of antibiotic factors in the resistant accessions.

Ahmed *et al.* (1993) evaluated seeds of 39 chickpea varieties infested with *C. chinensis* for number of damaged seeds, number of holed seed surface texture and seed coat thickness. They found that the varieties with a rough, hard, wrinkled and thick seed coat showed less damage and number of holes and therefore were more resistant than varieties with small, soft and thin seed coats. Correlation between the two damage parameters was positive and highly significant.

Dogre *et al.* (1993) evaluated seeds of 24 accessions of pigeon pea (*Cajanus cajan* (L.) Millsp.) and four other species of *Cajanus* for their resistance to infestation by *Callosobruchus maculatus* (F.). None of pigeon pea accessions was resistant but resistance was evident in the three species of *Cajanus*.

Relative susceptibility of 44 pigeon pea varieties attacked by *C. chinensis* and factors involved in their susceptibility were determined in a study by Modi *et al.* (1994). Based on number of eggs per 50 grains and grain damage, cultivars ICPL-89044, KM-9 and KPAS-120 were found to be less susceptible than the other varieties and susceptibility was affected by size and shape of seed but not by seed colour.

Kadoo and Rane (1995) used 12 commonly grown varieties of pigeon pea to study the extent of damage and varietal resistance and susceptibility to *C. chinensis*. None of the varieties were found to be immune to infestation by *C. chinensis*. However, there was a significant difference in the relative susceptibility of different varieties to bruchid attack.

Sison *et al.* (1996) screened several mungbean varieties for resistance to *C. chinensis*. Results of both free choice and no choice tests showed that TC 1966 was highly resistant while pag-asa (1, 3, 5 and 7) were susceptible.

Eight different varieties of mungbean (*Vigna radiata*) were evaluated for their susceptibility to *C. chinensis* by Muhammad Hussain *et al.* (1997) on the basis of number of eggs laid, duration of development of the immature stages, percentage adult emergence and weight loss due to damage by the pest. The varieties MB-2456 and Kanti were found to be highly susceptible with 13.6 and 13.0 per cent loss in the weight of seeds, respectively. The size, colour and protein content of the seeds had no influence on the susceptibility of mungbean seeds to *C. chinensis*.

Both artificial and natural infestation of *C. chinensis* was used by Liu-xuming *et al.* (1998) in the identification of resistance source of mungbean (*Vigna radiata*). Among the tested germplasm, 17 lines from AVRDC showed moderate resistance to immunity, while only 3 land races from Gangxi showed moderate resistance.

Lambrides and Imrie (2000) screened 26 mungbean (*Vigna radiata*) varieties and accessions for resistance to 4 bruchid species. On the basis of percentage of seed damage, all Australian commercial mungbean varieties tested were highly susceptible to strains of *C. chinensis* and *C. maculatus* (F). Three accessions (TC1966, ACC23 and ACC41) appeared to have bruchid resistance. All the three accessions had wild mungbean characteristics like small seed size and the presence of well formed texture layer on the seed.

Bhalla *et al.* (2002) reported that seeds of 63 genotypes of cowpea, *Vigna unguiculata* (L.) were evaluated for their relative susceptibility to cowpea weevil, *C. maculatus* (F). Genotype IC-58905, EC-240922A and Nic-1066 with growth indices of 0.96, 1.06 and 1.30, respectively were found to be superior to others in terms of bruchid resistance/tolerance.

Mahgoub *et al.* (2005) conducted an experiment to study the infestation potential of *C. chinensis* and *C. maculatus* (F) on seeds of cowpea, mung bean, lentil, chick pea, kidney bean, peas and broad bean. The data were recorded for susceptibility index values, weight loss and some biological activities. The kidney bean seeds were completely resistant to infestation by both bruchids, while seeds of cowpea and mung bean were completely susceptible. The other 4 pulses showed varying degree of susceptibility. However, it was also found that, all studied crops were more susceptible to *C. chinensis* than to *C. maculatus* (F).

Nagaraja (2006) evaluated different cowpea genotypes for bruchid resistance, reported that the genotypes KM-1, Goa local T-I and TV x 944 were least susceptible to *C. chinensis* and the genotypes DCP-2, V-118, T4, C-3 and KM4 were susceptible.

Parameshwarappa *et al.* (2007) studied the comparative response of the seeds of 12 chickpea varieties against *Callosobruchus chinensis* L. and found that ICC-10 was the most susceptible and ICCV-0331 was least susceptible to attack by pulse beetle.

Infestation studies were conducted to compare the susceptibility nature of the improved local varieties of pulses to the pulse beetle, *Callosobruchus maculatus* (Karthikeyan, *et al.*, 2008). The study confirmed that the varieties of pulses exhibit varied suitability to the life performance of *C. maculatus*. The varieties, Vamban-4 of *V. mungo*, Vamban-1 of *V. unguiculata* and Vamban-2 of *V. radiata* possess complete resistance to antibiosis in terms of not supporting any adult emergence, which is the most important parameter in assessing the seeds resistance to insect infestation. The resistance status of the seed varieties among the infested seeds, Vamban-1 and Vamban-2 of *C. cajan* and Vamban-2 and Vamban-3 of *V. mungo* and Vamban-1 of *V. radiata* revealed poorer host suitability.

#### 2.4.2 Quantitative losses

Chandola *et al.* (1969) have placed the loss at 20 per cent in cowpea infested with *C. chinensis*.

Siddiqui (1972) reported that under artificial inoculation, percentages of the seeds infested by *C. chinensis* were 97.5, 81.68 and 30 per cent in cowpea, mungbean and chick pea, respectively.

Studies carried out at ICRISAT, Hyderabad (Anon., 1976) on red gram revealed maximum bruchids infestation of 28 per cent with an average infestation of 5 per cent.

Gupta *et al.* (1981) reported that 84 per cent damage in bengalgram is due to *C. maculatus* (*F*) after six months of storage.

The loss caused by *C. maculatus* (*F*) in mung (T17) and cowpea (T171) was 63.2 and 31.3% according to Satya and Jindal (1981).

Singh and Sharma (1984) reported that 42.53 to 57.33 per cent damage in mung and 7.97 to 10.27 per cent in mash due to *C. maculatus* (*F*) during 5 months storage.

Venkategowda (1984) under forced infestation condition noticed the increase in apparent loss from 0.1 per cent (first month) to maximum of 12.31 per cent in 8 month after storage. He further recorded an actual loss of 45.45 per cent after 8 months of storage which did not increase further.

Sukprakaran (1985) estimated 1 to 25 per cent damage in legume grains which was caused by *C. maculatus* (*F*) during storage period.

Doharey *et al.* (1987) observed gradual increase in weight loss in green gram due to *C. maculatus* (*F*) with progressive increase in storage periods causing 1.15, 36.36, 48.84 and 51.91 per cent weight loss after 30, 60, 90 and 120 days after storage period, respectively.

Singhal *et al.* (1989) studied the effect of initial infestation of chick pea seeds inoculated with 1, 2, 3, 4 and 5 pairs of male and female *C. chinensis* and 92 per cent of seed damage was noticed in  $F_1$  and  $F_2$  generation of insect.

Ramzan *et al.* (1990) claimed that 69.2 per cent of seed damage was caused by *C. maculatus* (*F*) in cowpea (*Vigna unguiculata*) under natural storage conditions.

Ramesh (1993) studied the per cent soybean seeds inoculated with one and two pair of *C. maculatus* (*F*) and per cent actual loss was 45.36 and 100 after nine month of storage.

Muhammad Shafique and Maqbool Ahmad (2005) screened the grains of 22 chick pea genotypes for resistance to pulse beetle *C. analis*. They were found that free choice oviposition by the beetle, adult progeny development, grain damage and weight loss varied significantly among the chick pea cultivars. The genotypes CM 3142-2/92, CM 88, CM 3142-3/92, CM 72 and PB91 harbored significantly lower number of eggs, adult progeny development, seed damage and weight loss indicating resistance to *C. analis*.

Shaheen *et al.* (2006) screened grains of 15 chickpea cultivars against pulse beetle and reported that the minimum number of holes (0.80 per grain) made by pulse beetle was recorded in grains of Punjab-91 compared to the maximum of 1.77 holes per grain in Paidar-

91. The minimum grain damage (24.35%) was recorded in Bittle-98 while the maximum of 54.46% damage was seen in Flip 97-192C.

### 2.4.3 Per cent loss in seed weight

Gujar and Yadav (1978) studied the feeding habits of grubs and observed the feeding progress in three stages corresponding to the early, mid and later stages of development. The percentage of seed weight loss was 55.6 to 60.0 in seed inoculated with *C. maculatus* (F) and 30.2 to 55.7 in seed inoculated with *C. chinensis*.

According to Satya and Jindal (1981) *C. maculatus* (F) caused 63.2 and 31.3 per cent loss in seed weight in moong (G-2) and cowpea (T-17), respectively.

Gupta *et al.* (1981) reported 55.2 per cent weight loss in bengalgram by *C. maculatus* (F) after six months of storage.

Rustamani *et al.* (1985) studied four stored pulses in Pakistan for their resistance to the bruchid *C. maculatus* (F) and weight loss was 55.26, 46.70, 44.08 and 5.9 per cent in mash, mung, gram and pea, respectively.

Doharey *et al.* (1987) observed gradual increase in weight loss in green gram due to *C. maculatus* (F) with progressive increase in storage period causing 1.15, 36.36, 48.84 and 51.91 per cent weight loss after 30, 60, 90 and 120 days after storage period, respectively.

Ramzan *et al.* (1990) studied the damage caused by *C. maculatus* (F) on black eyed cowpea and reported 34.5 per cent of weight loss under natural storage conditions.

Ramesh (1993) studied the per cent loss in weight of soybean inoculated with one, two, four and eight pairs of *C. maculatus* (F) and reported 0.08 to 12.57, 0.16 to 26.05, 0.34 to 58.29, 0.65 to 60.20 per cent weight loss during nine months of storage period.

Bhatnagar *et al.* (2001) studied the fifteen varieties of cowpea which were evaluated for their effect on orientation, oviposition, development and survival of *C. maculatus* (Fab.). varieties IFC 9907 and IFC 9909 were less preferred for orientation and oviposition, which resulted in less percentage of seed damage and weight loss, the survival percentage and food consumed per grub was also less in these varieties.

Bhadauria and Jakhmola (2006) studied the oviposition preference and survival of the pulse beetle (*Callosobruchus maculatus*) and the effect of infestation intensity on the extent of losses and seed germination of different pulses (French bean, pigeon pea, chickpea, green gram, pea, black gram and cowpea) and reported that the loss within the damage seed was minimum in pea (8.8%) and chickpea (11.1%) and maximum in green gram (55.4%). These losses were inversely proportional to seed size, although such correlation was not significant.

Parameshwarappa *et al.* (2007) reported that apparent weight and seed weight losses of grain were maximum in ICCV-03311 with 4.53 and 5.33 per cent, respectively and highest loss of 15.3 and 17.0 per cent in ICCV-10, respectively in chickpea against pulse beetle.

### 2.4.4 Qualitative losses in terms of seed germination

Pingale (1953) reported that the viability of grains was considerably affected by insects. He found in green gram the germination percentage was reduced to nil from 88 per cent due to infestation at the end of six months Storage. In another study Pingale *et al.* (1956) observed in greengram, the uninfested samples showed 88 per cent germination after six months, whereas in infested samples the germination had fallen by 6, 10, 44 and 100 per cent after 1, 2, 3 and 4 months of infestation.

Jotwani *et al.* (1967) observed that the grubs of *C. maculatus* (F) during the first five days of their development did not cause much damage to cowpea, gram and greengram as the percentage of normal seedlings in the control and damaged lots were almost the same. As the development progressed the germination decreased. After 15 days of development the reduction in the germination was 46.2, 35.2 and 16.8 per cent in cowpea, gram and greengram, respectively.

Shehnaz and Theophilus (1975) observed in bengal gram 97, 39 and 18 per cent viability in uninfested, moderately infested and highly infested samples, respectively, whereas in field bean 88, 29 and zero per cent viability in uninfested, moderately infested and highly infested samples, respectively.

Yadav and Pant (1978) tested that germination of seven species of pulses infested with single egg of *C. maculatus* (F). The germination of green gram seeds infested with different developmental stages of *C. maculatus* (F) was reduced to 98, 97, 33 and 0 per cent after 5, 10, 15 and 20 days of oviposition, respectively. In black gram there was no significant reduction in germination upto 20 days of oviposition. However, after 25, 30 and 35 days of oviposition the germination was reduced to 25, 22 and 0 per cent, respectively.

Braich and Simwat (1984) recorded 96.3 to 59.3 per cent germination in mung bean seeds infested with 1, 2, 3 and 4 pairs of *C. chinensis* and *C. maculatus* (F).

Venkate Gowda (1984) claimed that the seed germination declined from 92.5 per cent to zero per cent in seed infested with *C. maculatus* (F) at the end of seven month of storage.

Vimala and Pushpamma (1983a) found, progressive increase in the loss of viability with increase in level of infestation by *C. chinensis*. It was highest in red gram followed by black gram and bengalgram.

Vimala and Pushpamma (1983b) from Andhra Pradesh claimed that bruchid infestation caused the reduction in viability of redgram seeds to the extent of 32.24, 26.03 and 22.02 per cent after 1.2 months of infestation in coastal, Telangana and Rayalaseema regions, respectively.

Singh and Sharma (1984) observed 47.53 to 70.6 and 14.13 to 19.7 per cent germination loss in mung and mash seeds after five months of storage.

Doharey *et al.* (1987) reported that *C. maculatus* (F) caused cent per cent loss in viability in green gram after 90 days of storage. He also observed that the germination per cent gradually decreased with the increase in seed damage and storage period.

In *Phaseolus vulgaris* increasing number of bruchid emergence holes per seed resulted in highly significant reduction in both germination and seedling vigour (Baiker and Webgster, 1992).

Ramesh (1993) reported the germination per cent of soybean infested with *C. maculatus* (F) was 54 in one holed seeds and the viability was nil in two holed seeds compared to healthy seeds with 95 per cent germination.

Lakshminarasimhaiah (1993) studied the reduction in germination percentage of pigeon pea seeds infested by *C. chinensis* and reported that 20, 4 and zero per cent germination in one, two and three holes seeds, respectively when compared to 86 per cent germination in uninfested seeds.

Bhadauria and Jakhmola (2006) studied the oviposition preference and survival of the pulse beetle (*Callosobruchus maculatus*) and the effect of infestation intensity on the extent of losses and seed germination of different pulses (French bean, pigeon pea, chickpea, green gram, pea, black gram and cowpea) and reported that infested seeds of green gram, black gram and pigeon pea having only a single hole per seed failed to germinate, while only 20, 40 and 52% of the infected seeds of pea, chickpea and cowpea were able to germinate. Pulse beetle infestation generally reduced seed germination by 30% in cowpea to 72% in black gram. Germination of seeds having two holes was very much lower than those with only one hole.

Shaheen *et al.* (2006) screened grains of 15 chickpea cultivars against pulse beetle and reported that the minimum grain weight loss of 25.66 per cent was recorded for Dasht compared to the maximum weight loss (39.48%) in CM-200. Chickpea cultivars of Punjab-91, Dasht, Bittle-98 and Parbat were resistant against pulse beetle while Paidar-91 and Flip 97-192C were found susceptible.

Parameshwarappa *et al.* (2007) reported that highest loss in germination, seedling vigour index in ICCV-10 and lowest in ICCV-03311 after the infestation of 60 days by pulse beetle in chickpea varieties.

### 3. MATERIAL AND METHODS

A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2009 for morphological 'identification of cowpea genotypes'. Further, the laboratory studies were also carried out at the Department of Seed Science and Technology Laboratory, Agricultural College, Dharwad to screen out the genotypes for seed protein content and genotypic relative response to bruchid infestation. The details of the materials used and methods adopted are presented here.

#### 3.1 Location of experimental site

The field experiment was conducted at Main Agricultural Research Station Farm, (Plot No.78 of Block E), UAS-Dharwad. Dharwad is situated in the North Transitional Zone (Zone-8) of Karnataka with latitude of 15<sup>0</sup> 26<sup>1</sup> North, a longitude of 75<sup>0</sup> 07<sup>1</sup> East and at an altitude of 678 m above mean sea level.

#### 3.2 Soil conditions

The soil of the experimental site was medium black in nature. The composite soil samples of the experimental site was collected from 0-15 cm depth before the start of the experiment and was analysed for different physical and chemical characteristics by adapting the standard procedure (Jackson, 1967). The results are presented in Appendix I.

#### 3.3 Climatic conditions

Dharwad district comes under agro-climatic zone-8 of the region-2 of Karnataka. It receives rainfall from both southwest and northeast monsoon. Dharwad is considered to be mild tropical rainy region. The outside mean maximum temperature during the period of experimentation ranged from 26.00 to 28.5<sup>0</sup>C, whereas the mean minimum temperature ranged from 20.7 to 20.9<sup>0</sup>C. The mean relative humidity ranged from 83 to 88 per cent. The highest rainfall during the period of experimentation was in September (229 mm). The meteorological data for the period of experiment from April, 2009 to March, 2010 are presented in Appendix II.

#### 3.4 Previous crop in the experimental site

Soybean crop was grown during *kharif* season of 2008 in the experimental site. The land was kept fallow during rabi.

#### 3.5 Experiment – I : Studies on identification of stable diagnostic characteristics of seed, seedling and plant of cowpea genotypes and assessment of genetic diversity

##### 3.5.1 Treatment details:

Each entry was sown in 5 m length in four rows and replicated thrice. Details of the genotypes have been given Table 1.

##### 3.5.2 Experimental design and layout

The field experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications (Fig.1 and Plate 1).

##### 3.5.3 Cultural operations

###### 3.5.3.1 Land preparation

The land was ploughed by mold board plough followed by two harrowing to bring the soil to fine tilth so as to facilitate sowing. The residing by the previous crop and weeds were removed from the experimental area and land was leveled.

### 3.5.3.2 Fertilizer application

The recommended dose of 12.5:25:12.5 kg NPK per ha was supplied in the form of Urea, DAP and Muriate of potash. Fifty per cent of nitrogen (6.25 kg) and entire quantity, phosphorous and potash were applied along with sowing, remaining fifty per cent of nitrogen was applied 30 days after sowing as top dressing.

### 3.5.3.3 Seed source and sowing

The seeds of 35 cowpea genotypes were obtained from the Department of Genetics and Plant Breeding, College of Agriculture, Dharwad.

Sowing was done with spacing of 60 cm between rows and 30 cm between the plants. Before sowing the seeds were treated with thiram @ 2 g per kg of seed to control seed borne disease. Thinning was done 15 days after sowing to retain one plant per hill.

### 3.5.3.4 After care

The necessary after care operations such as hand weeding and intercultivation were attended as and when required. Necessary plant protection measures were taken to a control pest and disease.

## 3.5.4 Collection of experimental data

### 3.5.4.1 Sampling procedure

Five plants were randomly selected in each genotype and replication and labeled. Observations on plant morphological characterization were recorded on these plants at different stages of crop growth.

### 3.5.4.2 Observations recorded

#### 3.5.4.2.1 At seed level

##### 1. Seed coat colour

The seed coat colour of each genotype was observed under natural day light condition using Munsell colour chart (Anon., 1954) and genotypes were grouped as white, creamish white, creamish brown, light brown, brown, dark brown, mottled and grey seed coloured types.

##### 2. Hilum colour

Genotypes were recorded as black and brown hilum colour types.

##### 3. Seed shape

Seed shape recorded on matured seed and genotypes were grouped as kidney, ovoid, crowdege, globose and rhomboid seed shaped types.

##### 4. Seed coat lusture

Seed coat lusture has recorded shiny and dull types.

##### 5. Hundred Seed weight (g)

Hundred seed each in three replications were counted and weighed separately and the mean weight was expressed in grams. Based on these, the genotypes were grouped in light, medium and heavy seeds.

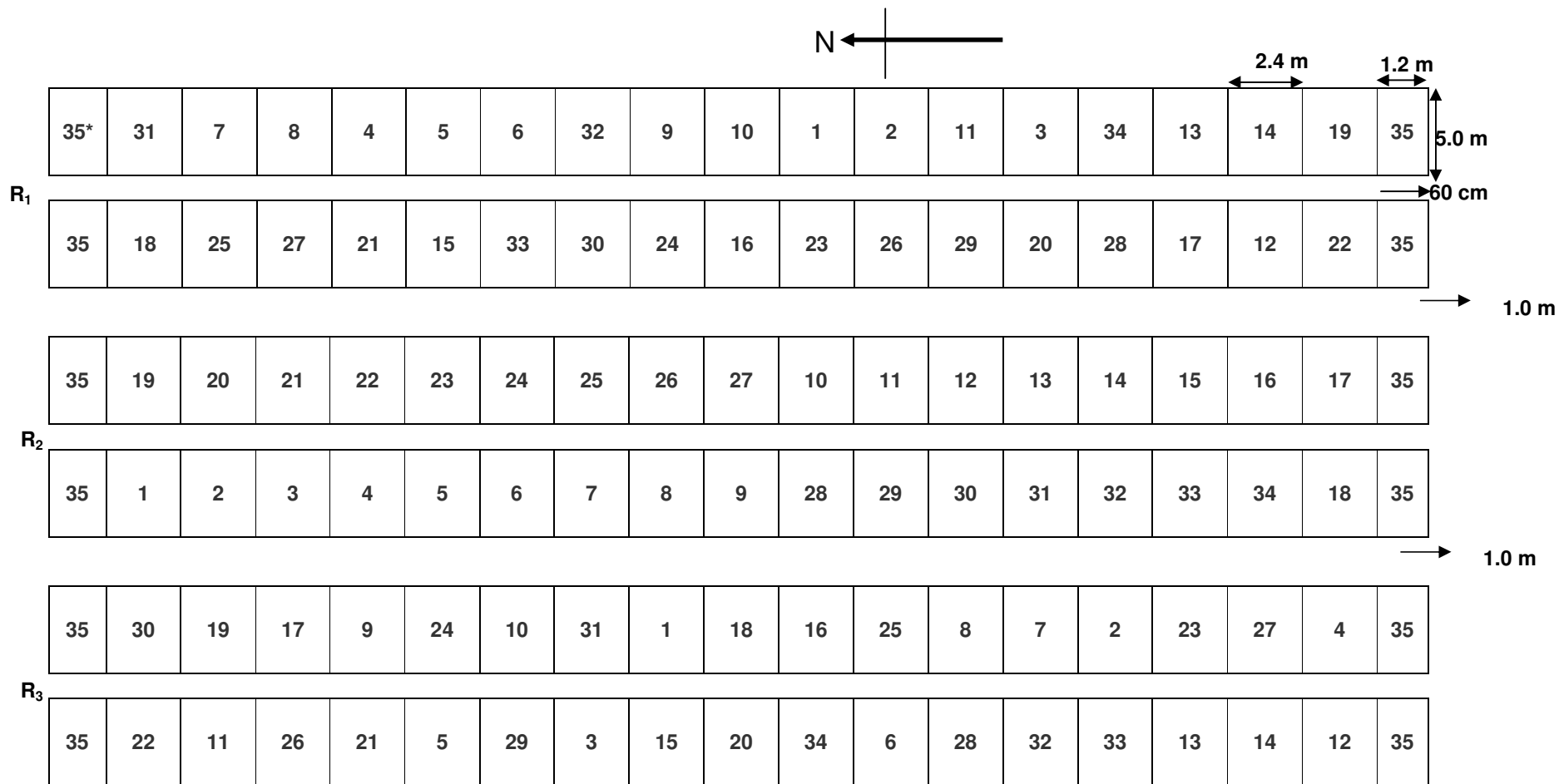
##### 6. Seed size (mm)

The seed size was calculated by cubic root of seed length (mm), width (mm) and thickness (mm). Seed length, width and thickness are measured with the help of Digital Calipers and grouped as big, medium and small sized seed types.

$$\text{Seed size (mm)} = (\text{length} \times \text{width} \times \text{thickness})^{1/3}$$

#### 3.5.4.2.2 At seedling level

Pigmentation on hypocotyl: was recorded at seedling level as present or absent.



\* In both the sides of each block two rows of C-152 check variety was grown

Fig. 1. Plan of layout of the experimental plot

Table 1. List of the genotypes used in the study

Sl. No.	Name of genotypes	Sl. No.	Name of genotypes
1	IC257413	19	IC212871
2	IC97787	20	IC212872
3	IC198323	21	IC249583
4	IC198326	22	IC253181
5	IC198333	23	IC253268
6	IC198335	24	IC253270
7	IC198349	25	IC253273
8	IC198361	26	IC253275
9	IC198701	27	IC257407
10	IC201087	28	IC259159-1
11	IC202789	29	IC259159-2
12	IC202806	30	IC202784
13	IC202867	31	IC4506
14	IC202868	32	IC5969
15	IC202881	33	Mumbai local
16	IC214757	34	Bailhongal local
17	IC219574	35	C-152
18	IC219599		



**Plate 1: General view of the experimental plot**

Plate.1. General view of the experimental plot

#### 3.5.4.2.3 At plant level

##### 1. Pigmentation on stem

The stem pigmentation was recorded on visual assessment at peak flowering stage and the genotypes were grouped into present and absent types.

##### 2. Plant growth pattern

Plant growth pattern was recorded at 50 per cent flowering stage and genotypes were grouped into determinate, semi determinate and indeterminate types.

##### 3. Days to 50 per cent flowering

The number of days taken from sowing to the opening of flowering in 50 per cent of plant population in each genotype was recorded and the genotypes were grouped as early and late flowering types.

##### 4. Flower colour

The colour of the flower was recorded at the time of flowering in the morning 7 am to 9 am and genotypes were grouped white, yellowish white, pale purple, purple and dark purple types.

##### 5. Plant growth habit

Plant growth habit recorded at completion of vegetative growth (at the end of sixth week after sowing) and genotypes were grouped erect (stem grows almost vertically upward ( $0-30^{\circ}$ )), semi erect or semi spreading (between erect and spreading) and spreading ( $>60^{\circ}$  leaning) types.

##### 6. Pubescence on stem

Pubescence on stem was recorded at 50 per cent flowering stage and grouped into present or absent types.

## 7. Leaf colour

The leaf colour of the sixth leaf from the top of the plant was recorded on visual assessment basis at peak flowering stage and the genotypes were grouped as pale green, intermediate green and dark green coloured types.

## 8. Immature pod pigmentation

Pattern of pigment distribution on full grown immature pods and genotypes were grouped. None, pigmented tip, pigmented sutures, pigmented valves with green sutures, splashes of pigment and uniformly pigmented types.

## 9. Pod or raceme position

Pod or raceme position was recorded when peduncles have reached full length and genotypes were grouped mostly above canopy, in upper canopy and throughout canopy types.

## 10. Pod attachment to peduncle

Pod attachment to peduncle recorded when pods are full grown and genotypes were grouped pendent, 30<sup>0</sup>-90<sup>0</sup> down from erect and erect pod attachment types.

## 11. Plant height

The plant height was measured in centimeter (cm) from the ground level to tip of the main stem of the plant at time of harvesting and genotypes were grouped in dwarf, medium and tall types.

## 12. Number of primary branches per plant

The number of branches arising directly from the main stem was counted and recorded in number. Based on number of primary branches, the genotypes were grouped on few and high branched types.

## 13. Number of clusters per plant

The total number of pod bearing cluster per plant were counted at the time of harvest.

## 14. Number of pods per peduncle

The number of pods per peduncle was counted and recorded in numbers at maturity and the genotypes were grouped as double and more than two types.

## 15. Number of pods per plant

Total numbers of pods per plant were counted at the time of harvest and genotypes were grouped on less, moderate and more podded types.

## 16. Mature pod constriction

Recorded as least, medium and high at mature pod stage.

## 17. Days to maturity

The number of days taken for each genotype from sowing to physiological maturity was recorded and genotypes were grouped as early, medium and late maturity types.

## 18. Pod length (cm)

Pod length in centimeters (cm) was measured from the randomly selected five longest pods from each genotype at the time of harvest.

## 19. Number of seeds per pod

Number of seeds per pod was taken as mean number of seeds of five pods measured for length.

## 20. Pod colour at maturity

Mature pod colour recorded at complete maturity and genotypes were grouped straw, purple, brown and black coloured pods types.

## 21. Seed yield per plant (g)

Seed weight in gram from five randomly selected plants was recorded at the time of harvest and genotypes were grouped into high, medium and low yielder.

## 22. Seed yield per hectare (Kg/ha)

The seed yield obtained from the net plot area of each genotype was added with the yield obtained for five earlier tagged and harvested plants. The seeds were cleaned after threshing of pods manually with wooden mallet and dried in shade for five days up to 12 per cent moisture content level. The seed yield per hectare was computed and expressed in kg per ha

## 23. Market value

Recorded as grain type, vegetable type and fodder type.

## 3.6 Experiment – II : Evaluation of cowpea genotypes for protein content

### 3.6.1 Protein content

The nitrogen content of seed was estimated by Microkjeldhal Method and protein content was computed as suggested by Association of Official Analytical Chemistry (Anon., 1980).

Fifty mg of ground sample was weighed into a Kjeldhal flask 2 ml of concentrated sulfuric acid ( $H_2SO_4$ ) and one spatula of digestion mixture (0.7 g of red mercuric oxide and 15 g of potassium sulphate) were added to the flask. The sample was digested till the contents of the flask were clear and free from yellowish tinge. The digested material was transferred to the Kjeldhal distillation apparatus and 15 ml of sodium hydroxide (40 per cent NaOH) was added. The ammonia liberated was absorbed in the 10 ml solution of 4 per cent boric acid containing mixed indicator. The distillate collected was titrated against 0.2 N  $H_2SO_4$ . A blank was run simultaneously. The results were expressed as percentage of total protein and calculated by multiply the nitrogen percentage with the factor.

$$\text{Per cent crude protein} = \frac{\text{ml of } H_2SO_4 \text{ used for titration} \times 0.2 \times 14.007 \times 6.25}{\text{Weight of the sample}} \times 100$$

Where,

0.2 is normality of  $H_2SO_4$

14.007 is factor

6.25 is factor to compute per cent protein from per cent nitrogen

## 3.7 Experiment – III: Screening of cowpea genotypes for their relative response to bruchid infestation and seed quality.

Freshly harvested seeds from each 35 genotypes of cowpea including check variety C-152 were screened for their relative susceptibility or resistance to bruchid (*Callosobruchus maculatus*) attack by artificial inoculation in the laboratory.

### 3.7.1 Main rearing of test insects

Initial culture of *Callosobruchus maculatus* was obtained from the infected grains of cowpea from the farm stores. They were reared and maintained on cowpea by releasing ten pairs of freshly emerged larvae in stem jars and mouth of the jar was covered with muslin cloth fastened by rubber band.

### 3.7.2 Method

1. The unaffected sound seeds of each genotype were dried in hot air oven for required length to achieve permissible moisture content (12 %).
2. Seeds of each variety weighing 250g were kept in a bottle of 500 ml capacity.
3. Ten pairs of five days old weevils were introduced in each bottle and tops were kept covered with muslin cloth and tightly secured by rubber bands (Plate 2).
4. These were kept under normal room temperature and humidity for a period of 90 days.
5. Three replication of all the given genotypes were maintained.
6. After the specified period each bottle was examined for loss of weight and per cent damaged seeds.
7. Before recording the damaged one, the seeds were thoroughly mixed and sample of 50g seeds were drawn from each bottle and replication.
8. Damaged seeds in sampled 50g seeds were counted and per cent damage was computed.

### 3.7.3 Initial observations recorded

#### 3.7.3.1 Seed moisture content (%)

The moisture content of seeds was determined by the oven dry ( $103 \pm 1^{\circ}\text{C}$  for 17 hours) method as per ISTA rules (Anon., 1999). The moisture content on wet basis was determined and expressed in percentage using the following formula.

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where

$M_1$  – Weight of the empty metal box (g)

$M_2$  – Weight of metal box with seed sample before drying (g)

$M_3$  – Weight of metal box with seed sample after drying (g)

#### 3.7.3.2 Electrical conductivity (EC)

For electrical conductivity (EC), 5 g of seeds from each genotype seed were taken in a beaker and soaked in 25 ml distilled water. Beakers were kept in an incubator at  $25 \pm 1^{\circ}\text{C}$  for 24 hours and seed leachate was collected. The electrical conductivity of the seed leachate was measured in Digital Conductivity Meter Model (sensitivity conductivity cell – CGS 811) and it was expressed in dS/m at  $25 \pm 1^{\circ}\text{C}$ .

#### 3.7.3.3 Germination percentage

Four hundred seeds were taken from each genotype and subjected for standard germination test in four replications of 100 seeds each. Seeds were placed at equidistance between two layers of moist germination paper and then germination papers were rolled into towels and kept in the germinator at  $30^{\circ} \pm 1^{\circ}\text{C}$  (Anon., 1999). Number of normal seedlings on seventh day was counted and germination was expressed as percentage.

$$\text{Per cent germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds put for germination}} \times 100$$



Plate.2. Experimental setup for testing relative response of bruchids in cowpea genotypes

### 3.7.3.4 Seedling length (cm)

From the germination test, ten normal seedlings from each of the replications from the germination test were carefully removed on 8<sup>th</sup> day and used for measuring seedling length. The seedling length from tip of shoot to tip of root was measured and the average length of the seedling was expressed in centimeters.

### 3.7.3.5 Vigour index

Vigour index was calculated by following formula as per Abdul-Baki and Anderson (1973).

Vigour index = per cent germination x mean seedling length in cm

### 3.7.4 Final observation recorded

Germination percentage, moisture content (%), seedling length (cm), vigour index, electrical conductivity (dS/m), from each genotypes and replication was recorded as explained in 3.7.3.1 to 3.7.3.5.

#### 3.7.4.1 Determination of seed loss due to bruchid infestation

To estimate actual and apparent loss in weight of cowpea seeds caused by bruchids, samples of 50 g seeds were drawn from each treatment in each replication after specified period (90 days) and below observations were recorded.

- 1) Number of damaged seeds (Nd) seeds showing emergent holes
- 2) Number of undamaged seeds (Nu).
- 3) Weight of damaged seeds (D)
- 4) Weight of undamaged seeds
- 5) Total number of seeds in 50 g (Nd+Nu)
- 6) Weight of seeds in each replications.

The per cent actual loss was calculated by using the following formula (Adams and Schulten, 1978).

$$\text{Per cent actual weight loss} = \frac{U(Nd) - D (Nu)}{U (Nu+Nd)} \times 100$$

The per cent loss in weight was worked out using the following formula (Girish *et al.*, 1975).

$$\text{Per cent apparent weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

In general,

$$\text{Per cent apparent loss} = \frac{W_i - W_n}{W_i} \times 100$$

Where,  $W_i$  = Initial weight of seeds at the beginning experiment

$W_n$  = Weight of seeds after 'n' months (3 month)

$$\text{Per cent infestation} = \frac{\text{No. of seeds with emergent holes}}{\text{Total number of seeds observed}} \times 100$$

Based on statistical analysis 35 cowpea genotypes were classified high, moderate and less susceptible groups against the bruchid attack during storage.

### 3.8 Statistical analysis

The data were processed with the help of various standard statistical procedures as mentioned below:

#### 3.8.1 Field experiment

The mean values of the genotypes in each replication were used for analysis of variance. Results and values were subjected to randomized complete block design as per the method outlined by Sundarraj *et al.* (1972). Critical differences were calculated at five per cent level.

#### 3.8.2 Laboratory experiments

The data obtained in laboratory experiments were suitably transferred into angular or square root transformation values as the case may be and subjected to completely randomized design analysis for the test of significance and calculation of critical differences as per Sundarraj *et al.* (1972).

#### 3.8.3 Genetic diversity

##### 3.8.3.1 Mahalanobis $D^2$ analysis

Mahalanobis (1936)  $D^2$  statistic was used for assessing the genetic divergence between populations. The generalized distance between any two populations is given by formula.

$$D^2 = \sum \sum \lambda_{ij} \sigma_{ai} \sigma_{aj}$$

Where,

- $D^2$  = Square of generalized distance
- $\lambda_{ij}$  = Reciprocal of the common dispersal matrix
- $\sigma_{ai}$  =  $(\mu_{i1} - \mu_{i2})$
- $\sigma_{aj}$  =  $(\mu_{j1} - \mu_{j2})$
- $\mu$  = General mean

Since, the formula for computation requires inversion of higher order determinant, transformation of the original correlated un-standardized character mean (Xs) to standardized uncorrelated variable (Ys) was done to simplify the computation procedure. The  $D^2$  values were obtained as the corresponding uncorrelated (Ys) values of any two uncorrelated genotype (Rao, 1952).

##### 3.8.3.2 Clustering of $D^2$ values

All the  $(n-1)/2$   $D^2$  values were clustered using Tocher's method as described by Rao (1952).

###### 3.8.3.2.1 Intra cluster distance

The intra cluster distances were calculated by formula given by Singh and Chaudhary (1977).

$$\text{Square of the intra cluster distance} = \frac{\sum D_1^2}{N}$$

Where,

$\sum D_1^2$  is the sum of distances between all possible combinations of the entries included in a cluster.

N = Number of possible combinations

###### 3.8.3.2.2 Inter cluster distance

The inter cluster distances were calculated by the formulae described by Singh and Chaudhary (1977).

$$\text{Square of the inter cluster distance} = \frac{\sum D_i^2}{n_i n_j}$$

Where,

$\sum D_i^2$  is the sum of distance between all possible combinations  $(n_i n_j)$  of the entries included in the cluster study.

$N_i$  = Number of entries in cluster i

$N_j$  = Number of entries in cluster j

## 4. EXPERIMENTAL RESULTS

The laboratory and field experiments were conducted to characterize the cowpea genotypes based on seed, seedling and plant morphological characteristics, evaluation of cowpea genotypes for protein content and screening them against bruchid are presented in this chapter.

### 4.1 Experiment - I : Studies on identification of stable diagnostic characteristics of seed, seedling and plant of cowpea genotypes and assessment of genetic diversity

#### 4.1.1 Seed characteristics

Seed qualitative characters like seed coat colour, lusture, shape, hilum colour and quantitative characters like 100 seed weight and seed size were studied based on these characters, the genotypes were grouped into different categories. The details of the characters and the results have been shown in different Plates and Tables.

##### 4.1.1.1 Seed coat colour

The seed coat colour varied among the cowpea genotypes (Table 2 and Plate 3). Based on the seed coat colour, the genotypes were grouped into white, creamish white, creamish brown, light brown, brown, dark brown, mottled and grey seed coloured types.

Genotypes with white colour included were IC201087, IC253273 and Mumbai local, creamish white seed coat colour genotypes were IC198323, IC202806, IC219599, IC219871 and IC249583, genotypes with creamish brown were IC97787 and IC202868, light brown were IC198333, IC198361, IC259159-2 and Bailhongal local, brown were IC257413, IC198701, IC202789, IC202867, IC253181, IC253268, IC259159-1, IC202784, IC4506 and C-152, dark brown seed coat colour genotypes were IC198349, IC219872, IC253270, IC253275 and IC257407. Whereas, genotypes IC198326 had mottled and IC198335, IC202881, IC219574, IC5969 had grey colour seed coat.

##### 4.1.1.2 Hilum colour

Based on hilum colour, the genotypes were separated into brown and black coloured hilum types and are presented in Table 2 and Plate 4.

The brown colour hilum genotypes were IC257413, IC198323, IC198326, IC198333, IC198349, IC198361, IC198701, IC202806, IC202867, IC202868, IC214757, IC219599, IC219872, IC249583, IC253181, IC253268, IC253270, IC253275, IC259159-1, IC259159-2, IC202784, IC4506, Bailhongal local and C-152 and IC97787, IC198335, IC201087, IC202789, IC202881, IC219574, IC219871, IC253273, IC257407, IC5969 and Mumbai local were black in colour.

##### 4.1.1.3 Seed shape

Cowpea genotypes varied for seed shape (Table 2 and Plate 4). Based on seed shape cowpea genotypes were grouped into five categories as kidney, ovoid, crowdege, globose and rhomboid seed shape.

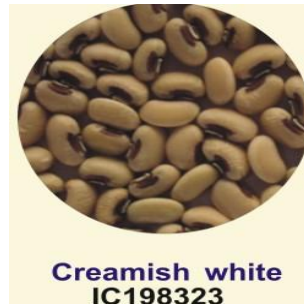
Among the 35 genotypes, 26 genotypes had rhomboid seed shape viz., IC257413, IC198323, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202867, IC202881, IC214757, IC219574, IC253181, IC253268, IC253270, IC253273, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969, Bailhongal local and C-152, six genotypes had kidney shaped (IC97787, IC198326, IC202868, IC212872, IC249583 and IC253278), three genotypes had avoid shape (IC219599, IC212871 and Mumbai local) and none of the genotypes had crowdege and globose seed shape.

Table 2. Grouping of cowpea genotypes based on seed morphological characters

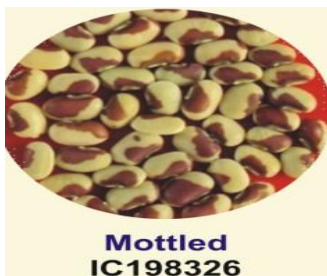
Sl. No.	Genotypes	Seed coat colour	Hilum colour	Seed shape	Seed coat lusture
1	IC257413	Brown	Brown	Rhomboid	Intermediate
2	IC97787	Creamish brown	Black	Kidney	Intermediate
3	IC198323	Creamish white	Brown	Rhomboid	Dull
4	IC198326	Mottled	Brown	Kidney	Dull
5	IC198333	Light brown	Brown	Rhomboid	Dull
6	IC198335	Grey	Black	Rhomboid	Dull
7	IC198349	Dark Brown	Brown	Rhomboid	Intermediate
8	IC198361	Light brown	Brown	Rhomboid	Dull
9	IC198701	Brown	Brown	Rhomboid	Dull
10	IC201087	White	Black	Rhomboid	Dull
11	IC202789	Brown	Black	Rhomboid	Shiny
12	IC202806	Creamish white	Brown	Rhomboid	Dull
13	IC202867	Brown	Brown	Rhomboid	Dull
14	IC202868	Creamish brown	Brown	Kidney	Shiny
15	IC202881	Grey	Black	Rhomboid	Dull
16	IC214757	Creamish white	Brown	Rhomboid	Dull
17	IC219574	Grey	Black	Rhomboid	Shiny
18	IC219599	Creamish white	Brown	Ovoid	Dull
19	IC212871	Creamish white	Black	Ovoid	Shiny
20	IC212872	Dark brown	Brown	Kidney	Shiny
21	IC249583	Creamish white	Brown	Kidney	Dull
22	IC253181	Brown	Brown	Rhomboid	Shiny
23	IC253268	Brown	Brown	Rhomboid	Shiny
24	IC253270	Dark brown	Brown	Rhomboid	Shiny
25	IC253273	White	Black	Rhomboid	Dull
26	IC253275	Dark brown	Brown	Kidney	Dull
27	IC257407	Dark brown	Black	Rhomboid	Shiny
28	IC259159-1	Brown	Brown	Rhomboid	Shiny
29	IC259159-2	Light Brown	Brown	Rhomboid	Dull
30	IC202784	Brown	Brown	Rhomboid	Shiny
31	IC4506	Brown	Brown	Rhomboid	Shiny
32	IC5969	Grey	Black	Rhomboid	Shiny
33	Mumbai local	White	Black	Ovoid	Dull
34	Bailhongal local	Light brown	Brown	Rhomboid	Shiny
35	C-152	Brown	Brown	Rhomboid	Intermediate



**White**  
IC201087



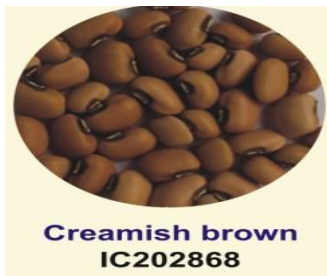
**Creamish white**  
IC198323



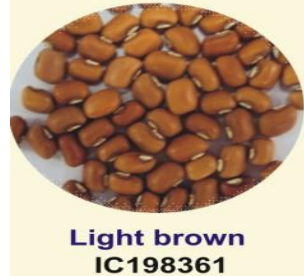
**Mottled**  
IC198326



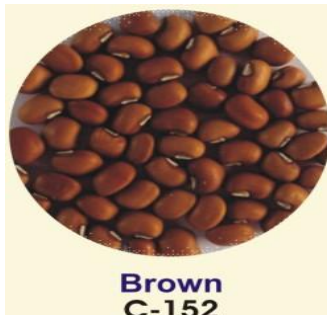
**Grey**  
IC5969



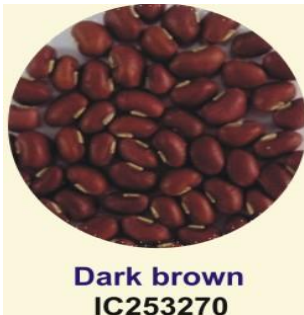
**Creamish brown**  
IC202868



**Light brown**  
IC198361



**Brown**  
C-152



**Dark brown**  
IC253270

Plate.3. Seed coat colour of different cowpea genotypes

#### 4.1.1.4 Seed coat lusture

Based on the seed coat lusture, cowpea genotypes were grouped into shiny, intermediate and dull in seed coat lusture and presented in Table 2.

Shiny seed coat genotypes were IC202789, IC202868, IC219574, IC212871, IC212872, IC253181, IC253268, IC253270, IC257407, IC259159-1, IC202784, IC4506, IC5969 and Bailhongal local. Intermediate genotypes were IC257413, IC97787, IC198349 and C-152. Dull seed coat lusture genotypes were IC198323, IC198326, IC198333, IC198335, IC198361, IC198701, IC201087, IC202806, IC202867, IC202881, IC214757, IC219599, IC249583, IC253273, IC253275, IC259159-2 and Mumbai local.

#### 4.1.1.5 Hundred seed weight (g)

The hundred seed weight varied significantly among different cowpea genotypes (Table 3). The mean hundred seed weight of the genotypes was 12.94 g. Significantly highest hundred seed weight was observed in genotype IC212872 (20.72 g) and lowest was observed in the genotype IC4506 (7.49 g). Based on hundred seed weight, the genotypes were grouped into three categories as light (<12 g), medium (12-15 g) and heavy (> 15 g) weight seeds.

Among the 35 genotypes, 12 genotypes were grouped into light *viz.* IC97787, IC198326, IC198333, IC198335, IC202789, IC214757, IC253181, IC259159-1, IC4506, IC5969, Bailhongal local and C-152, 17 genotypes were grouped into medium *viz.* IC257413, IC198323, IC198349, IC198361, IC198701, IC201087, IC202806, IC202867, IC22868, IC202881, IC219574, IC219599, IC212871, IC249583, IC253270, IC257407 and IC259159-2 and six genotypes were grouped into heavy *viz.* IC212872, IC253268, IC253273, IC253275, IC202784 and Mumbai local for hundred seed weight.

#### 4.1.1.6 Seed size (mm)

The seed size varied significantly among different cowpea genotypes (Table 3 and Plate 4). The mean seed size was 5.69 mm. Significantly the highest seed size was recorded in IC212872 (7.13 mm) and IC4506 (4.47 mm) was recorded the lowest seed size. Based on the seed size, the genotypes were grouped into three categories as small (< 5mm), medium (5-6 mm) and bold (> 6 mm) sized.

Among 35 genotypes, three were small (IC198326, IC19833 and IC4506), 25 were medium (IC257413, IC97787, IC198323, IC198333, IC198361, IC198701, IC201087, IC202789, IC202806, IC202867, IC202881, IC214757, IC219574, IC219599, IC219871, IC249583, IC253181, IC253270, IC257407, IC259159-1, IC259159-2, IC202784, Bailhongal local, C-152) and seven were bold (IC198349, IC202868, IC219872, IC253268, IC253273, IC253275 and Mumbai local) in seed size.

### 4.1.2 Seedling characters

#### 4.1.2.1 Pigmentation on hypocotyl

The pigmentation on hypocotyls was found absent in all cowpea genotypes under the study (Table 3).

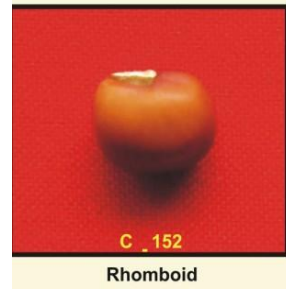
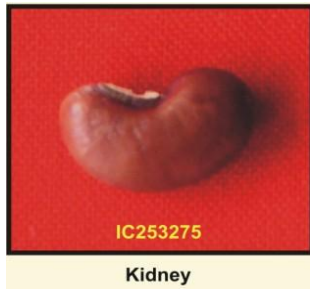
### 4.1.3 Plant morphological characters

#### 4.1.3.1 Pigmentation on stem

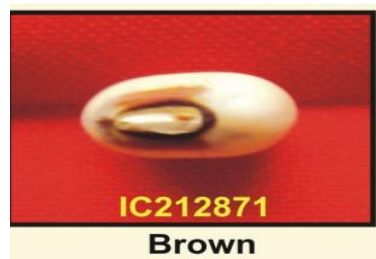
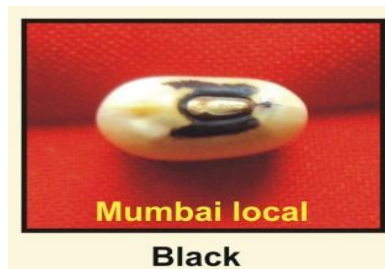
Based on pigmentation on stem, genotypes were grouped into present and absent and were presented in Table 4 and Plate 5.

IC97787 was the only one genotype recorded the presence of pigmentation and remaining 34 were grouped under absent *viz.*, IC257413, IC198323, IC198326, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202867, IC202868, IC202881, IC214757, IC219574, IC219599, IC219871, IC219872, IC249583, IC253181, IC253268, IC253270, IC253273, IC253275, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969, Mumbai local, Bailhongal local and C-152.

Seed Shape



Hilum colour



Seed Size



Plate.4. Seed shape, hilum colour and seed size of cowpea genotypes

Table 3. Grouping of cowpea genotypes based on 100 seed weight, seed size and pigmentation on hypocotyl

Sl. No.	Genotypes	100 seed weigh (g)	Groups	Seed size (mm)	Groups	Pigmentation on hypocotyl
1	IC257413	12.09	Medium	5.59	Medium	Absent
2	IC97787	11.37	Light	5.43	Medium	Absent
3	IC198323	12.18	Medium	5.70	Medium	Absent
4	IC198326	11.40	Light	4.99	Small	Absent
5	IC198333	11.56	Light	5.43	Medium	Absent
6	IC198335	9.66	Light	4.78	Small	Absent
7	IC198349	12.53	Medium	6.17	Bold	Absent
8	IC198361	12.96	Medium	5.97	Medium	Absent
9	IC198701	13.36	Medium	5.99	Medium	Absent
10	IC201087	13.60	Medium	5.60	Medium	Absent
11	IC202789	11.29	Light	5.69	Medium	Absent
12	IC202806	12.02	Medium	5.23	Medium	Absent
13	IC202867	12.04	Medium	5.53	Medium	Absent
14	IC202868	14.62	Medium	6.47	Bold	Absent
15	IC202881	12.57	Medium	5.70	Medium	Absent
16	IC214757	11.39	Light	5.29	Medium	Absent
17	IC219574	12.43	Medium	5.62	Medium	Absent
18	IC219599	12.09	Medium	5.73	Medium	Absent
19	IC212871	12.67	Medium	5.76	Medium	Absent
20	IC212872	20.72	Heavy	7.13	Bold	Absent
21	IC249583	13.10	Medium	5.80	Medium	Absent
22	IC253181	11.42	Light	5.42	Medium	Absent
23	IC253268	16.67	Heavy	6.53	Bold	Absent
24	IC253270	13.32	Medium	5.94	Medium	Absent
25	IC253273	16.75	Heavy	6.05	Bold	Absent
26	IC253275	18.09	Heavy	6.64	Bold	Absent
27	IC257407	12.12	Medium	5.36	Medium	Absent
28	IC259159-1	9.75	Light	5.06	Medium	Absent
29	IC259159-2	14.45	Medium	5.85	Medium	Absent
30	IC202784	15.75	Heavy	5.90	Medium	Absent
31	IC4506	7.49	Light	4.47	Small	Absent
32	IC5969	11.56	Light	5.44	Medium	Absent
33	Mumbai local	16.67	Heavy	6.26	Bold	Absent
34	Bailhongal local	11.82	Light	5.43	Medium	Absent
35	C-152	11.54	Light	5.13	Medium	Absent
	Mean	12.94		5.69		
	S.Em ±	0.28		0.05		
	CD (0.05)	0.81		0.15		

Note:

100 Seed weight (g)

Light : ≤ 12 g  
 Medium : 12 – 15 g  
 Heavy : > 15 g

Seed size (mm)

Small : ≤ 5 mm  
 Medium : 5 – 6 mm  
 Bold : > 6 mm

#### 4.1.3.2 Plant growth pattern

Based on plant growth pattern, the genotypes were grouped into determinate, semi determinate and indeterminate (Table 4).

Genotypes IC257413, IC97787, IC202868, IC214757, Mumbai local and Bailhongal local were determinate, IC202789 and IC259159-2 were semi determinate and indeterminate genotypes were IC198323, IC198326, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202867, IC202881, IC219574, IC219599, IC219871, IC219872, IC249583, IC253181, IC253268, IC253270, IC253273, IC253275, IC257407, IC259159-1, IC202784, IC4506, IC5969 and C-152.

#### 4.1.3.3 Days to 50 per cent flowering

Days to 50 per cent flowering varied significantly among the genotypes (Table 5). The average number of days taken by the genotypes for 50 per cent flowering was 45.33. The genotypes were grouped into three categories as early (< 48 days), medium (48-52 days) and late (>52 days).

Among the 35 genotypes, 10 genotypes were early (IC198326, IC202806, IC219574, IC219871, IC219872, IC253270, IC253273, IC259159-1, IC259159-2 and Mumbai local); whereas 21 genotypes were medium (IC198323, IC198323, IC198333, IC198335, IC198701, IC201087, IC202789, IC202867, IC202868, IC202881, IC214757, IC219599, IC249583, IC253181, IC253268, IC253275, IC257407, IC202784, IC4506, IC5969 and Bailhongal local) and four genotypes were late (IC257413, IC198349, IC198361 and C-152) in 50 per cent flowering.

#### 4.1.3.4 Flower colour

Based on flower colour at flowering, the genotypes were classified into five categories as white, yellowish white, pale purple, purple and dark purple colour types (Table 5 and Plate 5).

Among the 35 genotypes, two had white (G2 and Mumbai local), six genotypes had yellowish white (IC198323, IC201087, IC202806, IC214757, IC219871 and IC253273), 10 genotypes were pale purple (IC97787, IC198326, IC198333, IC198349, IC198361, IC219599, IC253275, IC259159-1, IC259159-2 and IC4506). Whereas, 14 genotypes had purple (IC257413, IC198335, IC198701, IC202789, IC202867, IC202868, IC202881, IC219872, IC253181, IC253270, IC202784, IC5969, Bailhongal local and C-152) and three had dark purple (IC219574, IC253268 and IC257407) in flower colour types.

#### 4.1.3.5 Plant growth habit

Based on growth habit, the genotypes were classified into erect, semi spreading and spreading (Table 4).

Among 35 genotypes, six genotypes were erect (IC257413, IC97787, IC202868, IC214757, Mumbai local and Bailhongal local), 17 genotypes were semi spreading (IC198326, IC198335, IC201087, IC202806, IC202867, IC202881, IC219871, IC219872, IC253181, IC253273, IC253275, IC257407, IC259159-1, IC202784, IC4506, IC5969 and C-152) and 12 genotypes were spreading (IC198323, IC198333, IC198349, IC198361, IC198701, IC219574, IC219599, IC249583, IC253268, IC253270 and IC259159-2) in plant growth habit.

#### 4.1.3.6 Pubescence on stem

The pubescence on stem did not vary among cowpea genotypes under study. Pubescence on stem was found absent in all genotypes (Table 7).

#### 4.1.3.7 Leaf colour

The leaf colour varied among different cowpea genotypes (Table 6 and Plate 6). Based on leaf colour, the genotypes were grouped into three categories as pale green, intermediate and dark green types.

Among the 35 genotypes, nine genotypes had pale green leaves (IC198335, IC198361, IC198701, IC201087, IC202789, IC219574, IC219872, IC257407, and IC202784), 19 genotypes had intermediate (IC198323, IC198326, IC198333, IC198349, IC202806,

Table 4. Grouping of cowpea genotypes based on pigmentation on stem, plant growth pattern and plant growth habit

Sl. No.	Genotypes	Pigmentation on stem	Plant growth pattern	Plant growth habit
1	IC257413	Absent	Determinate	Erect
2	IC97787	Present	Determinate	Erect
3	IC198323	Absent	Indeterminate	Spreading
4	IC198326	Absent	Indeterminate	Semi spreading
5	IC198333	Absent	Indeterminate	Spreading
6	IC198335	Absent	Indeterminate	Semi spreading
7	IC198349	Absent	Indeterminate	Spreading
8	IC198361	Absent	Indeterminate	Spreading
9	IC198701	Absent	Indeterminate	Spreading
10	IC201087	Absent	Indeterminate	Semi spreading
11	IC202789	Absent	Semi determinate	Spreading
12	IC202806	Absent	Indeterminate	Semi spreading
13	IC202867	Absent	Indeterminate	Semi spreading
14	IC202868	Absent	Determinate	Erect
15	IC202881	Absent	Indeterminate	Semi spreading
16	IC214757	Absent	Determinate	Erect
17	IC219574	Absent	Indeterminate	Spreading
18	IC219599	Absent	Indeterminate	Spreading
19	IC212871	Absent	Indeterminate	Semi spreading
20	IC212872	Absent	Indeterminate	Semi spreading
21	IC249583	Absent	Indeterminate	Spreading
22	IC253181	Absent	Indeterminate	Semi spreading
23	IC253268	Absent	Indeterminate	Spreading
24	IC253270	Absent	Indeterminate	Spreading
25	IC253273	Absent	Indeterminate	Semi spreading
26	IC253275	Absent	Indeterminate	Semi spreading
27	IC257407	Absent	Indeterminate	Semi spreading
28	IC259159-1	Absent	Indeterminate	Semi spreading
29	IC259159-2	Absent	Semi determinate	Spreading
30	IC202784	Absent	Indeterminate	Semi spreading
31	IC4506	Absent	Indeterminate	Semi spreading
32	IC5969	Absent	Indeterminate	Semi spreading
33	Mumbai local	Absent	Determinate	Erect
34	Bailhongal local	Absent	Determinate	Erect
35	C-152	Absent	Indeterminate	Semi spreading

Table 5. Grouping of cowpea genotypes based on 50 per cent flowering and flower colour

Sl. No.	Genotypes	Days to 50 per cent flowering (DAS)	Groups	Flower colour
1	IC257413	53.33	Late	Purple
2	IC97787	51.67	Medium	Pale Purple
3	IC198323	50.33	Medium	Yellowish white
4	IC198326	46.67	Early	Pale Purple
5	IC198333	48.67	Medium	Pale Purple
6	IC198335	49.00	Medium	Purple
7	IC198349	52.67	Late	Pale purple
8	IC198361	52.67	Late	Pale purple
9	IC198701	51.33	Medium	Purple
10	IC201087	49.33	Medium	Yellowish white
11	IC202789	50.33	Medium	Purple
12	IC202806	46.00	Early	Yellowish white
13	IC202867	50.00	Medium	Purple
14	IC202868	49.33	Medium	Purple
15	IC202881	51.00	Medium	Purple
16	IC214757	50.67	Medium	Yellowish white
17	IC219574	46.00	Early	Dark purple
18	IC219599	50.00	Medium	Pale purple
19	IC212871	46.33	Early	Yellowish white
20	IC212872	47.33	Early	Purple
21	IC249583	48.33	Medium	White
22	IC253181	50.33	Medium	Purple
23	IC253268	50.00	Medium	Dark purple
24	IC253270	47.33	Early	Purple
25	IC253273	47.67	Early	Yellowish white
26	IC253275	49.33	Medium	Pale purple
27	IC257407	50.33	Medium	Dark purple
28	IC259159-1	47.67	Early	Pale purple
29	IC259159-2	45.33	Early	Pale purple
30	IC202784	49.67	Medium	Purple
31	IC4506	50.00	Medium	Pale purple
32	IC5969	49.33	Medium	Purple
33	Mumbai local	45.67	Early	White
34	Bailhongal local	49.33	Medium	Purple
35	C-152	55.67	Late	Purple
	Mean	49.39		
	S.Em ±	0.88		
	CD (0.05)	2.48		

Note:

Days to 50 per cent flowering:

Early : ≤ 48 DAS

Medium: 48 – 52 DAS

Late : &gt; 52 DAS

Stem Pigmentation



**Present**  
**IC97787**



**Absent**  
**IC257413**

Flower colour



**White**  
**IC249583**



**Yellowish white**  
**IC212871**



**Pale purple**  
**IC249583**



**Purple**  
**IC198701**



**Dark purple**  
**IC253268**

Plate.5. Stem pigmentation and flower colour of cowpea genotypes

IC202867, IC202868, IC202881, IC214757, IC219599, IC249583, IC253181, IC253268, IC253270, IC253273, IC4506, IC5969, 37 and C-152) and seven genotypes had dark green leaves (IC257413, IC97787, IC219871, IC253275, IC259159-1, IC259159-2 and Bailhongal local).

#### 4.1.3.8 Immature pod pigmentation

The immature pod pigmentation varied among the cowpea genotypes. Based on this character, genotypes were grouped into none, pigmented tip, pigmented sutures, pigmented valves with green sutures, splashes of pigment and uniformly pigmented types (Table 6 and Plate 6).

Among 35 genotypes, 26 genotypes were grouped under none (IC257413, IC198323, IC198333, IC198361, IC198701, IC202806, IC202867, IC202868, IC219599, IC219871, IC253181, IC253268, IC253270, IC253275, IC202784 and C-152 were found green coloured pods and genotypes IC198335, IC198349, IC202881, IC214757, IC219872, IC249583, IC257407, IC259159-1, IC259159-2 and Bailhongal local was found pale green coloured pods), seven genotypes had pigmented tip (IC201087, IC4506, Mumbai local were green colour and IC202789, IC219574, IC253273, IC5969 were pale green colour pods other than tip), the genotype IC198326 was splashes of pigment, whereas the genotype IC97787 was uniformly pigmented and none of them have found pigmented suture and pigmented valves with green sutures for immature pod pigmentation.

#### 4.1.3.9 Pod or raceme position

Based on raceme position, genotypes were grouped into mostly above canopy, in upper canopy and throughout genotype types (Table 7).

The genotypes IC97787, IC198323, IC198326, IC198335, IC198361, IC198701, IC201087, IC202789, IC202806, IC202868, IC202881, IC214757, IC219574, IC219599, IC219871, IC219872, IC249583, IC253181, IC253268, IC253270, IC253273, IC253275, IC257407, IC259159-1, IC259159-2, IC4506, IC5969, Mumbai local and Bailhongal local were grouped into mostly above canopy, the genotypes IC257413, IC198333, IC198349, IC202867, IC202784 and C-152, were grouped into throughout canopy and none of them recorded raceme position in upper canopy.

#### 4.1.3.10 Pod attachment to peduncle

The genotypes were grouped into pendent, 30<sup>0</sup>-90<sup>0</sup> down from erect and erect pod attachment types based on the pod attachment to peduncle character (Table 7 Plate 7).

Among 35 genotypes, 29 genotypes were grouped in to pendent viz. IC257413, IC97787, IC198323, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202868, IC202881, IC214757, IC219574, IC219599, IC219871, IC219872, IC249583, IC253181, IC253268, IC253275, IC257407, IC202784, IC4506, IC5969, Mumbai local, Bailhongal local and C-152, six genotypes were grouped into 30<sup>0</sup>-90<sup>0</sup> down from erect viz. IC198326, IC202867, IC253270, IC253273, IC259159-1 and IC259159-2 and none of the genotype found erect pod attachment to peduncle.

#### 4.1.3.11 Plant height (cm)

The plant height varied among the different cowpea genotypes (Table 8). The mean plant height of the genotypes was 19.97 cm. Significantly, highest plant height was recorded in C-152 (29.88 cm) and the lowest plant height was recorded in IC198361 (9.93 cm). Based on the plant height, the genotypes were grouped into three categories as dwarf (<15 cm), medium (15-25 cm) and tall (> 25 cm) types.

Among the 35 genotypes, four genotypes were dwarf viz., IC198326, IC198361, IC219574 and IC253268, 29 genotypes were medium viz., IC257413, IC97787, IC198323, IC198333, IC198335, IC198349, IC198701, IC201087, IC202789, IC202806, IC202867, IC202868, IC202881, IC214757, IC219599, IC219871, IC219872, IC249583, IC253181, IC253270, IC253273, IC253275, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969 and Mumbai local and two genotypes were tall viz. Bailhongal local and C-152 in plant height.

Table 6. Grouping of cowpea genotypes based on leaf colour and immature pod pigmentation

Sl. No.	Genotypes	Leaf colour	Immature pod pigmentation
1	IC257413	Dark green	None (Green)
2	IC97787	Dark green	Uniformly pigmented
3	IC198323	Intermediate	None (Green)
4	IC198326	Intermediate	Splashes of pigment
5	IC198333	Intermediate	None (Green)
6	IC198335	Pale green	None (Pale Green)
7	IC198349	Intermediate	None (Pale Green)
8	IC198361	Pale green	None (Green)
9	IC198701	Pale green	None (Green)
10	IC201087	Pale green	Pigmented tip (Green)
11	IC202789	Pale green	Pigmented tip (Pale Green)
12	IC202806	Intermediate	None (Green)
13	IC202867	Intermediate	None (Green)
14	IC202868	Intermediate	None (Green)
15	IC202881	Intermediate	None (Pale Green)
16	IC214757	Intermediate	None (Pale Green)
17	IC219574	Pale green	Pigmented tip (Pale Green)
18	IC219599	Intermediate	None (Green)
19	IC212871	Dark green	None (Green)
20	IC212872	Pale green	None (Pale Green)
21	IC249583	Intermediate	None (Pale Green)
22	IC253181	Intermediate	None (Green)
23	IC253268	Intermediate	None (Green)
24	IC253270	Intermediate	None (Green)
25	IC253273	Intermediate	Pigmented tip (Pale Green)
26	IC253275	Dark green	None (Green)
27	IC257407	Pale green	None (Pale Green)
28	IC259159-1	Dark green	None (Pale Green)
29	IC259159-2	Dark green	None (Pale Green)
30	IC202784	Pale green	None (Green)
31	IC4506	Intermediate	Pigmented tip (Green)
32	IC5969	Intermediate	Pigmented tip (Pale Green)
33	Mumbai local	Intermediate	Pigmented tip (Green)
34	Bailhongal local	Dark green	None (Pale Green)
35	C-152	Intermediate	None (Green)

Table 7. Grouping of cowpea genotypes based on pubescence on stem, raceme position and pod attachment to peduncle

Sl. No.	Genotypes	Pubescence on stem	Raceme position	Pod attachment to peduncle
1	IC257413	Absent	Throughout canopy	Pendent
2	IC97787	Absent	Above canopy	Pendent
3	IC198323	Absent	Above canopy	Pendent
4	IC198326	Absent	Above canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
5	IC198333	Absent	Throughout canopy	Pendent
6	IC198335	Absent	Above canopy	Pendent
7	IC198349	Absent	Throughout canopy	Pendent
8	IC198361	Absent	Above canopy	Pendent
9	IC198701	Absent	Above canopy	Pendent
10	IC201087	Absent	Above canopy	Pendent
11	IC202789	Absent	Above canopy	Pendent
12	IC202806	Absent	Above canopy	Pendent
13	IC202867	Absent	Throughout canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
14	IC202868	Absent	Above canopy	Pendent
15	IC202881	Absent	Above canopy	Pendent
16	IC214757	Absent	Above canopy	Pendent
17	IC219574	Absent	Above canopy	Pendent
18	IC219599	Absent	Above canopy	Pendent
19	IC212871	Absent	Above canopy	Pendent
20	IC212872	Absent	Above canopy	Pendent
21	IC249583	Absent	Above canopy	Pendent
22	IC253181	Absent	Above canopy	Pendent
23	IC253268	Absent	Above canopy	Pendent
24	IC253270	Absent	Above canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
25	IC253273	Absent	Above canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
26	IC253275	Absent	Above canopy	Pendent
27	IC257407	Absent	Above canopy	Pendent
28	IC259159-1	Absent	Above canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
29	IC259159-2	Absent	Above canopy	30 <sup>0</sup> -90 <sup>0</sup> down from erect
30	IC202784	Absent	Throughout canopy	Pendent
31	IC4506	Absent	Above canopy	Pendent
32	IC5969	Absent	Above canopy	Pendent
33	Mumbai local	Absent	Above canopy	Pendent
34	Bailhongal local	Absent	Above canopy	Pendent
35	C-152	Absent	Throughout canopy	Pendent

Leaf colour



None

Plate.6. Leaf colour and immature pod pigmentation of cowpea genotypes

Table 8. Grouping of cowpea genotypes based on plant height and number of primary branches per plant

Sl. No.	Genotypes	Plant height (cm)	Groups	Number of primary branches per plant	Groups
1	IC257413	22.36	Medium	6.67	High
2	IC97787	21.05	Medium	5.33	Medium
3	IC198323	17.50	Medium	6.00	Medium
4	IC198326	14.67	Dwarf	5.00	Medium
5	IC198333	15.80	Medium	5.50	Medium
6	IC198335	22.07	Medium	5.84	Medium
7	IC198349	17.62	Medium	5.66	Medium
8	IC198361	9.93	Dwarf	4.34	Medium
9	IC198701	16.85	Medium	4.69	Medium
10	IC201087	21.98	Medium	4.50	Medium
11	IC202789	16.50	Medium	7.00	High
12	IC202806	23.00	Medium	5.00	Medium
13	IC202867	16.80	Medium	5.34	Medium
14	IC202868	19.03	Medium	5.00	Medium
15	IC202881	22.60	Medium	5.83	Medium
16	IC214757	25.93	Medium	4.17	Medium
17	IC219574	13.20	Dwarf	5.75	Medium
18	IC219599	21.37	Medium	7.17	High
19	IC212871	20.82	Medium	4.83	Medium
20	IC212872	19.22	Medium	4.67	Medium
21	IC249583	16.58	Medium	6.08	High
22	IC253181	24.50	Medium	6.75	High
23	IC253268	13.87	Dwarf	5.50	Medium
24	IC253270	19.40	Medium	5.59	Medium
25	IC253273	23.75	Medium	5.00	Medium
26	IC253275	21.84	Medium	5.08	Medium
27	IC257407	22.73	Medium	6.50	High
28	IC259159-1	21.25	Medium	4.80	Medium
29	IC259159-2	18.08	Medium	5.42	Medium
30	IC202784	20.00	Medium	6.42	High
31	IC4506	20.47	Medium	4.80	Medium
32	IC5969	18.52	Medium	5.50	Medium
33	Mumbai local	24.28	Medium	3.67	Less
34	Bailhongal local	25.55	Tall	6.60	High
35	C-152	29.88	Tall	5.67	Medium
Mean		19.97		5.47	
S.Em ±		1.55		0.45	
CD (0.05)		4.45		1.31	

Note:

Plant height (cm):

Dwarf : ≤ 15 cm  
 Medium : 15 –25 cm  
 Tall : > 25 cm

Primary branches/plant:

Less : ≤ 4  
 Medium : 4 - 6  
 High : > 6

#### 4.1.3.12 Number of primary branches per plant

The number of primary branches per plant differed among the cowpea genotypes (Table 8). The mean number of primary branches per plant was 5.47. Significantly higher number of primary branches were recorded in IC2129599 (7.17) and the lowest was in Mumbai local (3.67). Based on the number of primary branches, the genotypes were grouped into less (<4), medium (4-6) and high (>6) branched types.

Among 35 genotypes, Mumbai local genotype had less, 26 genotypes were grouped medium viz., IC97787, IC198323, IC198326, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202806, IC202867, IC202868, IC202881, IC214757, IC219574, IC219871, IC219872, IC253268, IC253270, IC253273, IC253275, IC259159-1, IC259159-2, IC4506, IC5969 and C-152. Whereas IC257413, IC202789, IC219599, IC249583, IC253181, IC257407, IC202784 and Bailhongal local had high number of primary branches per plant.

#### 4.1.3.13 Number of clusters per plant

The number of clusters per plant varied significantly among the cowpea genotypes (Table 9). The mean number of clusters per plant was 37.24. Highest number of clusters per plant were recorded in IC253270 (69.83) and lowest were in Mumbai local (17.67). Based on the number of cluster per plant, the genotypes were grouped into three categories as less (<25), medium (25-45) and more (>45) in cluster per plant.

Among the 35 genotypes, three genotypes had less viz., IC198361, IC202868 and Mumbai local, 24 genotypes had medium viz., IC257413, IC198326, IC198333, IC198335, IC198349, IC198701, IC201087, IC202867, IC202881, IC214757, IC219599, IC219871, IC219872, IC253268, IC253273, IC253275, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969, Bailhongal local and C-152. Whereas eight were more viz., IC97787, IC198323, IC202789, IC202806, IC219574, IC249583, IC253181 and IC253270 in clusters per plant.

#### 4.1.3.14 Number of pods per peduncle

The number of pods per peduncle varied among cowpea genotypes (Table 9). The mean number of pods per peduncle were 2.07. Significantly higher pods per peduncle were recorded in IC202789 (3.00) and lowest were in Mumbai local and IC219599 (1.33). Based on the number of pods per peduncle, the genotypes were recorded into two groups as few with less than two and more with more than two numbers of pods per peduncle.

Among 35 genotypes, 19 genotypes were few viz. IC257413, IC198323, IC198326, IC198333, IC198361, IC198701, IC202806, IC202867, IC219599, IC219871, IC219872, IC253181, IC253268, IC253273, IC253275, IC202784, IC5969, Mumbai local and C-152. Whereas, 16 genotypes were more viz. IC97787, IC198335, IC198349, IC201087, IC202789, IC202868, IC202881, IC214757, IC219574, IC249583, IC253270, IC257407, IC259159-1, IC259159-2, IC4506 and Bailhongal local in number of pods per peduncle.

#### 4.1.3.15 Number of pods per plant

The number of pods per plant varied significantly among cowpea genotypes (Table 10). The mean number of pods per plant were 61.20. Higher number of pods were recorded in IC253270 (107.00) and lowest were in Mumbai local (23.47). Based on number of pods per plant, the genotypes were grouped into four plant, the genotypes were grouped into four categories as less (< 40), moderate (40-60), high (60.90) and very high (>90) in number of pods per plant.

Among the 35 genotypes, three genotypes had less (IC198361, IC202867 and Mumbai local), 16 genotypes had moderate (IC198326, IC198335, IC198349, IC198701, IC201087, IC202868, IC214757, IC219599, IC219872, IC253273, IC253275, IC259159-2, IC202784, Bailhongal local and C-152), 13 genotypes had high (IC257413, IC97787, IC198323, IC198333, IC202806, IC202881, IC219574, IC219871, IC249583, IC257407, IC259159-1, IC4506 and IC5969). Whereas, three genotypes had very high (IC202789, IC253181 and IC253270) pod numbers per plant.

Table 9. Grouping of cowpea genotypes based on number of clusters per plant and number of pods per peduncle

Sl. No.	Genotypes	Number of clusters per plant	Groups	Number of Pods per peduncle	Groups
1	IC257413	42.33	Medium	2.00	Few
2	IC97787	47.08	More	2.75	More
3	IC198323	45.75	More	2.00	Few
4	IC198326	32.33	Medium	2.00	Few
5	IC198333	43.17	Medium	1.80	Few
6	IC198335	31.97	Medium	2.10	More
7	IC198349	25.58	Medium	2.45	More
8	IC198361	23.30	Less	2.00	Few
9	IC198701	36.20	Medium	1.80	Few
10	IC201087	26.59	Medium	2.15	More
11	IC202789	46.10	More	3.00	More
12	IC202806	62.55	More	1.80	Few
13	IC202867	27.39	Medium	1.80	Few
14	IC202868	20.50	Less	2.30	More
15	IC202881	35.34	Medium	2.84	More
16	IC214757	29.17	Medium	2.33	More
17	IC219574	53.00	More	2.17	More
18	IC219599	34.75	Medium	1.33	Few
19	IC212871	38.83	Medium	1.83	Few
20	IC212872	30.92	Medium	1.83	Few
21	IC249583	47.33	More	2.42	More
22	IC253181	57.50	More	2.00	Few
23	IC253268	34.17	Medium	1.50	Few
24	IC253270	69.83	More	2.17	More
25	IC253273	35.50	Medium	2.00	Few
26	IC253275	32.84	Medium	1.67	Few
27	IC257407	28.16	Medium	2.50	More
28	IC259159-1	37.55	Medium	2.20	More
29	IC259159-2	25.59	Medium	2.17	More
30	IC202784	40.63	Medium	2.00	Few
31	IC4506	35.40	Medium	2.10	More
32	IC5969	34.83	Medium	2.00	Few
33	Mumbai local	17.67	Less	1.33	Few
34	Bailhongal local	33.74	Medium	2.13	More
35	C-152	39.85	Medium	2.00	Few
	Mean	37.24		2.07	
	S.Em ±	2.09		0.18	
	CD (0.05)	6.02		0.52	

Note:

Number of clusters/plant:  
 Less : ≤ 25  
 Medium : 25 – 45  
 More : > 45

Number of pods/peduncle:  
 Few : < 2  
 More : > 2

#### 4.1.3.16 Mature pod constriction

Based on mature pod constriction, the genotypes were classified into three groups as least, medium and high pod constriction types (Table 10).

Among the 35 genotypes, 11 genotypes had least (IC257413, IC198326, IC198333, IC198335, IC201087, IC202789, IC202867, IC202881, IC214757, IC219574 and Bailhongal local); 18 were medium (IC97787, IC198323, IC198349, IC202806, IC202868, IC212871, IC249583, IC253181, IC253268, IC253270, IC253273, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969 and C-152 ) Whereas, six genotypes had high (IC198361, IC198701, IC219599, IC219872, IC253275 and Mumbai local) pod constriction types.

#### 4.1.3.17 Days to maturity

The number of days to maturity varied significantly among the genotypes (Table 10). The mean number of days taken by the genotypes for maturity was 89.58. The genotype IC202867 took more days to maturity (97.33 days) whereas the genotype IC4506 took less days for maturity (82.33 days). Based on the days to maturity, the genotypes were grouped into three categories as early (< 85 days) viz., IC198326, IC198335, IC202868, IC219574, IC219871, IC219872, IC4506 and Bailhongal local; medium (85-95 days) viz., IC257413, IC97787, IC198333, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202881, IC214757, IC219599, IC249583, IC253181, IC253270, IC253273, IC257407, IC259159-1, IC202784, IC5969 and Mumbai local and late (>95 days) viz., IC198323, IC202867, IC253268, IC253275, IC259159-2 and C-152 maturity types.

#### 4.1.3.18 Pod length (cm)

The cowpea genotypes varied significantly among themselves for pod length (Table 11 and Plate 7). The mean pod length was 18.64. Significantly highest pod length was recorded in IC219599 (25.77 cm) and lowest pod length was observed in IC4506 (12.53 cm). Based on the pod length, the genotypes were grouped into three categories as having short (< 15.00 cm), medium (15.00-20.00 cm) and long (>20.00 cm) pod length types.

Genotypes with short pod length were IC214757, IC259159-1 and IC4506; medium pod length were IC257413, IC97787, IC198323, IC198326, IC198333, IC198335, IC198349, IC198701, IC201087, IC202789, IC202806, IC202867, IC202881, IC219574, IC219871, IC253181, IC253268, IC253270, IC257407, IC259159-2, IC202784, IC5969 and C-152 Whereas, genotypes IC198361, IC202868, IC219599, IC219872, IC249583, IC253273, IC253275, Mumbai local and Bailhongal local had long pod length.

#### 4.1.3.19 Number of seeds per pod

The number of seeds per pod varied among cowpea genotypes (Table 11). The mean number of seeds per pod was 16.08. Significantly higher number of seeds were recorded in IC198335 (20.08) and lowest were in IC214757 (9.53). Based on number of seeds per pod, the genotypes were grouped into three categories as low (<14), medium (14-18) and high (>18) number of seeds types.

Among the 35 genotypes, three genotypes were low viz. IC214757, IC259159-1 and IC259159-2 ; 26 genotypes were medium viz., IC257413, IC97787, IC198323, IC198326, IC198333, IC198701, IC201087, IC202806, IC202867, IC202868, IC202881, IC219599, IC219871, IC219872, IC249583, IC253181, IC253268, IC253270, IC253273, IC253275, IC257407, IC202784, IC4506, IC5969, Mumbai local and C-152 whereas, six genotypes were high viz. IC198335, IC198349, IC198361, IC202789, IC219574 and Bailhongal local number of seeds per pod.

#### 4.1.3.20 Pod colour at maturity

Based on mature pod colour, genotypes were grouped into straw, purple, brown and black colour pod types (Table 11).

Genotypes IC257413, IC198335, IC198349, IC198701, IC201087, IC202789, IC202867, IC202881, IC214757, IC219574, IC219871, IC219872, IC249583, IC253268, IC253270, IC253273, IC253275, IC259159-2, IC202784, IC5969 and Bailhongal local were straw coloured pods. Whereas, brown colour genotypes were IC97787, IC198323, IC198326, IC198333, IC198361, IC202806, IC202868, IC219599, IC253181, IC257407, IC259159-1, IC4506 , Mumbai local and C-152.

Table 10. Grouping of cowpea genotypes based on number of pods per plant, days to maturity and matured pod constriction

Sl. No.	Genotypes	Number of pods/ plant	Groups	Days to maturity (DAS)	Groups	Mature pod constriction
1	IC257413	63.33	High	87.33	Medium	Least
2	IC97787	78.67	High	87.67	Medium	Medium
3	IC198323	81.92	High	97.00	Late	Medium
4	IC198326	59.17	Moderate	84.00	Early	Least
5	IC198333	65.34	High	86.00	Medium	Least
6	IC198335	51.44	Moderate	85.00	Early	Least
7	IC198349	45.59	Moderate	89.00	Medium	Medium
8	IC198361	34.58	Less	90.33	Medium	High
9	IC198701	53.60	Moderate	89.00	Medium	High
10	IC201087	47.25	Moderate	87.33	Medium	Least
11	IC202789	105.25	Very high	93.00	Medium	Least
12	IC202806	77.33	High	94.00	Medium	Medium
13	IC202867	38.25	Less	97.33	Late	Least
14	IC202868	45.40	Moderate	84.67	Early	Medium
15	IC202881	63.50	High	94.00	Medium	Least
16	IC214757	46.50	Moderate	87.00	Medium	Least
17	IC219574	82.42	High	83.33	Early	Least
18	IC219599	55.00	Moderate	87.67	Medium	High
19	IC212871	61.84	High	84.67	Early	Medium
20	IC212872	47.25	Moderate	84.00	Early	High
21	IC249583	85.75	High	87.33	Medium	Medium
22	IC253181	95.50	Very high	93.33	Medium	Medium
23	IC253268	43.67	Moderate	96.33	Late	Medium
24	IC253270	107.00	Very high	90.00	Medium	Medium
25	IC253273	52.83	Moderate	90.67	Medium	Medium
26	IC253275	46.75	Moderate	95.33	Late	High
27	IC257407	62.08	High	91.67	Medium	Medium
28	IC259159-1	62.50	High	92.33	Medium	Medium
29	IC259159-2	51.17	Moderate	96.33	Late	Medium
30	IC202784	55.50	Moderate	90.67	Medium	Medium
31	IC4506	74.90	High	82.33	Early	Medium
32	IC5969	64.17	High	90.00	Medium	Medium
33	Mumbai local	23.47	Less	85.67	Medium	High
34	Bailhongal local	57.00	Moderate	85.00	Early	Least
35	C-152	56.17	Moderate	96.00	Late	Medium
	Mean	61.20		89.58		
	S.Em ±	6.27		1.27		
	CD (0.05)	18.03		3.60		

Note:

Number of pods/plant:  
 Less : ≤ 40  
 Moderate : 40 – 60  
 High : 60 – 90  
 Very high : > 90

Days to maturity:  
 Early : ≤ 85 DAS  
 Medium : 85 – 95 DAS  
 Late : > 95 DAS

Table 11. Grouping of cowpea genotypes based on pod length, number of seeds per pod and mature pod colour

Sl. No.	Genotypes	Pod length (cm)	Groups	Number of seeds/pod	Groups	Mature pod colour
1	IC257413	18.27	Medium	16.55	Medium	Straw
2	IC97787	18.03	Medium	15.40	Medium	Brown
3	IC198323	18.07	Medium	16.88	Medium	Brown
4	IC198326	19.93	Medium	16.08	Medium	Brown
5	IC198333	15.30	Medium	16.06	Medium	Brown
6	IC198335	19.77	Medium	20.08	High	Straw
7	IC198349	17.70	Medium	18.13	High	Straw
8	IC198361	20.10	Long	18.50	High	Brown
9	IC198701	19.27	Medium	17.25	Medium	Straw
10	IC201087	17.50	Medium	15.00	Medium	Straw
11	IC202789	17.10	Medium	18.85	High	Straw
12	IC202806	17.43	Medium	16.50	Medium	Brown
13	IC202867	16.23	Medium	15.50	Medium	Straw
14	IC202868	20.30	Long	15.25	Medium	Brown
15	IC202881	18.20	Medium	17.00	Medium	Straw
16	IC214757	14.37	Short	9.53	Low	Straw
17	IC219574	18.63	Medium	18.52	High	Straw
18	IC219599	25.77	Long	14.62	Medium	Brown
19	IC212871	19.43	Medium	17.75	Medium	Straw
20	IC212872	20.80	Long	14.04	Medium	Straw
21	IC249583	24.00	Long	17.53	Medium	Straw
22	IC253181	16.80	Medium	16.75	Medium	Brown
23	IC253268	19.07	Medium	15.13	Medium	Straw
24	IC253270	18.33	Medium	17.25	Medium	Straw
25	IC253273	22.37	Long	15.03	Medium	Straw
26	IC253275	24.77	Long	15.75	Medium	Straw
27	IC257407	18.40	Medium	15.01	Medium	Brown
28	IC259159-1	14.70	Short	13.25	Low	Brown
29	IC259159-2	16.30	Medium	13.75	Low	Straw
30	IC202784	18.60	Medium	15.00	Medium	Straw
31	IC4506	12.53	Short	14.75	Medium	Brown
32	IC5969	15.27	Medium	15.25	Medium	Straw
33	Mumbai local	21.13	Long	14.50	Medium	Brown
34	Bailhongal local	20.37	Long	18.85	High	Straw
35	C-152	17.60	Medium	17.62	Medium	Brown
	Mean	18.64		16.08		
	S.Em ±	0.42		0.52		
	CD (0.05)	1.17		1.50		

Note:

Pod length (cm):

Short : ≤ 15 cm  
 Medium : 15 – 20 cm  
 Long : > 20 cm

Number of seeds/pod:

Low : ≤ 14  
 Medium : 14 - 18  
 High : > 18

Pod attachment to penduncle



Pod length



Plate.7. Pod attachment to penduncle and pod length of cowpea genotypes

#### 4.1.3.21 Seed yield per plant (g)

The seed yield per plant varied among cowpea genotypes (Table 12). The mean seed yield per plant was 57.69 g. Significantly higher seed yield was recorded in IC253181 (110.01 g). Whereas, lowest seed yield was in Mumbai local (20.94 g). Based on seed yield per plant, the genotypes were grouped into four categories as low (<40 g), moderate (40-70 g), high (70-100 g) and very high (>100 g) yielder of seed per plant.

Among the 35 genotypes, eight genotypes were low viz., IC202867, IC202868, IC219871, IC249583, IC259159-1, IC259159-2, IC202784 and Mumbai local; 18 genotypes were moderate viz., IC97787, IC198323, IC198326, IC198333, IC198349, IC198701, IC201087, IC202806, IC214757, IC219872, IC253268, IC253273, IC253275, IC257407, IC4506, IC5969, Bailhongal local and C-152; six genotypes were high viz., IC257413, IC198335, IC198361, IC202789, IC219599 and IC253270. Whereas, three genotypes were very high viz., IC202881, IC219574 and IC253181 yielding types.

#### 4.1.3.22 Seed yield per hectare (kg/ha)

The seed yield per hectare differed significantly among cowpea genotypes (Table 12). The mean seed yield per hectare was 1405.4 kg. Significantly highest seed yield was recorded in IC202881 (3194.4 kg) and lowest was in Mumbai local (594.1 kg). Based on seed yield per ha, the genotypes were grouped into four categories low (<1100 kg), moderate (1100-1600 kg), high (1600 – 2000 kg) and very high (> 2000 kg) in seed yield types.

Among the 35 genotypes, 10 genotypes were grouped into low (IC198326, IC198701, IC202867, IC202868, IC214757, IC219871, IC219872, IC249583, IC202784 and Mumbai local); 12 genotypes were grouped into moderate (IC97787, IC198333, IC198349, IC201087, IC202806, IC253273, IC253275, IC257407, IC259159-1, IC259159-2, IC4506 and Bailhongal local), 10 genotypes were high (IC257413, IC198323, IC198335, IC202789, IC219599, IC253181, IC253268, IC253270, IC5969 and C-152) Whereas, three genotypes were very high (IC198361, IC202881 and IC219574 seed yielding types).

#### 4.1.3.23 Market value

Based on market value, the genotypes were grouped into three categories as grain type, vegetable type and fodder type (Table 12).

Among the 35 genotypes, 30 genotypes were grain type viz. IC257413, IC97787, IC198323, IC198326, IC198333, IC198335, IC198349, IC198361, IC198701, IC201087, IC202789, IC202806, IC202867, IC202868, IC202881, IC214757, IC219574, IC219871, IC253181, IC253268, IC253270, IC253273, IC257407, IC259159-1, IC259159-2, IC202784, IC4506, IC5969, Bailhongal local and C-152. Whereas, five genotypes were vegetable type viz. IC219599, IC219872, IC249583, IC253275 and Mumbai local and none of them were found fodder type for market value.

#### 4.1.4 Genetic diversity

Genetic diversity analysis helps in assessing the nature of diversity in order to identify the genetically diverse genotypes for their use in heterosis programme.

##### 4.1.4.1 Mahalanobis generalized distance ( $D^2$ ) analysis

###### 4.1.4.1.1 Contribution of different characters towards divergence

Difference in proportion of contribution of each character to total  $D^2$  statistics was observed. They are presented in the Table 13. Out of 13 characters studied, seed size contributed maximum to the diversity (23.36%). This was followed by pod length (18.99%), protein content (18.82%), hundred seed weight (13.45%), number of clusters per plant (9.41%) seed yield per plant (6.72%), seeds per pod (6.05%), days to maturity (1.68%), pods per cluster (0.84%) and plant height (0.67%).

###### 4.1.4.1.2 Group constellations

The distribution pattern of genotypes into eighteen clusters using Tocher's method given by Rao (1952) is shown in Table 14. The diagrammatic representation of eighteen clusters consisting of different genotypes is shown in Fig. 2. Cluster-I was found largest with

Table 12. Grouping of cowpea genotypes based on seed yield per plant, seed yield per hectare and market value

Sl. No.	Genotypes	Seed yield (g/plant)	Groups	Seed yield (Kg/ha)	Groups	Market value
1	IC257413	73.90	High	1683.8	High	Grain type
2	IC97787	51.19	Moderate	1380.9	Moderate	Grain type
3	IC198323	59.79	Moderate	1677.2	High	Grain type
4	IC198326	45.53	Moderate	1006.6	Low	Grain type
5	IC198333	47.95	Moderate	1378.3	Moderate	Grain type
6	IC198335	77.02	High	1982.8	High	Grain type
7	IC198349	63.16	Moderate	1365.0	Moderate	Grain type
8	IC198361	74.96	High	2068.7	Very high	Grain type
9	IC198701	51.24	Moderate	944.5	Low	Grain type
10	IC201087	47.59	Moderate	1447.1	Moderate	Grain type
11	IC202789	87.00	High	1761.3	High	Grain type
12	IC202806	53.13	Moderate	1420.6	Moderate	Grain type
13	IC202867	27.16	Low	1035.7	Low	Grain type
14	IC202868	38.51	Low	911.4	Low	Grain type
15	IC202881	104.86	Very high	3194.4	Very high	Grain type
16	IC214757	44.03	Moderate	1041.0	Low	Grain type
17	IC219574	108.11	Very high	2218.3	Very high	Grain type
18	IC219599	77.88	High	1648.1	High	Vegetable type
19	IC212871	32.96	Low	828.5	Low	Grain type
20	IC212872	45.97	Moderate	910.0	Low	Vegetable type
21	IC249583	37.32	Low	1035.7	Low	Vegetable type
22	IC253181	110.01	Very high	1764.0	High	Grain type
23	IC253268	54.43	Moderate	1751.3	High	Grain type
24	IC253270	71.00	High	1614.8	High	Grain type
25	IC253273	61.35	Moderate	1460.3	Moderate	Grain type
26	IC253275	46.15	Moderate	1141.5	Moderate	Vegetable type
27	IC257407	45.53	Moderate	1338.6	Moderate	Grain type
28	IC259159-1	38.43	Low	1138.9	Moderate	Grain type
29	IC259159-2	34.44	Low	1228.8	Moderate	Grain type
30	IC202784	36.04	Low	697.6	Low	Grain type
31	IC4506	43.94	Moderate	1457.7	Moderate	Grain type
32	IC5969	61.39	Moderate	1783.1	High	Grain type
33	Mumbai local	20.94	Low	564.1	Low	Vegetable type
34	Bailhongal local	63.75	Moderate	1480.1	Moderate	Grain type
35	C-152	62.59	Moderate	2078.0	High	Grain type
	Mean	57.69		1405.4		
	S.Em ±	7.35		121.0		
	CD (0.05)	21.12		347.7		

Note:

Seed yield/plant (g):

Low : ≤ 40 g  
 Moderate : 40 – 70 g  
 High : 70 – 100 g  
 Very high : > 100 g

Seed yield/hectare (Kg/ha):

Low : ≤ 1100 Kg/ha  
 Moderate : 1100 – 1600 Kg/ha  
 High : 1600 – 2000 Kg/ha  
 Very high : > 2000 Kg/ha

16 genotypes followed by cluster II and X with two genotypes each and remaining all clusters were solitary with single genotype each.

#### 4.1.4.1.3 Intra and inter relation of clusters

The average  $D^2$  values of intra and inter cluster distances are given in Table 15. Maximum difference among the genotypes within the same cluster was shown by cluster-I (8.82) followed by cluster X (8.29) and cluster II (6.68). Remaining fifteen clusters harbored solitary genotypes.

The intercluster distances among the clusters varied from 7.64 to 40.89. Cluster XVII and XVIII showed maximum inter cluster distance (40.89) followed by between XVI and XVIII (37.81). The lowest inter cluster distance (7.64) was noticed between cluster IV and VI.

#### 4.1.4.1.4 Cluster means analysis

The cluster means in respect of thirteen characters and overall character wise score across the eighteen clusters are presented in the discussion chapter Table 16.

In case of days to 50 per cent flowering, cluster means ranged between 45.50 to 55.50 days. Genotypes of cluster XII and XIII showed characteristic early flowering habit with mean number of days to flowering being 45.50 days while genotypes of cluster V and IX had late flowering habit with 55.50 days.

With regard to plant height, the genotypes of cluster V exhibited the highest mean plant height (29.88 cm) followed by cluster XII genotypes (24.28 cm). Cluster VIII comprised of lines with a lowest mean plant height (13.20 cm). The Mean values of remaining clusters were intermediate. Number of primary branches recorded maximum mean in cluster X (6.62) while, minimum mean of 3.67 was observed in cluster XII. For clusters per plant, minimum mean of 17.67 in cluster XII and maximum mean of 69.83 in cluster XV was recorded.

Cluster-IX showed maximum mean (2.30) for number of pods per peduncle and cluster XII recorded minimum mean of 1.33. Cluster mean showing number of pods per plant was highest for cluster XV (107.00) and it was lowest for genotypes under cluster XII (23.47). For days to maturity, cluster mean ranged between 82.50 to 96.50 days. Genotype under cluster XVIII was of early maturity type with number of days to mature being 82.50 days. While that under cluster VII, X and XII were of late maturity types (96.50 days).

Pod length recorded maximum mean cluster X (25.15 cm) while minimum mean of 12.60 cm was in cluster XVII. With respect to number of seeds per pod, more mean was recorded by genotypes in cluster XIV (20.08), while cluster-II depicted less mean of 11.39. Cluster XVII showed maximum mean of 20.72 g for hundred seed weight whereas minimum in mean in cluster XVII (7.49 g).

Seed size recorded highest mean of 7.13 mm in cluster XVII while, lowest mean in cluster XVIII (4.47 mm). Cluster mean for seed yield per plant varied from as low as 20.94 g to as high as 108.11 g. Genotypes in cluster XII showed lowest yield and those in cluster VII had highest seed yield per plant. When observed for seed protein content, genotypes of cluster XI showed highest mean of 23.33 per cent and genotype of cluster XIII recorded the lowest mean of 13.88 per cent.

All 35 genotypes were spread over 18 clusters and means were scored across the clusters for all the 13 characters (Table 16). The highest cluster mean was given the first rank and next cluster possessing next best means were given 2<sup>nd</sup>, 3<sup>rd</sup> and so on upto 18<sup>th</sup> rank for all the traits. Finally the clusters are ranked based on the overall score obtained across 13 characters. The lowest scoring cluster was given first rank and next cluster possessing the score above the previous ones were given 2<sup>nd</sup>, 3<sup>rd</sup> and so on upto 18<sup>th</sup> rank. Accordingly, cluster VIII with overall score of 77 across the 13 characters secured first rank followed by cluster XV, X, VI and XVI indicating presence of potential genotypes for yield and yield related traits. So some of the potential genotypes in cluster VIII (IC219574), cluster XV (IC253270), cluster X (IC219599 and IC249583) for yield per se, test weight and protein content could be used in cowpea breeding to evolve superior varieties. Cluster XIII with overall score of 157 recorded last rank (17<sup>th</sup>) reflecting the presence of genotypes with lower per se.

Table 13. Per cent contribution of thirteen characters towards diversity in cowpea

Sl. No.	Character	Per cent contribution
1.	Days to 50 per cent flowering	0.00
2.	Plant height (cm)	0.67
3.	Number of primary branches per plant	0.00
4.	Number of clusters per plant	9.41
5.	Number of pods per cluster	0.84
6.	Number of pods per plant	0.00
7.	Days to maturity	1.68
8.	Pod length (cm)	18.99
9.	Number of seeds per pod	6.05
10.	100 seed weight (g)	13.45
11.	Seed size (mm)	23.36
12.	Seed yield per plant (g)	6.72
13.	Seed protein content (%)	18.82

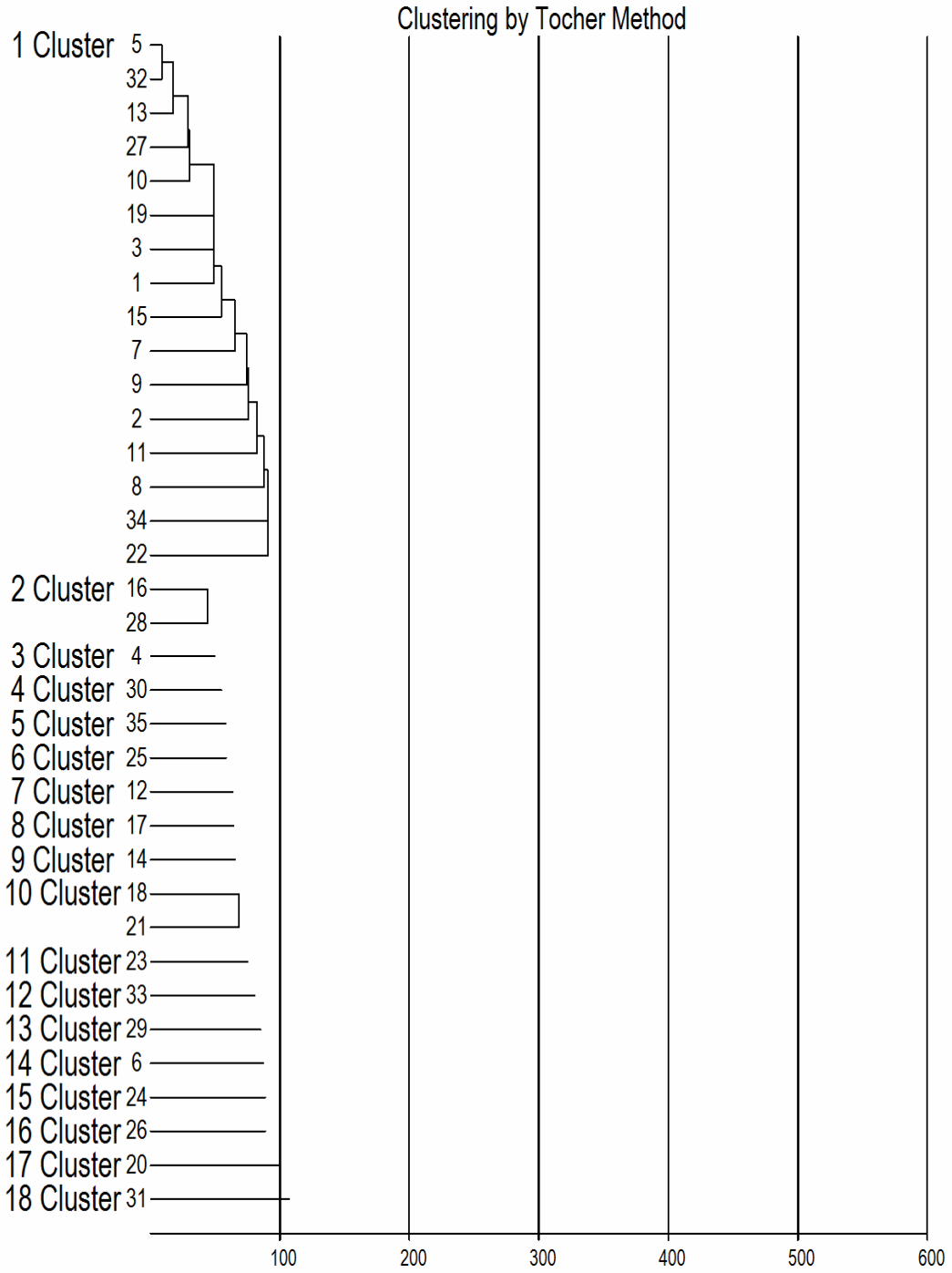


Fig. 2. Diagrammatic representation of different clusters

Table 14. Clustering pattern of 35 genotypes of cowpea on D<sup>2</sup> analysis

Cluster	No. of genotypes	Name of the genotypes
I	16	IC198333, IC5969, IC202867, IC257407, IC201087, IC212871, IC198323, IC257413, IC202881, IC198349, IC198701, IC97787, IC202789, IC198361, Bailhongal local, and IC253181
II	2	IC214757 and IC259159-1
III	1	IC198326
IV	1	IC202784
V	1	C-152
VI	1	IC253273
VII	1	IC202806
VIII	1	IC219574
IX	1	IC202868
X	2	IC219599 and IC249583
XI	1	IC253268
XII	1	Mumbai local
XIII	1	IC259159-2
XIV	1	IC198335
XV	1	IC253270
XVI	1	IC253275
XVII	1	IC212872
XVIII	1	IC4506



Table 16. Cluster means for thirteen characters in cowpea

Clusters	Days to 50 per cent flowering	Plant height (cm)	No. of primary branches	No. of clusters per plant	No. of Pods per cluster	No. of pods per plant	Days to maturity	Pod length (cm)	No. of seeds per pod	100 Seed weight (g)	Seed size (mm)	Seed yield per plant (g)	Seed protein content (%)	Score	Rank
I	50.47 (8)*	19.44 (10)	5.69 (5)	36.99 (7)	2.19 (3)	63.62 (6)	90.47 (10)	17.94 (14)	16.80 (5)	12.19 (11)	5.64 (11)	63.90 (4)	20.03 (11)	105	6
II	49.00 (5)	23.59 (4)	4.48 (14)	33.36 (11)	2.27 (2)	54.50 (10)	89.00 (8)	14.65 (17)	11.39 (18)	10.57 (15)	5.17 (14)	41.23 (14)	18.44 (12)	144	16
III	47.00 (3)	14.67 (16)	5.00 (11)	32.33 (13)	2.00 (6)	59.17 (7)	84.00 (4)	19.60 (8)	16.08 (7)	11.40 (14)	4.99 (16)	45.53 (12)	22.74 (2)	119	12
IV	49.50 (6)	20.00 (9)	6.42 (2)	40.63 (5)	2.00 (6)	55.50 (9)	91.00 (12)	18.40 (12)	15.00 (13)	15.75 (5)	5.90 (8)	36.04 (16)	20.25 (10)	113	10
V	55.50 (9)	29.88 (1)	5.67 (6)	39.85 (6)	2.00 (6)	56.17 (8)	96.00 (14)	18.15 (13)	17.62 (3)	11.54 (13)	5.13 (15)	62.59 (5)	20.95 (9)	108	8
VI	47.00 (3)	23.75 (3)	5.00 (11)	35.50 (8)	2.00 (6)	52.83 (11)	90.50 (11)	22.80 (3)	15.03 (12)	16.75 (3)	6.05 (6)	61.35 (6)	18.42 (13)	96	4
VII	46.00 (2)	23.00 (5)	5.00 (11)	62.55 (2)	1.80 (9)	77.33 (3)	96.50 (15)	17.40 (15)	16.50 (6)	12.02 (12)	5.23 (13)	53.13 (9)	17.33 (15)	117	11
VIII	46.00 (2)	13.20 (18)	5.75 (4)	53.00 (3)	2.17 (4)	82.42 (2)	83.50 (3)	19.00 (10)	18.52 (2)	12.43 (10)	5.62 (12)	108.11 (1)	22.09 (6)	77	1
IX	49.50 (6)	19.03 (13)	5.00 (11)	20.50 (17)	2.30 (1)	45.40 (16)	83.00 (2)	20.55 (6)	15.25 (10)	14.62 (6)	6.47 (4)	38.51 (15)	22.69 (3)	110	9
X	49.50 (6)	18.97 (14)	6.62 (1)	41.04 (4)	1.87 (7)	70.38 (5)	86.75 (7)	25.15 (1)	16.07 (8)	12.59 (9)	5.76 (10)	57.60 (7)	21.84 (7)	86	3
XI	50.50 (9)	13.87 (17)	5.50 (8)	34.17 (10)	1.50 (11)	43.67 (17)	96.50 (15)	19.15 (9)	15.13 (11)	16.67 (4)	6.53 (3)	54.44 (8)	23.33 (1)	123	13
XII	45.50 (1)	24.28 (2)	3.67 (15)	17.67 (18)	1.33 (12)	23.47 (18)	85.50 (6)	21.00 (5)	14.50 (15)	16.67 (4)	6.26 (5)	20.94 (18)	14.43 (17)	136	15
XIII	45.50 (1)	18.08 (15)	5.42 (9)	25.59 (16)	2.17 (4)	51.17 (13)	96.50 (15)	16.85 (16)	13.75 (17)	14.45 (7)	5.85 (9)	34.44 (17)	13.88 (18)	157	17
XIV	49.00 (5)	22.07 (6)	5.84 (3)	31.97 (14)	2.10 (5)	51.44 (12)	85.00 (5)	19.75 (7)	20.08 (1)	9.66 (16)	4.78 (17)	77.02 (2)	17.86 (14)	107	7
XV	47.00 (3)	19.40 (11)	5.59 (7)	69.83 (1)	2.17 (4)	107.00 (1)	90.00 (9)	18.45 (11)	17.25 (4)	13.32 (8)	5.94 (7)	71.00 (3)	15.74 (16)	85	2
XVI	48.50 (4)	21.84 (7)	5.08 (10)	32.84 (12)	1.67 (10)	46.75 (15)	95.50 (13)	25.00 (2)	15.75 (9)	18.09 (2)	6.64 (2)	46.15 (10)	22.62 (4)	100	5
XVII	47.00 (3)	19.22 (12)	4.67 (13)	30.92 (15)	1.83 (8)	47.25 (14)	84.00 (4)	21.10 (4)	14.04 (16)	20.72 (1)	7.13 (1)	45.97 (11)	22.32 (5)	107	7
XVIII	50.00 (7)	20.47 (8)	4.80 (12)	35.40 (9)	2.10 (5)	74.90 (4)	82.50 (1)	12.60 (18)	14.75 (14)	7.49 (17)	4.47 (18)	43.94 (13)	21.50 (8)	134	14

\* Figures in the parenthesis depict the scores from 1-18 based on cluster means

## 4.2 Experiment–II : Evaluation of cowpea genotypes for protein content

### 4.2.1 Protein content (%)

There was a significant difference among the cowpea genotypes studied for seed protein content and presented in Table 17.

The protein content of different cowpea genotypes ranged from 13.88-24.06 per cent and mean protein content was 19.91 per cent. The highest protein content of 24.06 per cent was recorded in the genotype IC97787, which was on par with IC253268 (23.33%), IC198326 (22.73%), IC202868 (22.68%), IC219599 (22.65%) and IC253275 (22.61%), while the genotype IC259159-2 showed lowest protein content of 13.88 per cent, which was on par with Mumbai local (14.42%) and followed by IC253270 (15.73%).

## 4.3 Experiment – III: Screening of cowpea genotypes for their relative response to bruchid infestation and seed quality

### 4.3.1 Apparent weight loss (%)

The data pertaining to apparent weight loss (%) in cowpea seeds of 35 genotypes due to infestation during 90 days after release (DAR) of bruchids are furnished in Table 18.

There was significant difference noticed among the genotypes with respect to apparent weight loss after infestation. The apparent loss ranged between 8.87 to 31.17 per cent with mean apparent loss of 22.18 per cent. The highest loss of 31.17 per cent was recorded in the genotype IC202806, which was statistically on par with IC198361 (31.03%), IC259159-1 (29.09%), IC253181 (29.07%) and IC214757 (28.84%). While, genotype IC202784 showed lowest apparent loss of 8.87 per cent. The check variety C-152 recorded 24.29 per cent apparent weight loss.

### 4.3.2 Actual weight loss (%)

The per cent actual weight loss in cowpea genotypes after infestation presented in Table 18.

The per cent actual weight loss differed significantly among the cowpea genotypes after infestation of 90 DAR of bruchids. The actual loss ranged between 3.14 -27.02 per cent with mean actual loss 11.00 per cent. The highest was recorded in the genotypes IC214757 (27.02%) which was on par with IC198361 (26.70%) and IC198326 (23.81%). The lowest was recorded in genotype IC202867 (3.14%) which was on par with IC249583 (3.51%), IC97787 (3.63%), IC202784 (3.66%), IC4506 (3.99%) and IC253181 (4.71%). The check variety C-152 showed 6.99 per cent.

### 4.3.3 Total number of adults emerged

The data pertaining to total number of adult of bruchids emerged from each of 35 genotypes on 90 DAR of bruchids are depicted in Table 18.

There was a significant difference among the cowpea genotypes with regard to total number of adult bruchids emerged 90 DAR. Total number of adult bruchids emerged were ranged between 608-2776 with a mean of 1330. The highest number of bruchids (2776) were emerged from seeds of the genotype IC198361 followed by IC214757 (2043), IC259159-1 (1984) and IC249583 (1873); while the lowest number of 608 adult bruchids were recorded from the genotype IC202784 followed by next lowest were IC4506 (883), IC212872 (970), IC253275 (1008) and IC253268 (1009).

### 4.3.4 Bruchid infestation (%)

The results pertaining to the bruchid infestation were presented in Table 18.

Among the 35 genotypes, screened for relative response to bruchid attack artificially; the per cent infestation varied between 42.71 to 97.29 per cent with mean infestation of 80.33 per cent. The genotype IC202784 (42.71%) exhibited least seed damage followed by IC212872 (57.00%). The infestation level of the genotype IC214757 showed heavy damage

Table 17. The protein content (%) of 35 different cowpea genotypes

SI No	Genotypes	Protein content (%)
1	IC257413	17.48
2	IC97787	24.06
3	IC198323	19.71
4	IC198326	22.73
5	IC198333	19.81
6	IC198335	17.85
7	IC198349	18.60
8	IC198361	21.44
9	IC198701	22.28
10	IC201087	18.24
11	IC202789	18.74
12	IC202806	17.33
13	IC202867	19.30
14	IC202868	22.68
15	IC202881	21.11
16	IC214757	18.66
17	IC219574	22.09
18	IC219599	22.65
19	IC212871	18.53
20	IC212872	22.31
21	IC249583	21.02
22	IC253181	21.60
23	IC253268	23.33
24	IC253270	15.73
25	IC253273	18.41
26	IC253275	22.61
27	IC257407	18.43
28	IC259159-1	18.22
29	IC259159-2	13.88
30	IC202784	20.25
31	IC4506	21.49
32	IC5969	20.21
33	Mumbai local	14.42
34	Bailhongal local	20.88
35	C-152	20.95
Mean		19.91
S.Em ±		0.39
CD (0.01)		1.49

Table 18. Varietal resistance and susceptibility in cowpea to bruchid [*Callasobruchus maculatus* (F.)]

Sl. No	Genotypes	Apparent weight loss (%)	Actual weight loss (%)	Mean adult emergence 90 DAR	Bruchid infestation (%)
1	IC257413	23.72	9.47 (17.91)*	1361 (36.90)**	88.41 (70.08)*
2	IC97787	17.90	3.63 (10.98)	1281 (35.81)	68.33 (55.75)
3	IC198323	23.81	21.13 (27.35)	1673 (40.91)	92.75 (74.39)
4	IC198326	23.82	23.81 (29.19)	1313 (36.23)	83.00 (65.68)
5	IC198333	25.11	7.92 (16.33)	1277 (35.75)	81.67 (64.65)
6	IC198335	26.51	5.53 (13.59)	1469 (38.33)	87.33 (69.15)
7	IC198349	18.87	8.50 (16.94)	1065 (32.66)	72.82 (58.55)
8	IC198361	31.03	26.70 (31.04)	2776 (52.68)	92.85 (75.21)
9	IC198701	11.77	10.61 (19.00)	1152 (33.92)	68.07 (55.57)
10	IC201087	24.91	12.43 (20.64)	1420 (37.69)	76.86 (61.24)
11	IC202789	13.89	10.55 (18.94)	1181 (34.37)	68.96 (56.12)
12	IC202806	31.17	15.32 (23.03)	1528 (39.10)	90.85 (72.52)
13	IC202867	27.39	3.14 (10.10)	1545 (39.32)	90.88 (72.68)
14	IC202868	20.47	16.06 (23.62)	1258 (35.49)	88.82 (70.55)
15	IC202881	21.54	13.29 (21.37)	1261 (35.53)	86.74 (69.13)
16	IC214757	28.84	27.02 (31.31)	2043 (45.21)	97.29 (80.51)
17	IC219574	20.94	7.21 (15.57)	1349 (36.74)	70.67 (57.21)
18	IC219599	23.27	6.98 (15.31)	1375 (37.09)	91.74 (73.31)
19	IC212871	16.78	16.18 (23.71)	1241 (35.24)	61.01 (51.34)
20	IC212872	14.66	5.51 (13.56)	970 (31.17)	57.00 (49.00)
21	IC249583	27.19	3.51 (10.79)	1873 (43.29)	85.70 (67.79)
22	IC253181	29.07	4.71 (12.50)	1169 (34.21)	84.69 (67.01)
23	IC253268	17.81	5.50 (13.56)	1009 (31.78)	73.00 (58.69)
24	IC253270	22.75	14.82 (22.63)	1166 (34.16)	81.44 (64.55)
25	IC253273	15.87	8.15 (16.58)	916 (30.28)	82.73 (65.47)
26	IC253275	18.92	5.64 (13.73)	1008 (31.76)	70.89 (57.34)
27	IC257407	27.27	7.45 (15.83)	1248 (35.29)	86.48 (68.92)
28	IC259159-1	29.09	23.12 (28.73)	1984 (44.55)	91.63 (73.39)
29	IC259159-2	23.82	9.79 (18.23)	1257 (35.47)	88.00 (69.88)
30	IC202784	8.87	3.66 (11.02)	608 (24.67)	42.71 (40.78)
31	IC4506	12.61	3.99 (11.52)	883 (29.72)	59.91 (50.70)
32	IC5969	21.89	9.43 (17.88)	1130 (33.63)	79.61 (63.18)
33	Mumbai local	24.59	11.08 (19.43)	1201 (34.67)	86.58 (68.73)
34	Bailhongal local	27.62	16.07 (23.61)	1283 (35.83)	91.56 (73.15)
35	C-152	24.29	6.99 (15.32)	1286 (35.84)	90.71 (72.51)
	Mean	22.23	11.00 (18.59)	1330 (36.15)	80.33 (64.72)
	S.Em ±	0.62	0.64	0.57	1.73
	CD (0.01)	2.40	2.46	2.20	6.48

\* Figures in the parenthesis are arc sin transformed value

\*\*  $\sqrt{n+1}$  transformed values

Table 19. Classification of cowpea genotypes based on per cent seed infestation by bruchids

Class	Per cent seed infestation	Number of genotypes
Highly resistant	0-20	0
Moderately resistant	21-40	0
Least susceptible	41-60	3
Moderately susceptible	61-80	10
Highly susceptible	81-100	22

(97.29%), which was on par with IC198361 (92.85%) and IC198323 (92.75%). The damage level of IC259159-1 (91.63%), IC219599 (91.74%), Bailhongal local (91.56%), IC202867 (90.88%), IC202806 (90.85%) and C-152 (90.71%) were also high and statistically on par with each other. Classification of cowpea genotypes based on per cent seed infestation by bruchids is presented in Table 19.

#### 4.3.5 Seed moisture content (%)

The seed moisture content of different cowpea genotypes at initial, at 90 days after infestation and per cent increase in moisture content after infestation over initial are given in Table 20.

There was a non significant difference among different genotypes at initial seed moisture content showing a narrow range of 10.11 to 11.86 per cent with mean of 11.14 per cent. However, significant difference in seed moisture content among the genotypes was noticed at 90 days after release of bruchid and was varied between 14.85 to 17.03 per cent with mean moisture content of 15.93 per cent. The highest moisture content was recorded in the genotype IC214757 (17.03%), while the genotype IC198323 was recorded lowest (14.85%) moisture content after infestation.

The per cent increase in moisture content after infestation over initial was found significant among cowpea genotypes. The per cent increase was ranged between 26.31 to 62.14 per cent with mean increase of 43.83 per cent. The highest per cent increase in moisture content was recorded in genotype IC214757 (62.14%), which was on par with IC198361 (58.29%) and IC202881 (56.40%). While, IC202784 was recorded lowest (26.31%), which was on par with IC219574 (30.14), IC202789 (30.25%) and IC212871 (31.43%), in per cent increase in moisture content over initial.

#### 4.3.6 Electrical conductivity ( $\text{dSm}^{-1}$ ) of seed leachate

The data on electrical conductivity of seed leachate at initial stage, 90 DAR of bruchids and its per cent increase over initial EC of each of cowpea seeds as influenced by bruchid infestation are presented in the Table 20.

There was significant difference in initial electrical conductivity of cowpea genotypes was observed and ranged between 0.073 to 0.218  $\text{dSm}^{-1}$  with the mean of 0.112  $\text{dSm}^{-1}$ . The lowest electrical conductivity was showed in the genotype IC198361 (0.073  $\text{dSm}^{-1}$ ). Whereas, highest was recorded in IC202784 (0.218  $\text{dSm}^{-1}$ ).

Electrical conductivity of seed leachate at 90 days after release of bruchids also differed significantly among the genotypes and it was ranged between 0.139 to 0.402  $\text{dSm}^{-1}$  with mean electrical conductivity value of 0.316  $\text{dSm}^{-1}$ . The lowest was recorded in IC97787 (0.139  $\text{dSm}^{-1}$ ) followed by IC253275 (0.239  $\text{dSm}^{-1}$ ), IC257413 (0.239  $\text{dSm}^{-1}$ ) and IC198333 (0.241  $\text{dSm}^{-1}$ ), while the highest was recorded in Mumbai local (0.402  $\text{dSm}^{-1}$ ) which was on par with IC214757 (0.394  $\text{dSm}^{-1}$ ), IC249583 (0.394  $\text{dSm}^{-1}$ ), IC198349 (0.387  $\text{dSm}^{-1}$ ) and IC201087 (0.375  $\text{dSm}^{-1}$ ) at 90 days after release of bruchids.

The per cent increase in electrical conductivity among genotypes over initial stage due to infestation was in the range of 33.47 to 375.62 per cent with mean increase of 204.20 per cent. Significantly, the lowest increase was noticed in IC202784 (33.47%), which was on par with IC253268 (69.27%), IC97787 (71.54%), IC198701 (75.34%) and IC212871 (76.75%). The genotype IC198361 showed highest per cent increase in EC (375.62%) which was statistically on par with IC214757 (358.26%).

#### 4.3.7 Seed germination (%)

The seed germination percentage at initial and 90 days after release of bruchids and per cent fall in germination of cowpea seeds as influenced by *Callasobruchus maculatus* infestation is given in the Table 21.

There was significant difference in per cent seed germination. Among the different genotypes at initial and 90 days after release of bruchids, the initial seed germination percentage was highest in Bailhongal local (97.50%) and the lowest in IC212872 (75.25%). Initial mean per cent germination was 88.89 per cent. Whereas, the per cent seed germination at 90 days was maximum in IC198701 (40.25%) and least in Mumbai local (4.75%). The mean germination percentage of 19.06 was recorded at 90 DAR of bruchids.

With respect to per cent fall in germination over initial due infestation among genotypes was in the range of 56.79 to 94.13 per cent with mean fall of 78.45 per cent. Significantly the lowest fall in germination (56.79%) was recorded in the genotype IC212872 which was on par with IC198701 (56.95%) and IC4506 (58.58%). While, the genotype Mumbai local showed the highest fall in germination of 94.13 per cent which was statistically on par with IC198361 (93.28%) and IC5969 (91.43%) followed by IC257413 (90.33%). The per cent fall in germination on check variety C-152 (78.08%) was relatively low as compared to these high per cent fail in germination.

#### 4.3.8 Seedling length (cm)

The data pertaining to seedling length of cowpea genotypes at initial, 90 days after release of bruchids and per cent reduction in seedling length over initial were furnished in Table 21.

There was the significant difference in seedling length among the different genotypes both at initial and after infestation. The initial seedling length of genotypes ranged between 36.08 to 54.58 cm with mean seedling length of 46.40 cm. Significantly highest was recorded in IC253268 (54.58 cm) and lowest was in IC201087 (36.08 cm). whereas, seedling length as influenced by bruchid infestation after 90 days of release bruchids was ranged between 16.53 to 43.80 cm with mean length of 30.17 cm. The genotype IC4506 recorded highest (43.80 cm) while, lowest was in Mumbai local (16.53 cm) which was on par with IC198361 (17.86 cm).

The significant reduction in seedling length at 90 days was noticed. The per cent reduction in seedling length over initial was ranged between 6.12 to 59.65 per cent. The mean reduction was 34.81 per cent among different cowpea genotypes. The highest reduction of 59.65 per cent was observed in IC198361, which was on par with IC202806 (58.28%) and Mumbai local (57.17%) while, lowest reduction of 6.12 per cent in IC4506, which was on par with IC202789 (7.90%) followed by IC198701 (9.82%) and check variety C-152 (15.31%) in per cent reduction of seedling length.

#### 4.3.9 Seedling vigour index

There was significant difference noticed among cowpea genotypes (Table 21) studied with respect to vigour index both at initial and 90 days after release of bruchids. Seedling vigour index at initial stage was ranged between 2865 to 5055 with mean of 4095. The genotype IC219599 was recorded the highest (5085), while the lowest was in IC198349 (2865). Whereas, seedling vigour index at 90 days was ranged between 66 to 1664 with a mean of 598. The seedling vigour index was more in IC4506 (1664), which was on par with IC198701 (1612). The genotype Mumbai local was recorded the least vigour index (66) which was on par with IC198361 (105).

Per cent reduction in vigour index at 90 days was varied significantly among the genotypes (Table 21). The per cent reduction varied between 54.81 to 97.91 per cent with mean reduction of 84.84 per cent in vigour index over initial after infestation. The highest reduction of 97.91 per cent was showed by Mumbai local, which was statistically on par with

Table 20. Effect of *Callosobruchus maculatus* on seed moisture content (%) and electrical conductivity of seed leachate in cowpea genotypes

Sl. No.	Genotypes	Seed moisture content (%)		Per cent increase in MC over initial	Electrical conductivity (dS/m)		Per cent increase in EC Over initial
		Initial	90 DAR		Initial	90 DAR	
1	IC257413	11.47	16.29	42.02	0.085	0.239	181.16
2	IC97787	11.78	15.65	32.82	0.081	0.139	71.54
3	IC198323	10.28	14.85	51.08	0.093	0.363	292.43
4	IC198326	11.01	16.39	48.86	0.105	0.296	183.46
5	IC198333	10.60	16.37	54.43	0.092	0.241	162.03
6	IC198335	11.07	16.37	47.88	0.090	0.364	304.74
7	IC198349	11.24	15.08	34.16	0.130	0.387	197.64
8	IC198361	10.46	16.55	58.29	0.073	0.347	375.62
9	IC198701	11.01	16.01	45.41	0.154	0.270	75.34
10	IC201087	11.58	15.50	33.81	0.116	0.375	223.47
11	IC202789	11.82	15.40	30.25	0.121	0.293	142.32
12	IC202806	10.48	15.46	47.47	0.124	0.333	169.63
13	IC202867	11.04	16.23	46.97	0.083	0.328	295.38
14	IC202868	10.81	16.45	52.17	0.127	0.301	136.99
15	IC202881	10.11	15.81	56.40	0.084	0.306	264.55
16	IC214757	10.50	17.03	62.14	0.086	0.394	358.26
17	IC219574	11.77	15.32	30.14	0.122	0.339	177.95
18	IC219599	11.16	15.32	37.23	0.081	0.341	321.05
19	IC212871	11.79	15.50	31.43	0.181	0.319	76.75
20	IC212872	11.43	15.40	34.69	0.094	0.285	203.28
21	IC249583	10.67	16.57	55.25	0.112	0.394	251.78
22	IC253181	11.61	15.85	36.56	0.091	0.305	239.02
23	IC253268	11.58	16.59	43.24	0.158	0.266	69.27
24	IC253270	11.41	16.43	43.98	0.123	0.320	160.16
25	IC253273	10.81	16.61	53.62	0.083	0.314	278.72
26	IC253275	11.49	15.83	37.80	0.082	0.239	191.49
27	IC257407	10.26	15.24	48.52	0.089	0.278	212.72
28	IC259159-1	10.82	16.35	51.09	0.085	0.362	326.50
29	IC259159-2	10.83	15.67	44.72	0.080	0.324	305.13
30	IC202784	11.86	14.98	26.31	0.218	0.291	33.47
31	IC4506	11.20	16.45	46.88	0.156	0.289	85.36
32	IC5969	10.90	16.07	47.46	0.113	0.349	209.10
33	Mumbai local	11.45	16.29	42.26	0.182	0.402	120.91
34	Bailhongal local	11.65	15.50	33.01	0.098	0.348	254.93
35	C-152	11.12	16.23	45.95	0.114	0.336	194.79
	Mean	11.12	15.93	43.83	0.112	0.316	204.20
	S.Em ±	0.51	0.35	1.53	0.003	0.007	10.63
	CD (0.01)	NS	1.35	5.92	0.013	0.025	41.02

MC- Moisture content

EC – Electrical conductivity

Table 21. Effect of *Callosobruchus maculatus* on seed germination (%), seedling length (cm) and vigour index in cowpea genotypes

Sl. No.	Genotypes	Germination (%)		Per cent fall in germination over initial	Seedling length (cm)		Per cent reduction in seedling length over initial	Vigour index		Per cent fall in vigour index
		Initial	90 DAR		Initial	90 DAR		Initial	90 DAR	
1	IC257413	85.50 (67.60)*	8.25 (16.64)	90.33	39.74	26.46	33.56	3398	191	94.38
2	IC97787	91.50 (73.16)	24.50 (29.64)	73.18	46.54	33.62	27.70	4258	752	82.35
3	IC198323	86.75 (68.82)	26.00 (30.63)	69.97	50.88	34.72	31.32	4414	826	81.29
4	IC198326	93.25 (75.00)	30.50 (33.51)	67.30	54.04	42.58	21.21	5039	1193	76.33
5	IC198333	89.50 (71.15)	26.25 (30.81)	70.66	44.70	29.18	34.72	4001	725	81.88
6	IC198335	93.75 (75.60)	20.50 (26.90)	78.12	43.30	25.00	42.26	4059	544	86.60
7	IC198349	82.75 (65.47)	30.75 (33.66)	62.84	43.90	34.64	21.08	2865	1180	58.82
8	IC198361	89.50 (71.09)	6.00 (14.05)	93.28	44.26	17.86	59.65	3961	105	97.35
9	IC198701	93.50 (75.25)	40.25 (39.36)	56.95	44.40	40.04	9.82	4151	1612	61.17
10	IC201087	85.75 (67.91)	20.25 (26.73)	76.34	36.08	20.06	44.40	3094	406	86.88
11	IC202789	86.25 (68.21)	30.00 (33.20)	65.22	44.44	40.94	7.90	3531	1326	62.45
12	IC202806	86.75 (68.83)	10.50 (18.87)	87.85	49.54	20.67	58.28	4298	217	94.95
13	IC202867	81.25 (64.40)	10.25 (18.66)	87.35	51.10	40.36	21.01	4152	356	91.43
14	IC202868	78.50 (62.39)	16.00 (23.56)	79.61	51.76	34.12	33.92	3533	541	84.68
15	IC202881	93.00 (75.20)	24.00 (29.32)	74.14	51.50	22.70	55.67	4790	586	87.77
16	IC214757	80.50 (63.80)	8.75 (17.18)	89.15	43.20	33.44	22.13	3478	256	92.64
17	IC219574	91.00 (72.53)	14.00 (21.90)	84.60	42.74	23.00	46.19	3889	326	91.61
18	IC219599	93.50 (75.25)	24.50 (29.64)	73.78	54.06	28.60	47.10	5055	643	87.27
19	IC212871	87.50 (69.29)	32.75 (34.88)	62.54	45.60	34.30	24.78	3990	1098	72.49
20	IC212872	75.25 (60.16)	32.50 (34.74)	56.79	41.52	28.60	31.12	3093	1059	65.76
21	IC249583	90.50 (72.44)	12.50 (20.68)	86.14	37.72	28.06	25.31	3414	342	89.99
22	IC253181	91.50 (73.39)	10.75 (19.09)	88.28	46.54	24.40	47.57	4258	239	94.39
23	IC253268	92.25 (73.81)	12.25 (20.42)	86.72	54.58	38.20	30.01	5035	470	90.66
24	IC253270	93.25 (75.10)	16.00 (23.56)	82.85	51.36	29.80	41.98	4789	422	91.18
25	IC253273	88.75 (70.44)	16.00 (23.56)	81.97	50.92	33.70	33.78	4519	485	89.27
26	IC253275	89.50 (71.60)	14.25 (22.16)	84.01	44.00	22.20	49.44	3938	329	91.64
27	IC257407	87.75 (70.11)	14.75 (22.56)	83.00	44.12	25.38	42.48	3872	322	91.69
28	IC259159-1	95.25 (79.14)	10.00 (18.37)	89.44	50.00	22.13	55.68	4763	213	95.52
29	IC259159-2	91.25 (73.57)	10.25 (18.59)	88.68	52.60	27.08	48.17	4800	232	95.17
30	IC202784	85.25 (67.44)	26.50 (30.96)	68.93	50.74	36.30	28.07	4326	902	79.14
31	IC4506	91.75 (73.35)	38.00 (38.04)	58.58	46.66	43.80	6.12	4281	1664	54.81
32	IC5969	96.25 (78.82)	8.25 (16.67)	91.43	48.78	35.65	26.74	4695	263	94.39
33	Mumbai local	81.50 (64.79)	4.75 (12.49)	94.13	38.60	16.53	57.17	3146	66	97.91
34	Bailhongal local	97.50 (81.12)	16.00 (23.56)	83.58	43.66	27.40	36.87	4257	411	90.36
35	C-152	93.50 (75.25)	20.50 (26.89)	78.08	40.60	34.38	15.31	4181	628	84.99
	Mean	88.89 (71.18)	19.06 (25.19)	78.45	46.40	30.17	34.81	4095	598	84.84
	S.Em ±	0.93	1.64	0.61	0.92	0.57	0.77	86.35	17.03	1.24
	CD (0.01)	3.43	6.10	2.27	3.43	2.11	2.84	333.20	65.71	4.80

\* Figures in the parenthesis are arc sin transformed value

IC198361 (97.35%), IC259159-1 (95.52%), IC259159-2 (95.17%), IC202806 (94.94%), IC253181 (94.39%), IC5969 (94.39%), IC257413 (94.38%) and IC214757 (92.64%); whereas lowest reduction of 54.81 per cent was showed by IC4506, which was on par with IC198349 (58.82%). The check variety C-152 showed comparatively more reduction (84.99%) in seedling vigour index after infestation.

#### 4.3.10 Correlation analysis

The correlation coefficients worked out between pairs of variables is presented in Table 22.

From the Table, it can be seen that in whole, majority of cases of correlation values between seed characters and bruchid damage characters are negatively correlated and also significant. Hence, inference can be drawn that with increase in bruchid damage characters like adult emergence, seed weight losses, bruchid infestation there had been decrease in seed germination, seedling length, vigour index was showed except for seed moisture content and electrical conductivity were positively correlated and significant. Whereas, with respect to adult emergence and infestation, weight losses were positively and highly significantly correlated.

The results also revealed that, the correlation between seed size, hundred seed weight and seed protein content with bruchid damage characters viz., adult emergence, seed weight losses and bruchid infestation were non-significant. Hence, inference can be drawn, the size, weight and protein content of seeds had no influence on the susceptibility or resistant of cowpea seeds to *Callasobruchus maculatus*.

Table 22. Correlation coefficients between seed characters and bruchid damage characters in cowpea genotypes

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>	X <sub>17</sub>
X <sub>1</sub>	1.00																
X <sub>2</sub>	0.91**	1.00															
X <sub>3</sub>	0.12	0.04	1.00														
X <sub>4</sub>	-0.09	-0.05	0.05	1.00													
X <sub>5</sub>	-0.04	-0.09	0.34	-0.36*	1.00												
X <sub>6</sub>	-0.13	-0.18	0.31	0.08	0.56**	1.00											
X <sub>7</sub>	-0.06	-0.13	0.33	-0.24	0.96**	0.71**	1.00										
X <sub>8</sub>	-0.10	-0.11	-0.43*	0.00	-0.29	-0.26	-0.27	1.00									
X <sub>9</sub>	-0.24	-0.34	-0.09	0.21	-0.44*	-0.38*	-0.44*	0.40*	1.00								
X <sub>10</sub>	-0.34	-0.33	-0.28	0.18	-0.67**	-0.57**	-0.72**	0.42*	0.74**	1.00							
X <sub>11</sub>	-0.04	-0.07	-0.26	0.02	-0.11	-0.16	-0.12	0.35*	0.45*	0.31	1.00						
X <sub>12</sub>	-0.28	-0.31	-0.27	0.31	-0.60**	-0.35*	-0.61**	0.43*	0.71**	0.84**	0.44*	1.00					
X <sub>13</sub>	-0.22	-0.20	-0.10	0.63**	-0.31	-0.05	-0.27	0.23	0.54**	0.46*	0.32	0.65**	1.00				
X <sub>14</sub>	-0.05	0.01	-0.32	0.39*	-0.99**	-0.55**	-0.95**	0.27	0.45*	0.69**	0.12	0.63**	0.33	1.00			
X <sub>15</sub>	0.14	0.20	-0.27	-0.04	-0.59**	-0.90**	-0.73**	0.19	0.32	0.56**	0.26	0.39*	0.12	0.59**	1.00		
X <sub>16</sub>	-0.02	0.08	-0.27	0.28	-0.92**	-0.63**	-0.97**	0.20	0.42*	0.70**	0.16	0.63**	0.31	0.93**	0.71**	1.00	
X <sub>17</sub>	-0.17	-0.17	-0.20	0.09	-0.45*	-0.39*	-0.50**	0.52**	0.67**	0.67**	0.32	0.75**	0.50**	0.44*	0.40*	0.46*	1.00

\* Significant at 5% level  
0.47

X<sub>1</sub> – Seed size (mm)  
X<sub>4</sub> – Seed moisture content at 90 DAR  
X<sub>7</sub> – Vigour index at 90 DAR  
X<sub>10</sub> – Apparent weight loss (%)  
X<sub>13</sub> – Per cent increase in moisture content  
X<sub>16</sub> – Per cent fall in vigour index

\*\* Significant at 1% level

X<sub>2</sub> – Hundred seed weight (g)  
X<sub>5</sub> – Seed germination (%) at 90 DAR  
X<sub>8</sub> – Electrical conductivity (dS/m) at 90 DAR  
X<sub>11</sub> – Actual weight loss (%)  
X<sub>14</sub> – Per cent fall in germination  
X<sub>17</sub> – Per cent increase in electrical conductivity

P (0.05) = 0.35

P (0.01) =

X<sub>3</sub> – Protein content (%)  
X<sub>6</sub> – Seedling length (cm) at 90 DAR  
X<sub>9</sub> – Total adult emergence at 90 DAR  
X<sub>12</sub> – Bruchid infestation (%) at 90 DAR  
X<sub>15</sub> – Per cent reduction in seedling length

## 5. DISCUSSION

The varietal description for identification of crop varieties has assumed significant importance in national and international seed programmes and there is a considerable need for the development of reliable methods and identifiable characters for the purpose. A genetically homozygous basic seed stock is a primary requirement for absolute uniformity in any variety. Varieties in general are variable when they are introduced or released. No variety is absolutely uniform but all individual's react exactly alike, to a given set of environmental conditions. There is a danger that one type in the population of a variety may be more prolific in its characteristics. To prevent build up of these undesirable types, seed grower need to have most uniform basic seed stock. By following a varietal maintenance programme coupled with good seed production practices, deterioration of varietal characters can be prevented (Ramamoorthy *et al.*, 2010).

Cowpea is an important source of food worldwide and occupied an important place in the vegetarian diets of many countries as an excellent and inexpensive source of protein. The genetic improvement in the nutritional quality of locally adapted and desirable cowpea cultivars deserve an urgent attention in order to avert malnutrition, hunger and other deficiencies. There has been lot of variation exists among different genotypes with regard to relative susceptibility against stored pests in various crops with no exception to pulses.

In the present investigation, attempts to characterize some of the cowpea genotypes on the basis of seed, seedling and plant morphological characters along with evaluation of seed protein content and screening of cowpea genotypes for their relative response to the attack by bruchids [*Callosobruchus maculatus* (F)]. The results generated from above experiments have been discussed separately in following pages in this chapter.

### 5.1 Seed morphological characters

Seed morphological characters are useful in development of varietal identification keys and also in genetic purity testing. The seed characteristics such as seed coat colour, lusture, shape, size, hilum colour, hundred seed weight have been recorded and based on the variation in these characteristics, genotypes were grouped into different categories and identification keys were prepared (Fig. 3).

#### 5.1.1 Seed qualitative characters

The seed colour is one of the important parameter useful in varietal identification. Based on the variations in the seed colour, the genotypes were grouped as white, creamish white, creamish brown, light brown, brown, dark brown, mottled and grey. Mottled genotype was IC198326, Creamish brown were IC97787 and IC202868, whereas three were white, six were creamish white, four were light brown, ten were brown, four were grey and remaining all genotypes were dark brown seed colour. Similar groupisum based on seed colour were reported by Sankrapandian (2002) in cowpea; Gnyandev (2009) in chickpea; Ashok *et al.* (2008), Chandrashekhar (2005 and 2008) in french bean; Suhasini (2006) in sesame and Khare *et al.* (2009) in linseed. Though, seed coat colour is a heritable character and variation in seed colour is due to presence of phytan content in cowpea (Nagalakshmi *et al.*, 2009) and it is also influenced by environmental conditions such rainfall during harvest and incidence of the diseases.

A fair grouping of the cowpea genotypes was made based on hilum colour as black (11 genotypes) and brown (24 genotypes). The similar work also reported by Henshaw (2008), Naima *et al.* (2009) in cowpea; Ravikumar (1999), Roopa Anantareddy (2008) in soybean; Ashok *et al.* (2008) in french bean. Drabo *et al.* (1988) noted that incomplete dominance of several seed coat pattern genes including hilum colour trait.

The marked variation was observed in seed shape for different cowpea genotypes. Only three found ovoid in seed shape (IC219599, IC212871 and Mumbai local), seven were found kidney shaped, remaining all found rhomboid shaped. Similar classification was also reported in cowpea seed shape by many workers Nkouannessi (2005), Naima *et al.* (2009) and Henshaw (2008); Gnyandev (2009) in chickpea; Ashok *et al.* (2008) in french bean. Richard and Payne (1979) reported that the seeds of the same cultivar may vary in shape.

This may be due to genetic characters of the varieties, the position of seed in pod and may be influenced by environmental conditions during the pod filling stage.

A fair grouping of the cowpea genotypes based on seed coat lusture was made and were grouped as shiny (14 genotypes), dull (17 genotypes) and intermediate (IC257413, IC97787, IC198349 and C-152). Similar type of work was reported by Jain and Khare (2002a) in green gram.

Richard and Payne (1979) said that seed qualitative characters for comparisons valid when the seed crop is not adversely affected by rains, mould or any other biotic or abiotic factors. The crop is grown under similar agroclimatic conditions as that of the standard reference sample.

### 5.1.2 Seed quantitative characters

Hundred seed weight varied significantly among the genotypes and ranged from 7.49 g (IC4506) to 20.72 g (IC212872) with mean weight of 12.94 g. Based on this, genotypes were grouped as light (<12 g), medium (12-15 g) and heavy (>15 g). Among the genotypes, 12 were light, 17 were medium and six cultivars had heavy weight seeds. The same pattern of classification was reported earlier by Elsaed (1967) in broad bean; Chakrabarthy and Agrawal (1989) in black gram; Gnyandev (2009) in chickpea and similar variations in seed weight was noticed by Nkouannessi (2005), Henshaw (2008), Naima *et al.* (2009) and Stoilova and Berova (2009) in cowpea. The variation among the genotypes may be due to inherent genotypic differences that had existed during the crop growth, seed development and maturation. The genotypic variation in test weight may also be due to the varied capacity of the genotype to utilize the reserved food material.

The marked variation was also observed in seed size and it was ranged from 4.47 mm (IC4506) to 7.13 mm (IC212872) with mean seed size of 5.69 mm. Based on this, genotypes were grouped as small (IC198326, IC198335, IC4506), medium (25 genotypes) and bold (seven genotypes). Similar type variation in seed size was reported by Henshaw (2008) and Stoilova and Berova (2009) in cowpea; Gnyandev (2009) in chickpea; Sharma *et al.* (1991) in greengram. The bold seed size was dominant over small and proposed the symbol 'Bg' for this gene in cowpea (Karkannavar *et al.*, 1991). The variation in seed size in terms of length, breadth and thickness are under genetic control in most of the crops. Drabo *et al.* (1984) concluded that the gene action controlling seed size is predominantly additive.

## 5.2 Seedling characters

The genotypes under present study did not vary in their pigmentation on hypocotyl. All genotypes were showed absence of pigmentation on hypocotyl.

## 5.3 Plant morphological characters

Use of plant diagnostic characters to identify a variety has been classical taxonomic approach for both varietal purity testing and varietal identification. The plant morphological characters such as pigmentation on stem, pubescence on stem, plant growth pattern, plant growth habit, plant height and number of primary branches per plant were observed and classified into different groups. Based on the grouping identification keys were prepared (Fig. 4).

The stem pigmentation is one of the conspicuous characteristics in varietal identification. Based on the stem pigmentation, the genotypes were grouped into present and absent. The only one genotype IC97787 showed presence of pigmentation on stem and remaining all were showed absence. Similar grouping was earlier reported by Nkouannessi (2005) in cowpea; Jain and Khare (2002b) in green gram; Yadav and Srivastava (2002) and Gnyandev (2009) in chickpea. The stem pigmentation is under genetic control and it may also be affected by light intensity and temperature prevailing during the crop growth (Chakrabarthy and Agrawal, 1989b). Karkannavar *et al.* (1991) reported that two duplicate genes (Pp-1 and Pp-2) responsible for stem pigmentation. These two duplicate genes may be present in IC97787 genotype.

Though Nkouannessi (2005) observed variation in stem pubescence as glabrescent, short appressed hairs and pubescent to hirsute in cowpea genotypes, the genotypes under



the present study did not varied in their stem pubescence. The pubescence on stem was absent in all the genotypes under study.

Based on plant growth pattern, genotypes were grouped into determinate (IC257413, IC97787, IC202868, IC214757, Mumbai local and Bailhongal local), semi determinate (IC202789, IC259159-2) and indeterminate (27 genotypes) variation in growth pattern is due to the genetic characters of genotypes. Similar results and grouping were reported by Nkouannessi (2005), Sarutayophat *et al.* (2007) in cowpea; Jain and Khare (2002b) in green gram. Determinate and indeterminate expressions of plant are stable but semi determinate expression is highly influenced by environment (Jain and Khare, 2002b).

The plant growth habit also varied among the cowpea genotypes based on this, genotypes were grouped into erect, semi spreading and spreading types. All determinate genotypes were showed erect (Six genotypes), 17 were semi spreading and 12 were spreading. Variation in this character is also under genetic control. Similar grouping was reported by Boema *et al.* (1990) in soybean and Muthaiah (2006) in green gram.

The plant height is one of the important characteristics, which helps in differentiating the genotypes. Based on this character, the genotypes were grouped under dwarf, medium and tall. The cowpea genotypes exhibited significant variability in plant height ranging from 9.93 cm (IC198361) to 29.88 cm (C-152) with a mean height of 19.97 cm. The genotypes C-152 and Bailhongal local were in tall; four were dwarf and remaining all were medium in height. The results are in accordance with Nkouannessi (2005), Lingaraj (2009) in cowpea; Tarasatyavathi *et al.* (2004), Manjaya and Bapat (2008) in soybean; Suhasini (2006) and Parameshwarappa *et al.* (2009) in sesame. Wide variation in plant height was due to genetic characters of the varieties and also might be influenced by agronomical and environmental conditions.

The number of primary branches determines ultimately, the pod bearing ability of plant which will intern contributes to the yield, hence identification and selection of genotypes with more branching ability is necessary. In the present study, the genotypes exhibited varied branching ability ranging from 3.67 (Mumbai local) to 7.17 (IC219599) with a mean branches of 5.47. Based on this, 35 genotypes grouped into less (<4), medium (4-6) and high (>6). Only one genotype Mumbai local had less, eight genotypes were medium and remaining all was medium. Similar observation are reported by Nkouannessi (2005), Lingaraj (2009) in cowpea; Muhammad Arshad *et al.* (2006), Purnima *et al.* (2008) in soybean; Suhasini (2006) and Sudhakar *et al.* (2007) in sesame. The variation in the branches was mainly due to genetic factors and it also affected by environmental condition, sowing seasons, seed rate and spacing (Weiss, 1971).

## 5.4 Leaf characteristics

The leaf colour is one of the important characters used for grouping of the genotypes. The leaf colour depends upon the intensity of chlorophyll pigmentation which intern varies with genotypes according to their genetic constitution. The genotypic variation in colour of leaf is also governed to some extent by the varied response to environmental conditions such as light intensity and nutrition. Thus, in the present investigation, leaf colour of the cowpea genotypes varied from pale green to dark green. Among the 35 genotypes, nine were pale green, seven were dark green and remaining all were intermediate. Similar results were reported earlier by Nkouannessi (2005) in cowpea; Jain and Khare (2002a) in green gram; Surendra and Singhal (1997) in pea.

## 5.5 Flower characters

Based on the flower characteristics *viz.*, days to 50 per cent flowering and flower colour, the genotypes were grouped into different categories. These characteristics are also useful in genetic purity testing of the seed lots.

The days to 50 per cent flowering varied with the genotypes, ranging from 45.33 days (IC259159-2) to 55.67 days (C-152) with an average of 49.39 days. Based on this, genotypes were grouped into early (<48 DAS), medium (48-52 DAS) and late (>52 DAS). Among the 35 genotypes, 10 were early, 21 were medium and four were late. These observations are in accordance with Sarutayophat *et al.* (2007), Stoilova and Berova (2009), Naima *et al.* (2009), Lingaraj (2009) in cowpea; Muhammad Arshad *et al.* (2006) in soybean; Suhasini (2006) in

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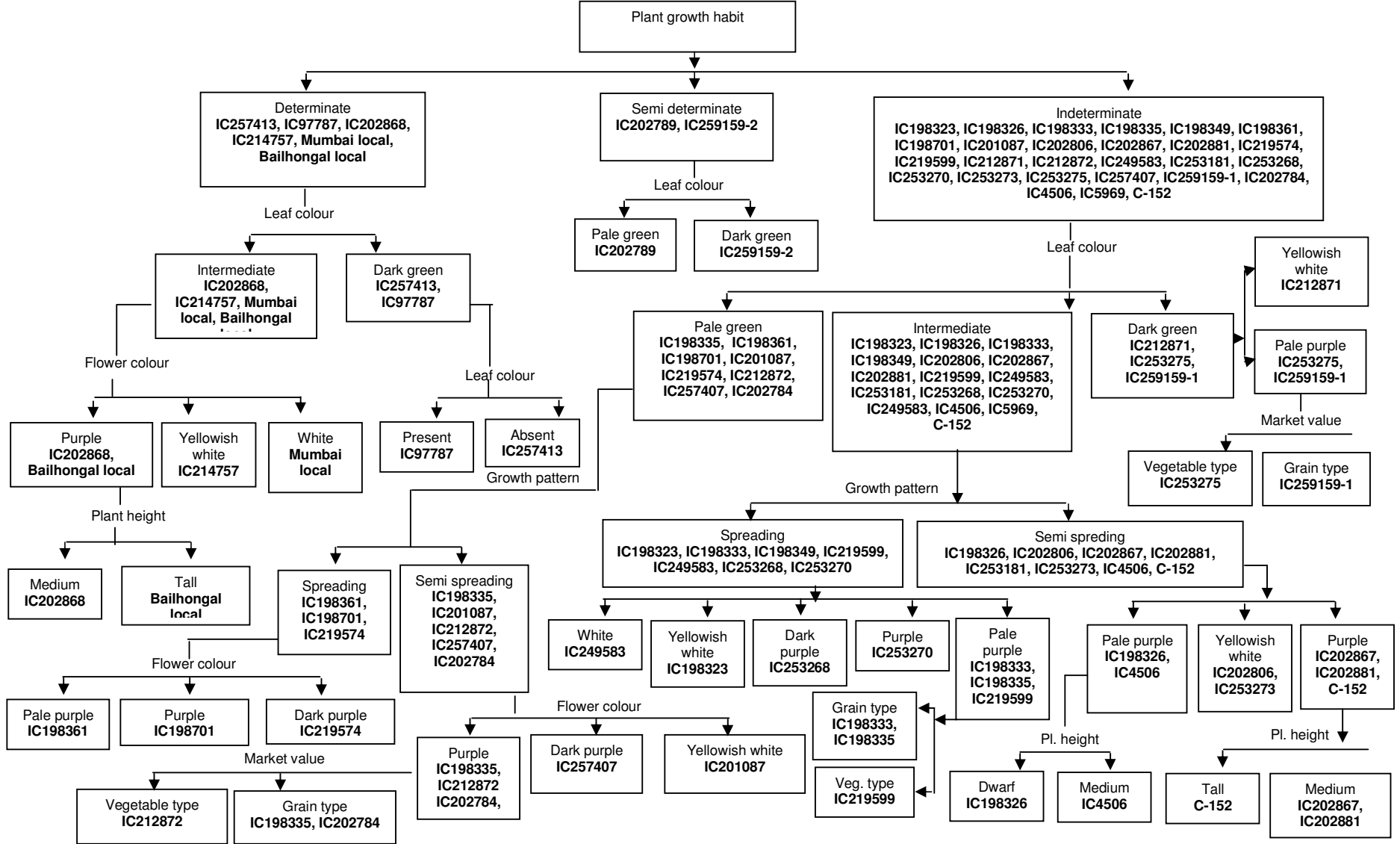


Fig. 4. Identification keys for cowpea genotypes based on plant characters

sesame. Reasons attributed for difference in days to flowering among the genotypes is that, the character is dependent on a minor gene complex (Weiss, 1971) and Adu-Dapaah *et al.* (1988) also observed tendency for dominance of early flowering in cowpea. The environmental conditions also have selective influence on flowering.

The flower colour is one of the important characters for characterization. Based on variation in the flower colour, the genotypes were grouped as white (IC249583 and Mumbai local), yellowish white (six genotypes), pale purple (10 genotypes), purple (14 genotypes) and dark purple (three genotypes). The genotypes IC249583 and Mumbai local can be easily identified because they possessed white flower. Similar results were observed by Nkouannessi (2005) in cowpea; Ashok *et al.* (2008) in french bean; Muthaiah (2006) in green gram; Tarasatyavathi *et al.* (2004) in soybean. The actions of the genes were responsible for variations in the flower colour of the genotype. The genes determine the colour of the petal by developing or blocking of anthocyanin pigmentation.

## 5.6 Pod characteristics

The pod characteristics influence the yielding ability of the plant. The phenotypic variation was observed for various characteristics such as immature pod pigmentation, pod position, pod attachment to peduncle, number of clusters per plant, number of pods per peduncle, number of pods per plant, pod length, number of seeds per pod, mature pod colour, pod constriction, days to maturity, seed yield per plant and per hectare and market value which helps for classification of the genotypes. Based on these characters, the genotypes were categorized into different groups under present study and identification keys were prepared (Fig. 5).

The immature pod pigmentation is one of the important characteristics in cowpea. The lot of variation was observed for this character in present study. Based on the variation, the genotypes were grouped into none (no pigmentation or green colour pods), pigmented tip, splashes of pigment and uniformly pigmented. The genotype IC97787 was uniformly pigmented, IC198326 showed splashes of pigment, whereas seven genotypes showed pigmented tip and remaining all were none i.e. green coloured pods. Similar results were reported by Nkouannessi (2005), Naima *et al.* (2009) in cowpea; Jain and Khare (2002b) in green gram. The expression of the trait is stable and uniform (Jain and Khare, 2002b). The exact reason for pigmentation was not known.

The raceme position and attachment to peduncle in cowpea genotypes differed distinctly. The raceme position in IC257413, IC198333, IC198349, IC202867, IC2027854 and C-152 was throughout canopy and remaining all were above canopy; whereas with respect to pod attachment IC198326, IC202867, IC253270, IC253273, IC259159-1 and IC259159-2 were 30°-90° down from erect and remaining all were pendent. These observations are in accordance with as reported by Nkouannessi (2005) in cowpea; Jain and Khare (2002b) in greengram. These characters are under genetic control and heritable.

The number of clusters per plant varied significantly among the cowpea genotypes and ranged from 17.67 (Mumbai local) to 69.83 (IC253270). Based on this character, the genotypes were grouped as less (IC1983361, IC2028687 and Mumbai local) medium (24 genotypes) and more (eight genotypes). The variation may be due to genotypic ability of plant itself and varied response to environmental conditions and nutritional status of the soil to some extent.

The number of pods per peduncle also varied significantly among the cowpea genotypes and ranged from 1.33 (Mumbai local) to 3.00 (IC202789) with mean number of 2.07. Based on this variation, fair grouping was made as few (<2.0) and more (>2.0). Similar grouping was reported earlier by Nkouannessi (2005) in cowpea. It might be the genetic factor of particular genotype.

The number of pods per plant varied among the genotypes with highest pods noticed in the genotype IC253270 (107.00) and least was observed in genotype Mumbai local (23.47). Based on this character, the genotypes were grouped as less (<40), moderate (40-60), high (60-90) and very high (>90) pod bearing types. The genotypes IC202789 (105.25), IC253181 (95.50) and IC253270 (107.00) recorded superiority very high number of pods per plant. Similar variation were observed by Nkouannessi (2005), Sarutayophat *et al.* (2007), Stoilova and Berova (2009), Lingaraj (2009) in cowpea; Yadav and Srivastava (2002),

Gnyandev (2009) in chickpea; Suhasini (2006) in sesame. The variation in pod number may be due to pod bearing ability of the genotype itself and varied response to environmental conditions and nutritional status of the soil to some extent.

The pod constriction at maturity also varied within the genotypes. Based on this, genotypes were grouped as least (11 genotypes), medium (18 genotypes) and high (six genotypes). Similar grouping was earlier reported by Jain and Khare (2002b) in greengram; Ashok *et al.* (2008) in french bean. The expression of constrictions on pod is uniform and stable character. Therefore, it can be used to verify the genetic purity (Jain and Khare, 2002b).

The days to maturity varied with the genotypes ranging from 82.33 days (IC4506) to 97.33 days (IC202867) with average days to maturity of 89.58. Eight were grouped as early (<85 days), six were grouped as late (>95 days) and remaining all were grouped as medium (85-95 days). Similar type of variation and grouping was reported earlier by Stoilova and Berova (2009) in cowpea; Tarasatyavathi *et al.* (2004) in soybean; Yadav and Srivastava (2002) in chickpea; Suhasini (2006) in sesame genotypes. Though the duration of the crop growth is a genetically controlled character it is also influenced by the environment and crop growth conditions such as soil moisture *etc.*

The pod length varied among the genotypes. Based on this variation in pod length, the genotypes were grouped as short (<15 cm), medium (15-20 cm) and long (>20 cm). The largest was observed in IC219599 (25.77 cm) and shortest was in IC4506 (12.53 cm) with mean pod length of 18.64 cm. Among the 35 genotypes, three were short, nine were long and remaining all were medium. The similar variation was earlier reported by Nkouannessi (2005), Sarutayophat *et al.* (2007), Naima *et al.* (2003), Lingaraj (2009) in cowpea; similar grouping was reported by Jain and Khare (2002b) in green gram; Gupta and Gupta (1977), Suhasini (2006) in sesame. Singh *et al.* (1997b) reported that pod length is moderately to highly heritable with an average heritability value of 70 per cent indicating the genetic influence in determining the pod length in cowpea.

The variation in number of seeds per pod also found significant. Based on variation cowpea genotypes were grouped into low (<14), medium (14-18) and high (>18) number of seeds per pod. The highest number of seeds were recorded in IC198335 (20.08) and lowest was in IC214757 (9.53). Similar difference in seeds number was earlier noticed by Nkouannessi (2005), Naima *et al.* (2009) in cowpea. Singh *et al.* (1997b) reported that the number of seeds per pod is moderately to highly heritable with an average heritability value of 64 per cent. Ogunbodebe and Fatunla (1985) demonstrated that seed crowding within the pod was due to the additive gene effects. These reports indicated that the genetic influence in determining the seeds per pod in cowpea.

A fair grouping of the cowpea genotypes were made based on pod colour at maturity as straw (21 genotypes) and brown (14 genotypes). Similar grouping was earlier reported by Sarutayophat *et al.* (2007) in cowpea; Jain and Khare (2002b) in greengram. The variation in the pod colour is due to genetic control.

The seed yield per plant and hectare was also varied significantly with genotypes. Based on seed yield per plant and per hectare, the genotypes were grouped into four categories as low, moderate, high and very high yielder. With respect to seed yield per plant concern, the seed yield ranged from 20.94 g (Mumbai local) to 110.01 g (IC253181) with mean of 57.69 g, while seed yield per hectare concern, it ranged from 564.1 kg (Mumbai local) to 3194.4 kg (IC202881) with average yield of 1405.4 kg. Similar variation and classification was reported earlier by Sarutayophat *et al.* (2007), Stoilova and Berova (2009) in cowpea; Purnima *et al.* (2008) in soybean.

The difference in seed yield depends upon days to maturity; usually late and early maturity varieties gave high and low seed yield, respectively. This is also inherent capacity of genotype, seed size, influence of cultural practices and environmental conditions and important thing was due to per cent field emergence. Siddique and Gupta (1991) reported that additive gene effects were important in conditioning seed yield in cowpea.

Based on the market value, the 35 genotypes were classified into grain type and vegetable types according to classification given by IBPGR, descriptors for cowpea (Anon., 1983). The genotypes IC219599, IC219872, IC249583, IC253275 and Mumbai local were



grouped under vegetable type and remaining were grain type. This variation may be due to genetic character of the genotype.

## 5.7 Genetic diversity

Genetic relationship existing among germplasm can be measured by similarity or dissimilarity of any number of quantitative characters assuming that the differences between characters of genotypes reflect the divergence of genotypes. In heterosis breeding programme, the diversity of parents is always emphasized. More diverse the parent within a reasonable range, better the chances of improving economic character under consideration, in the resulting offspring.

In the present investigation, objective was to know the genetic diversity in a set of 35 germplasm of cowpea for 13 characters. The diversity was determined by using Mahalanobis  $D^2$  statistics. It also helped to know the relative distances between these genotypes for the characters under study.

### 5.7.1 Genetic diversity in different groups

The maximum  $D^2$  value of 40.89 was between the cluster XVII and XVIII, while the lowest  $D^2$  value of 7.64 was observed between cluster IV and VI. Based on  $D^2$  values 35 cowpea genotypes were grouped into eighteen clusters. There were 16 genotypes in cluster I, two genotypes each in cluster II and X and remaining all were solitary clusters. The solitary clusters may be due to total isolation preventing the formation of gene flow or natural or human selection for diverse adaptive complexes.

The intra cluster distance varied from 6.68 in cluster II to 8.82 in cluster I. This indicates the presence of divergent genotypes within these clusters. It is desirable to select genotypes from clusters showing high inter cluster distance (cluster XVII and XVIII) and also with high seed yield as parents in hybridization programme for obtaining desirable segregants.

### 5.7.2 Contribution of characters towards divergence

In the present investigation among the 13 quantitative characters studied, the most important character contributing to the divergence was seed size, this was followed by pod length, protein content, hundred seed weight and number of clusters per branch. These observations were in accordance with Backiyarani *et al.* (2000).

### 5.7.3 Cluster mean analysis

It is difficult to decide the cluster having best genotypes solely based on ranking method whenever many yield attributing traits are involved for analysis.

So, in present study simple and weighted scores analysis was done in cowpea germplasm lines for important quantitative traits based on cluster means (Table 23).

#### 5.7.3.1 Simple score analysis

In case of simple scores analysis, the ranking of I, II, III was given for 18 clusters with respect to important quantitative traits namely, number of pods per plant, pod length (cm), number of seeds per pod, 100 seed weight (g), days to maturity, seed protein content (%) and seed yield per plant (g). The scores were totaled across the characters to arrive at simple score value. Each of the ranks (I-II) will receive for each character will receive a point of one which gets cumulative added of to have the final simple scores for each cluster. Any cluster having the highest simple score value which found to be accommodative superior genotypes for various quantitative traits listed above. In the present study, the cluster VIII scored highest simple score of 4 and hence harbors the potential genotypes for yield and yield attributing traits followed by cluster VI, IX, XIV, XV and XVI which have final score 2.

#### 5.7.3.2 Weighted score analysis

In a crop like cowpea different quantitative traits, contribute differentially towards yield per se. Hence, in the present study different weights were given to the yield attributing traits based on the experience of several cowpea breeders. These weights were used to decide the superiority of the cluster. Based on weighted scores, the cluster VIII was found to possess desirable genotypes for yield per se, protein content and other yield related traits (Table 23).

Table 23. Simple and weighted scores for important quantitative traits in cowpea germplasm lines based on cluster means

↓ Cluster	No. of pods per plant	Days to maturity	Pod length (cm)	No. of seeds per pod	100 Seed weight (g)	Seed yield per plant (g)	Seed protein content (%)	Simple scores	Weighted scores
Weights	5	3	4	4	5	7	6		
I	63.62	90.47	17.94	16.80	12.19	63.90	20.03		
II	54.50	89.00	14.65	11.39	10.57	41.23	18.44		
III	59.17	84.00	19.60	16.08	11.40	45.53	22.74 II	1	6
IV	55.50	91.00	18.40	15.00	15.75	36.04	20.25		
V	56.17	96.00	18.15	17.62 III	11.54	62.59	20.95	1	4
VI	52.83	90.50	22.80 III	15.03	16.75 III	61.35	18.42	2	9
VII	77.33 III	96.50	17.40	16.50	12.02	53.13	17.33	1	5
VIII	82.42 II	83.50 III	19.00	18.52 II	12.43	108.11 I	22.09	4	17
IX	45.40	83.00 II	20.55	15.25	14.62	38.51	22.69 III	2	9
X	70.38	86.75	25.15 I	16.07	12.59	57.60	21.84	1	4
XI	43.67	96.50	19.15	15.13	16.67	54.44	23.33 I	1	6
XII	23.47	85.50	21.00	14.50	16.67	20.94	14.43		
XIII	51.17	96.50	16.85	13.75	14.45	34.44	13.88		
XIV	51.44	85.00	19.75	20.08 I	9.66	77.02 II	17.86	2	11
XV	107.00 I	90.00	18.45	17.25	13.32	71.00 III	15.74	2	12
XVI	46.75	95.50	25.00 II	15.75	18.09 II	46.15	22.62	2	9
XVII	47.25	84.00	21.10	14.04	20.72 I	45.97	22.32	1	5
XVIII	74.90	82.50 I	12.60	14.75	7.49	43.94	21.50	1	3

All three types of analysis revealed superiority of cowpea genotypes in cluster VIII. Hence, such of these promising germplasm lines could be used in cowpea hybridization programme to introgress favourable alleles for yield and yield related traits, protein content (%) in already released cowpea varieties having good agronomic base.

## 5.8 Seed protein content (%)

It is evident from Table 17 with regard to seed protein content that there was a significant difference among cowpea genotypes studied. It was ranged from 13.88 per cent (IC259159-2) to 24.06 per cent (IC97787) with mean of 19.91 per cent. The genotypes IC97787, IC198326, IC198361, IC198701, IC202868, IC202881, IC219574, IC219599, IC212872, IC249583, IC2532181, IC253268, IC253275 and IC4506 were have higher seed protein content as compared to check variety C-152 (20.95%). The wide range of protein content was also reported by Kachare *et al.* (1988), Umoren *et al.* (1997), Henshaw (2008), Lingaraj (2009) and Sebetha *et al.* (2010) in cowpea. The wide range of variation may be due to genetic factors and it also influenced by nutrition during crop growth especially due to nitrogen in soil and also additional application. Lingaraj (2009) reported that, seed protein content was highly heritable.

## 5.9 Screening of different cowpea genotypes against bruchids during storage

### 5.9.1 Bruchid damage character

At 90 days after release of bruchids, per cent apparent weight loss was significantly maximum was in IC202806 (31.17%), which was on par with IC198361, IC259159-1, IC253181 and IC214757 with 31.03, 29.09, 29.07, and 28.84 per cent weight loss, respectively. While, significantly minimum was in IC20278 with 8.87 per cent.

The actual weight loss at 90 DAR also showed significant difference with maximum loss in IC214757 (27.02%), IC198361 (26.70%) and IC198326 (23.81%), whereas the genotype IC202867 showed lowest actual loss of 3.14 per cent.

It is evident from the Table 18 with regard to total adult bruchids emergence that there has been a significant difference among the genotypes. Highest number of adults emerged from the IC198361 (2776) followed by IC214757 (2043), while lowest was in IC202784 (608) at 90 DAR.

The results showed similar trend with respect to per cent bruchid infestation. Here also the genotypes IC214757 (97.29%) and IC198361 (92.85%) were recorded highest per cent infestation. It might be the reason that highest adult bruchid emergence. The least per cent infestation was recorded in IC202784, IC212872 and IC4506 with 42.71, 57.00 and 59.91 per cent infestation, respectively. It might be reason that, less number of adult bruchid emergence

Based on bruchid infestation percentage, the genotypes can be classified as highly susceptible, moderately susceptible and least susceptible. Only three genotypes *viz.*, IC202784, IC212872 and IC4506 were least susceptible 10 were moderate and 22 were highly susceptible (Table 19 and Plate 8). This classification is based on the earlier classification as reported by Nagaraj (2002) as highly resistant (0-20%), moderately resistant (21-40%), inter mediate (41-60%), susceptible (61.80%) and highly susceptible (81-100%) in greengram against *Chinensis* L.

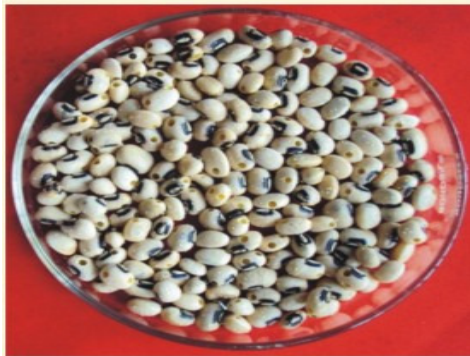
The variation in different parameters may be due to genetic factors, possible presence of bio chemical content of seeds such as antibiotics, tannin content, trypsin inhibitor, phenol content *etc.*

Similar results were also reported in different varieties of cowpea by Bhatnagar *et al.* (2001), Bhalla *et al.* (2002), Satya Vir (1983) and Nagaraja (2006); in chickpea Mahammad and Ahmad (2005), Parameshwarappa *et al.* (2007); in greengram by Nagaraj (2002) and in horsegram by Hanamantappa (1996).

### 5.9.2 Seed quality parameters

The seed parameters like germination, seedling length, vigour index, electrical conductivity of seed leachate of all genotypes showed significant difference except for

Highly susceptible



**Mumbai local**



**IC214757**



**IC198361**

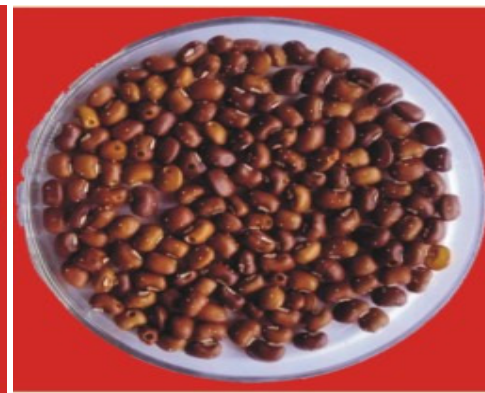
Latest Susceptible



**IC202784**



**IC212872**



**IC198701**

Plate.8. Some of the highly and least susceptible genotypes of cowpea

moisture content which was non-significant at initial stage of the experiment. At initial, the seed germination of all genotypes recorded above the minimum seed certification standards (min 75%). All initial seed parameters were devoid of influence on the insect infestation.

The per cent increase in seed moisture content and electrical conductivity of seed leachate were also differed significantly. The highest per cent increase in moisture content and electrical conductivity were recorded in IC214757 and IC198361 with 62.14 and 358.26 and 58.29 and 375.62 per cent, respectively. While, lowest was in IC202784 with 26.31 and 33.47 per cent in per cent increase in moisture content and electrical conductivity, respectively at 90 DAR.

At 90 DAR, the seed germination, seedling length and vigour index were differed significantly with range of 4.75 (Mumbai local) to 40.25 per cent (IC198701), 16.53 cm (Mumbai local) to 43.80 cm (IC4506) and 66 (Mumbai local) to 1664 (IC4506), respectively. While, with regard to per cent fall in germination over initial value due to *C. maculatus* was lowest in IC212872 (56.79%) which was on par with IC198701 (56.95%) and IC4506 (58.58%) while IC202784 recorded comparatively low per cent fall in germination (68.93%). Whereas, highest per cent fall in germination was in IC5969 (96.43%) Mumbai local (94.13%), and IC198361 (93.28%) followed by IC257413 (90.33%) (Plate 9). The per cent fall in seedling length and vigour index were also highest in Mumbai local, IC198361, IC214757 with 57.17 and 97.91, 59.65 and 97.35 and 22.13 and 92.64 per cent, respectively. However, per cent fall in seedling length in IC214757 was less but germination was low (8.75%). While, per cent fall in seedling length and vigour index were lowest in IC4506 with 6.12 and 54.81 per cent, respectively. While, IC198701, IC202789, IC202787 and IC212872 were also comparatively low.

The variation in seed parameters was mainly due to variation in per cent infestation level, adult emergence and reduction in seed weight and also inherent capacity of each genotype response to be attacked by bruchid *C. maculatus*.

The similar results with respect to seed parameters also earlier was reported by Nagaraja (2006), Bhaduria and Jakhmola (2006) in cowpea; Parameshwarappa *et al.* (2007), Biradar patil *et al.* (1995), Patil *et al.* (2003) in chickpea, Khairaner *et al.* (1996) in pigeon pea; Hanumantappa (1996) in horsegram; Lakshminaresimhaiah (1993) and Doharey *et al.* (1987) in greengram.

The fact that to *C. maculatus* resistance is controlled by two recessive genes (Adjadi *et al.*, 1985) indicates that in chemical and for physical factors responsible for resistance should be present in all resistant lines and absent in all susceptible. In present study, none of the genotypes were immune to *C. maculatus*.

Taking into account of all seed and bruchid infestation measured through different damage parameters, comparatively least susceptible genotypes were IC202784, IC212872, IC4506 and IC198701 while highly susceptible genotypes were IC214757, IC198361 and Mumbai local and rest of all were moderate to highly susceptible to attack by *C. maculatus*.

### 5.9.3 Correlation analysis

From the results of correlation between bruchid infestation effect on seed quality parameters covering seed size, weight and protein content has no influence on the relative susceptibility of cowpea genotypes to *C. maculatus*. While within the bruchid damage characters such as number of adult emergence, weight loss of seed, per cent infestation were highly and positively correlated. It also showed that per cent fall in seed germination, seedling length and vigour index were significant and negatively correlated with bruchid damage characters; Whereas, moisture content and electrical conductivity were positively correlated and significant with bruchid damage characters.

Similar results with regard to correlation was reported by Kapila and Rajni (1989) in pea; Talekar and Lin (1992) in mung and blackgram; Muhammad Hussain *et al.* (1997) in mungbean varieties.

From the present study, it is evident that seed size, weight and protein content have no influence with regard to resistance to bruchid. Hence, it is worthwhile if plant breeder considers other seed characters and biochemical content of seed as basis in reducing the susceptibility of cowpea genotypes to bruchid attack during storage.



Plate.9. Effect of *Callosbruchus maculatus* on seed germination in cowpea

## Practical utility

1. The morphological characters studied can be effectively utilized for rouging during seed production to safe guard genetic purity.
2. The morphological characters studied can be utilized for identification and characterization of cowpea varieties in DUS testing.
3. These identification characters are also helpful in genetic purity testing (GOT) conducted by seed certification agencies.
4. Seed keys developed for these genotypes can be utilized in routine seed testing for physical purity and genetic purity analysis.
5. Some of the genotypes were found better for their seed protein content and these can be utilized for further breeding or directly in consumption.
6. The genotypes IC202784, IC212872, IC4506 and IC198701 which were found comparatively least susceptible against bruchid infestation can be utilized in breeding process.

## Future line of work

1. A system may be developed to identify the varieties based on seed colour by using electronic sorter for perfect identification of cowpea varieties.
2. Use of Image analyzer for cowpea varieties and other crop varieties, hybrids and their parental lines for varietal identification.
3. To develop and standardize a biographic characteristics descriptor for identification of crop varieties especially for seed industry based on morphological traits, chemical tests and electrophoretic banding pattern.
4. Use molecular markers *viz.*, RAPD, SSR, SRAP, *etc.*, to characterize further research in cowpea crop is to be carried out.
5. The pairs of cowpea genotypes identified as most diverse must be involved in crosses to develop productive sugregants from promising combinations.
6. Molecular studies need to be carried out to estimate genetic diversity.

## 6. SUMMARY AND CONCLUSIONS

The laboratory and field experiments were carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad; Karnataka during 2009-10 to characterize thirty five cowpea genotypes based on seed, seedling and plant morphology, to screen their relative response against bruchid [*Callosobruchus maculatus* (F.)] and also evaluate seed protein content and genetic diversity. The findings are summarized in this chapter.

### Seed and seedling characteristics

Based on the seed coat colour, the genotypes were grouped into white, creamish white, creamish brown, light brown, brown, dark brown, mottled and grey. IC198326 due to its mottled seed colour can easily identified from other genotypes at seed level. A fair grouping of the cowpea genotypes based on seed coat lusture was made and were grouped as shiny (14 genotypes), dull (17 genotypes) and intermediate (three). Genotypes IC219599, IC212871 and Mumbai local were identified by ovoid seed shape.

A fair grouping of the cowpea genotypes was made based on hilum colour as black (11 genotypes) and brown (24 genotypes). Seed morphometric characters like hundred seed weight and seed size also important for varietal characterization of cowpea genotypes. Highest hundred seed weight and seed size was observed in IC212872 and lowest in IC4506. Genotypes under present study did not vary in their pigmentation on hypocotyls. All genotypes were showed absence of pigmentation on hypocotyls.

### Plant morphological characteristics

The thirty five cowpea genotypes were studied for various plant morphological characteristics such as pigmentation on stem, pubescence on stem, plant growth pattern, plant growth habit, plant height and number of primary branches. The only one genotype IC97787 showed presence of pigmentation on stem and remaining all were showed absence. The genotypes under the present study did not differ in their stem pubescence, showing complete absence.

Expression of plant growth pattern character is uniform and stable, based on this IC257413, IC97787, IC202868, IC214757, Mumbai local and Bailhongal local were grouped into determinate, while the genotypes IC202789 and IC259159-2 were found semi determinate and 27 genotypes were found indeterminate. Based on the plant growth habit, genotypes were grouped into erect, semi spreading and spreading types. The genotypes C-152 and Bailhongal local were tall; four were dwarf and twenty nine genotypes were medium in plant height. Significantly higher number of branches were recorded in IC219599 and the lowest was in Mumbai local.

### Leaf and flower characteristics

Among the different plant characters observed for varietal identification leaf colour, flower colour and days to 50 per cent flowering were most discriminating factors among the genotypes. In the present investigation, leaf colour of the cowpea genotypes varied from pale green to dark green. On the basis of days to 50 per cent flowering, the cowpea genotypes were grouped in to three categories as early (<48 days), medium (48-52 days) and late (>52.00 days). The genotype C-152 took highest days while IC259159-2 took less days for 50 per cent flowering. Genotypes IC249583 and Mumbai local were identified from remaining genotypes due to their white flower colour.

### Pod morphological characters

The phenotypic variation was observed for various pod characteristics such as immature pod pigmentation, pod position, pod attachment to peduncle, number of clusters per plant, number of pods per peduncle, number of pods per plant, pod length, number of seeds per pod, mature pod colour, pod constriction, days to maturity, seed yield per plant and hectare and market value among 35 cowpea genotypes and grouped in to different categories.

The immature pod pigmentation is one of the important characteristics in cowpea. The genotype IC97787 and IC198326 were uniformly pigmented and splashes of pigment on immature pod, respectively, hence easily identified from other genotypes. The raceme position and attachment to peduncle in cowpea genotypes differed distinctly. The raceme position in IC257413, IC198333, IC198349, IC202867, IC2027854 and C-152 was throughout canopy and remaining all were above canopy; whereas with respect to pod attachment IC198326, IC202867, IC253270, IC253273, IC259159-1 and IC259159-2 were 30<sup>0</sup>-90<sup>0</sup> down from erect and remaining all were pendent. Highest number of clusters per plant was recorded in the IC253270 and the lowest in Mumbai local variety. Based on number of pods per peduncle variation, fair grouping was made as few (<2.0) and more (>2.0).

The number of pods per plant varied among the genotypes. The genotypes IC202789 (105.25), IC253181 (95.50) and IC253270 (107.00) recorded superiority very high number of pods per plant. Based on pod constriction, genotypes were grouped as least (11 genotypes), medium (18 genotypes) and high (six genotypes). Based on the days to maturity, the genotypes were grouped into three categories as early (<85 days), medium (85-95 days) and late (>95 days). The genotype IC202867 took more days for maturity, while IC4506 took less days for maturity.

Based on variation in pod length, the genotypes were grouped as short (<15 cm), medium (15-20 cm) and long (>20 cm). IC219599 had longest pods and shortest pods were in IC4506. The highest number of seeds per pod were recorded in IC198335 and lowest were in IC214757. A fair grouping of the cowpea genotypes were made based on pod colour at maturity as straw (21 genotypes) and brown (14 genotypes). Highest seed yield per plant was recorded in IC25318, while highest seed yield per hectare was recorded in IC202881 and lowest seed yield per plant and hectare was recorded in Mumbai local. Based on seed yield per plant and hectare, the genotypes were grouped into four categories as low, moderate, high and very high yielder. Under the present study IC219599, IC219872, IC249583, IC253275 and Mumbai local were found vegetable type.

### Genetic diversity

Among 13 characters studied ten characters contributed to diversity, in which the highest contribution was recorded by the seed size followed by pod length. Based on D<sup>2</sup> values thirty five genotypes were grouped into 18 clusters. Cluster I was the biggest with 16 genotypes followed by cluster II and X. The clusters III to IX and clusters X to XVIII were solitary clusters. D<sup>2</sup> values ranged from 0.00 to 40.89, intra cluster D<sup>2</sup> values exhibited a range of 0.00 to 8.82 and inter cluster D<sup>2</sup> values ranged from 7.64 to 40.89. All three types of analysis revealed superiority of cowpea genotypes in cluster VIII

### Seed protein content (%)

Significant difference was recorded in protein content of seed. The highest percentage of protein content was noticed in IC97787 and lowest was in IC259159-2 genotype.

### Screening of cowpea genotypes against bruchids

Seed moisture content, electrical conductivity, seed germination, seedling length and seedling vigour index in 35 genotypes of cowpea were estimated both at initial as well at 90 days after infestation and they were screened for their relative response to the attack by *C. maculatus* with artificial infestation and were classified based on total number of adults emergence, apparent and real weight loss in seed, per cent seed damage, per cent fall in germination, seedling length, seedling vigour index and per cent increase in seed moisture content and electrical conductivity.

Significant difference between genotypes was observed with regard to their relative susceptibility to bruchid to immune. Correlation analysis indicated that seed size, weight and protein content have no influence on the relative susceptibility of cowpea genotypes to *C. maculatus*. The 35 cowpea genotypes screened were therefore classified, taking into account of all seed and bruchid damage parameters as high, moderate and least susceptible groups. Comparatively least susceptible genotypes were IC202784, IC212872, IC4506 and IC198701 while highly susceptible genotypes were IC214757, IC198361 and Mumbai local and rest of all were moderate to highly susceptible to attack by *C. maculatus*.

## REFERENCES

- Abdul-Baki, A. A. and Anderson, J. D., 1973, Vigour determination in soybean by multiple criteria. *Crop Sci.*, **13** : 630-633.
- Adams, J. M. and Schulten, G. G. M., 1978, Losses caused by insects, mites and micro organisms in post-harvest grain loss assessment methods. *An Assoc. Cereal Cheme., St.*, Paul Minnesota, USA., p. 193.
- Adjadi, O., Singh, B. B. and Singh, S. R., 1985, Inheritance of bruchid resistance in cowpea. *Crop Sci.*, **25**:740-742.
- Adu-Dapaah, H., Singh, B. B. and Fatokun, C. A., 1988, Heterosis and inbreeding depression in cowpea. *Tropical Grain Legume Bul.*, **35** : 23-27.
- Aghora, J. S., Mohan, N. and Somkumar, R. G., 1994, Evaluation of vegetable cowpea for earliness, protein content and green pod yield. *Legume Res.*, **17** (2) : 138-140.
- Agrawal, R. L., 1984, *Identification of Crop Varieties*, Oxford and IBH Publishing Co., New Delhi, pp. 228.
- Agrawal, R.L., Anil Pawar A., 1990, Identification of soybean varieties based on seed and seedling characteristics. *Seed Res.*, **18**(1): 77-81.
- Ahmed, K., Khalique, F., Afzal, M., Tahir, M. and Malik, B. A., 1989, Variability in chickpea (*Cicer cirietinum* L.) genotypes for resistance to *Callosobruchus maculatus* (F.) Bruchidae. *J. of Stored Product Res.*, **25**(2): 97-99.
- Ahmed, K., Khalique, F., Khan, I. A. and Malik, B. A., 1993, Genetic differences for susceptibility of chickpea to bruchid beetle, *Callosobruchus chinensis* L. attack. *Pak. J. of Scientific and Industrial Res.*, **36**: 96-98.
- Albina, F., Musil, 1980, Identification of crop and weed seeds. *Agril. Hand Book*, England (219) pp. 147.
- Anonymous, 1954, Munsell soil colour charts, munsell colour Macbesh Division of Kollmorgan Corporation, 2441, North Calvert Street, Baltimore.
- Anonymous, 1976, ICRISAT, *Ann. Rep.*, p.136.
- Anonymous, 1980, Official methods of analysis, 13<sup>th</sup> Ed., Association Official Agricultural Chemist, Washington, D. C., 20044.
- Anonymous, 1983, IBPGR, Descriptors for cowpea, Rome, J. Summerfield and A. H. Bunting), HMSO, London. pp 183-185.
- Anonymous, 1985, NBPGR, *Ann. Rep.*, New Delhi, p. 133.
- Anonymous, 1986, AVRDC, *Prog. Rep.*, Taiwan, pp. 79-82.
- Anonymous, 1988, AVRDC, *Prog. Rep.*, Taiwan, pp. 38-39.
- Anonymous, 1989, NBPGR, *Ann. Rep.*, New Delhi, p. 197.
- Anonymous, 1990, NBPGR, *Ann. Rep.*, New Dehi, p. 197.
- Anonymous, 1991, AVRDC, *Prog. Rep.*, Taiwan, pp. 70-72.
- Anonymous, 1992a, NBPGR, *Ann. Rep.*, New Delhi, pp. 197.
- Anonymous, 1992b, NBPGR, *Ann. Rep.*, New Delhi, p.125.
- Anonymous, 1992c, AVRDC, *Prog. Rep.*, Taiwan pp. 91-94.
- Anonymous, 1995, ICAR, *National Seed Projects (Crops)*, New Delhi, pp. 26.
- Anonymous, 1999, International Rules for Seed Testing. *Seed Sci. Technol.* **27**: 25-30.
- Anonymous, 2004, FAO, <http://www.fao.stat.fao.org>
- Anonymous, 2008, FAO, <http://www.fao.stat.fao.org>

- Anonymous, 2009a, Final Estimates of Area, Production and Yield of Important agricultural crops in Karnataka, Directorate of Economics and Statistics. Govt. of Karnataka.
- Anonymous, 2009b, Protection of Plant Varieties and Farmers Right Act, Government of India. <http://www.plantauthority.gov.in/drafteropguide.htm>.
- Arora, G. L., 1977, Bruchids of northwest India. *Oriental Insects*, The association for the study of oriental insects, New Delhi, p. 132.
- Arunkumar, M. B., Bherry, R. J., Malavika, D., Anuradha, V. and Sharma, S. P., 2004, Characterization of pearl millet hybrids and parental lines using morphological characters. *Seed Res.*, **32** (1) : 15 – 19.
- Ashok S. Sajjan, Prashanth, N. D. and Hosmani, R. M., 2008, RAPD markers and morphological characteristics for identification of french bean (*Phaseolus vulgaris* L.) cultivars. *Seed Res.*, **36**(1) : 81-83.
- Awasthi, P. C., Gutam, V. C., Kumar, S. and Kumar, S., 1989, Biochemical composition and nutritional quality of edible pods of promising genotypes of cowpea (*Vigna unguiculata* (L.) Walp.). *Prog. Hort.*, **21**(3-4):203-207.
- Backiyarani, S., Nadarajan, N., Rajendran, C. and Shanthi, S., 2000, Genetic divergence for physiological traits in cowpea, (*Vigna unguiculata* (L.) Walp). *Legume. Res.*, **23**(2): 114-117.
- Bahrenfus, J.F. and Fehr, W.R., 1984, Registration of 'Harper' and 'Lakota' soybean. *Crop Sci.*, **21**: 385.
- Baiker, K. A., and Webggster, 1992, Control of *Aganitho scelides obtectus* SAY (Coleoptera : Bruchidae) in *Phaseolus vulgaris* L. Seeds stored on small farms-II. Germination and cooking time. *J. Stored Prod. Res.*, **28** (4) : 295-299.
- Bhadauria, N.S. and Jakhmola, S.S., 2006, Effect of intensity of infestation caused by pulse beetle on extent of losses and germination of seeds in different pulses. *Indian J. Ent.* **68**(1): 92-94.
- Bhagat, N. R., Taslim Ahmd, H. B., Lalwani and Harender Singh, 1985, Status of National resource of cultivated groundnuts. *Indian J. Genetics and Plant Breeding*, **45** : 171 – 177.
- Bhalla, S., Kapur, M. L. and Verma, B. R., 2002, Relative susceptibility of cowpea genotypes to cowpea weevil *C. maculatus*. *Indian J. Ent.*, **64**(1):63-67.
- Bhatnagar, A., Bhadauria, N. S. and Jakhmola, S. S., 2001, Efficacy of vegetable oils against pulse beetle, *Callosobruchus maculatus* in cowpea. *Indian J. of Ent.*, **63**(3):237-239.
- Biradarpatil, N. K., Shekhargoud, M. and Giraddi, R. S., 1995, Viability of Bengal gram seeds infested with bruchids. *Seed Res.*, **23**(1) : 58-59.
- Boerma, H. R., Hussey, R.S., Phillips, D.V., Wood, E.D., 1990, Registration of 'Colquitt' soybean. *Crop Seed.*, **30**(3): 748.
- Bonetti, A., Miggiano, A., Dinelli, G. and Lovato, A., 1995, Identification of bean (*Phaseolus vulgaris* L.) cultivars grown in Italy by field and electrophoresis tests: a comparative study. *Seed Sci. Tech.*, **23** : 69 – 84.
- Borah, H. K. and Khan, A. K. F., 2002, Genetic divergence in fodder cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.*, **88**(10/12): 625-628.
- Bowers, G. R., Hussey, R. S., Phillips, D. V. and Wood, E. D., 1990, Registration of 'Crockett' soybean. *Crop Sci.*, **30** (2): 427.
- Braich, J. S. and Simwat, G., 1984, Effect of different levels of initial infestation of *C. chinensis* (L.) and *C. maculatus* (F.) on their population build up and resultant loss to moong. *Bull. Grain Tech.*, **22** (3) : 240-243.
- Chakrabarthy, S. K. and Agrawal, R. L., 1989a, Identification of blackgram varieties-I Utilization of seed characteristics. *Seed Res.*, **17**(1): 23-28.

- Chakrabarthy, S. K. and Agrawal, R. L., 1989b, Identification of blackgram varieties-II Utilization of morphological characteristics of seedlings. *Seed Res.*, **17**(2): 139-142.
- Chandola, R.P., Trechan, K. and Bagrecha, L.R., 1969, Varietal resistance of *Bruchus* sp. in cowpea under storage conditions, *Curr. Sci.*, **38** : p. 370.
- Chandrashekhara, S. S., 2005, Influence of the age of the seed on plant growth, seed yield and quality and characterization of French bean genotypes. *M.Sc. (Agri.) Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka (India).
- Chandrashekhara, S. S., 2008, Seed technological studies in French bean. *Ph.D. Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka (India).
- Charjan, S. K. U., Tarar, J. L., 1991, Influence of seed size on germination and seedling vigour in soybean varieties. *Bioved*, **7**(2): 165-168.
- Copeland, L. O. and McDonald, M. B., 1997, *Principles of Seed Science and Technology*, III Edition, Pub., New York, pp. 393.
- Cupic, T., Tucak, M., Popovic, S., Bolaric, S., Grijusic, S. and Kozumplik, V. (2009) Genetic diversity of pea (*Pisum sativum* L.) genotypes assessed by pedigree, morphological and molecular data, *J. Food Agric. Environ.*, **7** (3&4): 343-348.
- Dabi, R. K., Gupta, H. C. and Sharma, S. K., 1979, Relative susceptibility of some cowpea varieties to pulse beetle (*Collosobruchus maculatus*). *Indian J. Agril. Sci.*, **49**(1) : 48-50.
- Darlington, C. D. and Wylie, A. P., 1955, *Chromosome Atlas of flowering plants*, George Allen and Unwin., London, pp 132-134.
- Dharmalingam, V. and Kadambavanasundaram, M., 1989, Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.*, **76**(7): 394-399.
- Diazcarrasco, H., Abreuferrer, S., Velazquez, O., Garcia, O., 1986, Similarities between some agronomic characters in soybean. *Ciencias de la Agricultura*, **27**: 108-113.
- Dogre, T. K., Pawar, S. E. and Harwalkar, M. R., 1993, Resistance to *Callosobruchus maculatus* (F.) (Coleoptera : Bruchidae) in pigeonpea (*Cajanus cajan* L. Millsp.) and other *Cajanus* species. *J. of Stored Product Res.*, **29**(4): 319-322.
- Doharey, R. B., Katiyar, R. N. and Singh, K.M., 1987, Ecotoxicological studies on pulse beetles infesting green gram. *Bull. Grain Tech.*, **25** (1) : 12-15.
- Drabo, I., T. A. O., Ladeinde and Reden, R., 1988, Inheritance of eye pattern and seed coat colour in cowpea [*Vigna unguiculata* (L.) Walp]. *Plant Breeding*, **100** : 119-123.
- Dushyant, S., Khokhar, K. S. and Singh, D., 1991, Susceptibility of pigeon pea genotypes to pulse beetle *Callosobruchus chinensis* (L.) incidence. *Int. J. of Tropical Agril.*, **9**:78-50.
- Edgar, E., Hartwig and Calton, J., Edwards, J. R., 1970, Effects of morphological characteristics upon seed yield in soybean. *Agron. J.*, **62**: 64-65.
- Elsaeed, E. A. K., 1967, Seed size as a varietal differences in broad beans (*Vicia faba* L.). *J. Agric. Sci., Camb.*, **68** : 69-73.
- Girish, G. K., Jain, S. K., Ashok Kumar and Agrawal, N. S., 1975, Ashok Kumar and Agrawal, N. S., 1975, Assessment of storage losses quality and particular concentration in wheat availability in the marker of Western UP, Punjab and Haryana. *Bull. Grain Tech.*, **13** : 8-18.
- Gnyandev, B., 2009, Seed Technological Studies in Chickpea Varieties (*Cicer arietinum* L.), Ph. D., *Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka (India).
- Gobindan, R., Narayanaswamy, T. K., Rao, M. R. G. and Munirajappa, R., 1989, Relative susceptibility of wild mung and other pulse seeds for *Callosobruchus chinensis*. *Env. and Eco.*, **7** : 469-471.

- Gujar, G.T. and Yadav, T.D., 1978, Feeding of *Callosobruchus maculatus* (F.) and *Callosobruchus chinensis* L. in green gram. *Indian J. Ent.*, 40 (2) : 108-112.
- Gupta, S. K., Singaal and Doharey, R.B., 1981, Studies on the chemical and nutritional changes in Bengal Gram (*Cicer arietinum*) during storage caused by the attack of pulse beetle *Callosobruchus maculatus* F. *Bull. Grain Tech.*, 19 (3) 185-190.
- Gupta, V.K. and Gupta, Y.K., 1977, Variability, interrelationship and path coefficient analysis for some qualitative characters in sesame (*Sesamum indicum* L.) cultivars. *Indian J. of Heredity*, 9 : 31 – 37.
- Hanamantappa, R., 1996, Screening of horse gram and efficacy of different seed treatments against bruchids (*Callosobruchus chinensis* L.) during storage. *M.Sc.(Agri.) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Harville, B. G., Elkins, W. M., Hall, W. and Green, M. A., 1988, Registration of 'Gregg' soybean. *Crop Sci.*, 28: 196.
- Henshaw, F. O., 2008, Varietal Differences in Physical Characteristics and Proximate Composition of Cowpea (*Vigna unguiculata*). *World J. Agric. Sci.*, 4 (3): 302-306.
- Indradeo Pandey, 2007, Genetic diversity in grain cowpea [*Vigna unguiculata* (L.) Walp]. *Legume Res.*, 30(2): 92-97.
- International Board for Plant Genetic Resources, 1983, Cowpea descriptors. IBPGR, Rome. J. Summerfield and A. H. Bunting), HMSO, London, pp 183-185.
- Jackson, M. L., 1967, *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 183-192.
- Jain, S. and Khare, D., 2002a, Characterization of mung bean varieties for verification of genetic purity at seed level. *JNKVV Res. J.*, 36 (1&2) : 35-37.
- Jain, S. and Khare, D., 2002b, Characterization of mung bean varieties for verification of genetic purity at plant level. *JNKVV Res. J.*, 36 (1&2) : 38-43.
- Jotwani, M. G., Sircar, P. and Yadav, T. D., 1967, Studies on the extent of damage and germination of seeds. I. Germination of pea seeds damaged by *C. maculatus* (F.). *Indian J. Ent.*, 29 (3) : 309 – 311.
- Kachare, D. P., Chavan, J.K. and Kadam S. S. 1988, Nutritional quality of some improved cultivars of cowpea, *Plant Foods for Human Nutrition* 38 : 155-162.
- Kadoo, S. and Rane, A. E., 1995, Relative susceptibility of some pigeon pea varieties to pulse beetle *Callosobruchus chinensis* L. in storage. *J. of Soils and Crops*, 5: 49-52.
- Kamble, R. M., Khan, T.N. and Reddy, N. S. 1998, Nutritional quality evaluation of newly developed varieties of pigeonpea. *Legume Res.*, 21(2) : 67-73.
- Kameshwara Rao, P. and Krjshnamorthy Rao, B. H., 1982, Studies on the relative resistance to certain pigeon pea varieties to *Callosobruchus maculatus* (F.). *The Andhra Agril. J.*, 29(1): 51-54.
- Kapila, R. and Rajni, H. R., 1989, Screening of different cultivars of *Phaseolus vulgaris* to the attack of *Zabrotes subfasciatus*. *Bulletin of Entomology*, 28: 138-144.
- Karivartharaju, T. V., 2005, Physiological and biochemical techniques for crop variety identification. *Training Manual*, DUS test in cotton with reference to PPV and FR legislation, 2001, pp. 101-115.
- Karkannavar, J. C., Venugopal, R. and Goud, J. V., 1991, Inheritance and linkage studies in cowpea [*Vigna unguiculata* (L.) Walp.]. *Indian J. Gen.*, 51: 203-207.
- Karthikeyan, K. A. M., Vijayakumar, I., Suresh, P. and Janarthanan, S., 2008, Susceptibility of genetically improved varieties of Indian pulses to the pulse beetle, *Callosobruchus maculatus* (Fab.). *Indian J. Ent.*, 70(1) : 64-67.
- Katiyar, P. N. and Khare, B. P., 1983, Relative susceptibility of twenty germplasms of gram to pulse beetle *C. Chinensis* (Linnaeus). *Bull. Grain Technol.*, 21(1) : 31-36.

- Kenworthy, W. J., 1988, Registration of 'Morgan' soybean. *Crop. Sci.*, **28**: 196.
- Khairnar, G. P., Adsule, V. M. and Thakur, S. G., 1996, Quantitative and qualitative losses caused by *Callosobruchus chinensis* L. in pigeonpea over different period of storage. *Seed Res.*, **24**(1): 42-44.
- Khare, D., Shukla, S.S., Nair, P. and Bhale, M.S., 2009, Characterisation of linseed varieties based on seed coat colour. *Seed Res.*, **37** (1 & 2): 62-67.
- Kooistra, E., 1964, Identification research on pulses. *Proceedings of Intl. Seed Testing Assoc.*, **29** (4) : 937 – 947.
- Koszykowski, W. J. and Burgoon, A. C., 1983, Soybean cultivar testing update. *Newslett. AOSA*, **57**(2): 32-39.
- Kumawat, K. C. and Raje, R. S., 2005, Association analysis in cowpea [*Vigna unguiculata* (L.) Walp.]. *J. Arid Legumes*, **2**(1): 47-49.
- Lakshminarasimhaiah, M. N., 1993, Bio—efficacy of non-edible plant oils as seed protectants against *Callosobruchus chinensis* L. and their effect on seed quality of pigeon pea (*Cajanus cajan* L.) during storage. *M.Sc.(Agri) Thesis*, Univ. of Agric. Sci., Bangalore, Karnataka (India).
- Lambrides, C. J. and Imrie, B. C., 2000, Susceptibility of mungbean varieties to the bruchid species *Callosobruchus maculatus* (F.), *C. phaseoli* (Gyll), *C. chinensis* (L.) and *Achenthoscelides obtectus* (Say) (Coleoptera:Chrysomelidae). *Aust. Agric. Res.*, **50** : 85 – 89.
- Lingaraj, C., Halemani, 2009, Assessment of genetic diversity in cowpea (*Vigna unguiculata* L. Walp.) germplasm. *M.Sc. (Agri) Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka (India).
- Lirindae, M. A., 1986, Laboratory methodology for cultivar purity testing in US rices. *Dissertation Abstracts Int.*, B (Sciences and Engg.), **47** (4) : 1336B – 1337B.
- Liu-xuming, Jin-Dasheng,. Cheng-Xuzhen and Wu-Xiaofei, 1998, Preliminary evaluation on their resistance to *Callosobruchus chinensis* L. in mungbean germplasm. *Crop Genetic Resources*, **2**: 35-37.
- Mahalanobis, P. C., 1936, On the generalized distance in statistics. *Proc. Natl. Acad. Sci.*, **2**: 55-79.
- Mahgoub, S. M., Hamed, M. S., Ali, S. M. and Gharib, M. S. A., 2005, Susceptibility of some Egyptian pulses to infestation by *Callosobruchus chinensis* (L.) and *Callosobruchus maculatus*(F.). *Egyptian J. Agric. Res.*, **83**(4): 1601-1612.
- Manjaya, J.G. and Bapat, V.A., 2008, Studies on genetic divergence in soybean, *Glycine max* (L). *J. Oilseeds Res.*, **25** (2): 178-180.
- Manohar, S. S. and Yadav, S. R. S., 1990, Laboratory observation on relative resistance and susceptibility of some cowpea cultivars to pulse beetle *Callosobruchus maculatus* F. (Bruchidae:Coleoptera). *Indian J. of Ento.*, **52**(2): 180-186.
- Mate, S. N. and Shelar, V. R., 2006, Morphological characterization of sorghum hybrids and their parental lines. *Abstract XII National Seed Seminar*, 24-26 February, ANGRAU, Hyderabad, pp. 175 – 176.
- Modesta, R. C. D. and Cabral, L. C., 1987, Characteristics of seeds of some soybean lines with coloured testas. *EMBRAPA, News lett. Brazil*: (17). p. 17.
- Modi, B. N., Papasai, S. K., Verma, R. S. and Singh, C. B., 1994, The reaction of pulse beetle *C. chinensis* L. on grains of 44 varieties of pigeon pea. *Bhartiya Krishi Anusandhan Patrika*, **9**:283-288.
- Mohanrao, 1993, Influence of genotypes and seed size on seed quality, storability and field performance in soybean. *M. Sc. (Agri) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).

- Mudzana, G., Pickett, A. A., Jarman, R. J. and Cooke, R. J., 1995, Variety discrimination in faba beans: an integrated approach. *Plant Varieties and Seed*, **8** : 135 – 145.
- Muhammad Arshad, Naazar Ali and Abdul Ghafoor, 2006, Character Correlation and Path Coefficient In Soybean *Glycine max* (L.) Merrill, *Pak. J. Bot.*, **38**(1): 121-130.
- Muhammad Hussain, Roy, G. C. and Husain, M., 1997, Laboratory evaluation of some mungbean strains for susceptibility to pulse beetle, *Callosobruchus chinensis* L. *Bangladesh J. of Ento.*, **7**: 21-26.
- Muhammad Shafique and Maqbool Ahmad, 2005, Chickpea grains resistance to pulse beetle, *Callosobruchus analis* (F.) (Coleoptera:Bruchidae) *Pakistan J. Zoology*. **37** (2):123-126.
- Murthy, G. S. and Pavate, M. Y., 1962. Studies on quantitative inheritance in *Nicotiana tobaccum* L. I. Varietal classification and selection by multivariate analysis. *Indian J. Genet.*, **22**: 68.
- Muthaiah, A.R., 2006, Morphological varietal characterization in pulses. In: Advance in Seed Science and Technology. Vol. I. Recent trends in Seed Technology and Management. (Ed) Vanangamudi, K., Agrobios, Jodhapure.
- Naeem Ahmad and Mohammad Rahim, 2007, 'Swat Kulat-1' A High Yielding And Semi Erect Cowpea Variety For Irrigated Areas Of Malakand Division, *Gomal Univ. J. Res.*, **23** (2): 13-17.
- Nagalakshmi, R. M., Usha Kumari, U. and Anandha Kumar, C. R., 2009, Cowpea : The unexploited pulse. *Agribios News Letter*, **7** (9) : p. 41.
- Nagaraj, M. M., 2002, Genetics variation for productivity and bruchid resistance in greengram (*Vigna radiata* (L.) Wiczek). *M.Sc.(Agri.) Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka, India.
- Nagaraja, M., 2006, Evaluation of pigeon pea and cowpea genotypes for bruchid resistance (bruchids). *M.Sc.(Agri.) Thesis*, Univ. of Agric. Sci., Dharwad, Karnataka, India.
- Naima Ghalmi, Marie Malice, Jean-Marie Jacquemin, Sidi-Mohamed Ounane, Leila Mekliche and Jean-Pierre Baudoin, 2009, Morphological and molecular diversity within Algerian cowpea (*Vigna unguiculata* (L.) Walp.) landraces, *Genet. Resour. Crop Evol.*, [springerlink.com](http://springerlink.com).
- Nair, K. R. and Mukherjee, H. K., 1960, Classification of natural plantation teak (*Tectona grandis*) grown at different location of India and Burma with respect to its mechanical and physiological properties. *Sankhya*, **22**:11-20.
- Narayanankutty, C., Mili, R. and Jaikumar, U. 2003, Variability and genetic divergence in vegetable cowpea. *J. Maharashtra Agric. Univ.*, **28**(1): 26-29.
- Nigude. A. D., Dumbre, A. D. and Lad, D. B., 2004, Genetic diversity studies in cowpea. *J Maharashtra Agric. Univ.*, **29**(3): 250-252.
- Nirmal de, Rajkumar and Kallo, G., 2001, Diet versatility in cowpea genotypes. *Indian J. Agric. Sci.*, **71**(9): 598-601.
- Nkouannessi Magloire, 2005, The genetic, morphological and physiological evaluation of African cowpea genotypes. *M.Sc. (Agri) Thesis*, Univ. of Free State, Bioemrontein, South Africa.
- Ogunbodede, B. A. and Fatunla, T. 1985, Quantitative studies of some cowpea [*Vigna unguiculata* (L.) Walp.] traits. *East African Agril. and Forestry J.*, **50** : 89-100.
- Paramesh, R., 1983, Screening of soybean cultivars for seed size, seed vigour and establishment of the relationship with yield and yield components. *M. Sc. (Agri) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Parameshwarappa, S. G., Deshpande, V. K. and Salimath, P. M., 2007, Studies on comparative response and seed quality attributes of certain chickpea varieties to pulse beetle (*Callosobruchus chinensis* L.) in storage. *Karnataka J. Agric. Sci.*, **20** (3) : 492-495.

- Parameshwarappa, S.G., Palakshappa, M.G., Salimath, P.M. and Parameshwarappa, K.G., 2009, Studies on genetic variability and character association in germplasm collection of Sesame (*S. indicum* L.) *Karnataka J. Agric. Sci.*, **22**(2): 252-254.
- Patil, S. K., Tanpure, S. V. and Mate, S. N., 2003, Effect of different levels of pulse beetle [*Callosobruchus maculatus* (Fab.)] infestation on chickpea during storage. *Seed Res.*, **31**(1) : 119-120.
- Payne, R.C. and Koszykowski, T.J., 1979, The effect of seed size on hypocotyl length of soybean cultivars. *Seed Sci. Technol.*, **7** : 109-115.
- Pingale, S. V., 1953, Effect of damage by some insects on the viability and weight of stored grain. *Bull. Cent. Fd. Technol. Res. Inst.*, Mysore. **2** : 153.
- Piper, C. S., 1966, *Soil and Plant Analysis*. Academic Press, New York, p. 368.
- Purnima, Jharia, A.N., Shrivastava, K.M.S., Raghuwanshi and Shrivastava, M.K., 2008, Genetic variability in induced mutants of soybean, *Glycin max* (L.). *J. Oilseeds Res.*, **25** (2):175-177.
- Ramamoorthy, K., Ponnuswamy, A. S. and Sundareshwaran, 2010, varietal deterioration and reference variety maintenance. *Training Manual on "Vareital Purity Testing-Testing of Specified Traits*. 4<sup>th</sup> to 8<sup>th</sup> January, 2010. Coimbatore, Tamilnadu.
- Ramesh, C. V., 1993, Effectiveness of edible oils and chemicals as seed protectants on Bruchid infestation in soybean and their effects on seed quality and storability. *M.Sc. (Agri) Thesis*. Univ. of Agric. Sci., Bangalore, Karnataka (India).
- Ramzan, M., Chahal, B.S. and Judge, B.K., 1990, Storage losses to some commonly used pulses caused by pulse beetle. *J. Insect Sci.*, **3** (1) : 106 - 108.
- Rao, C. R., 1952, *Advanced statistical methods in Biometrical Research*. John Wiley and sons, New York.
- Rasaily, S.K., Desai, N.D. and Kukadia, M.U., 1986, Genetic variability in soybean (*Glycine max* (L.) Merrill ). *Gujarat Agril. Uni. Res. J.*, **11**(2) 57-60.
- Ravikumar, 1999, Identification of soybean varieties based on seed, seedling and plant characters. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Reddy, P.N., Reddy, K.N. and Singh, S.P. 1989, Effect of seed size on qualitative and quantitative traits in soybean. *Seed Sci. and Technol.*, **17**: 289-295.
- Renganayaki, K. and Rengasamy, S. R.. 1992, Path co-efficient analysis in cowpea [*Vigna unguiculata* (L.) Walp.]. *Madras Agric. J.*, **79**: 476-481.
- Rewale, A. P., Birari, S. P. and Apte. U. B., 1996, Genetic divergence in cowpea [*Vigna unguiculata* (L.) Walp.]. *Indian .J. Agric. Res.*, **30** (2): 73-79.
- Richard and Payne, R.C. 1979, Sonic new test and procedures for determining variety (soybeans). *J. Seed Technol.*, **3**(2): 61-77.
- Roopa Anantareddy, 2008, Varietal characterization and identification of soybean genotypes through morphological and molecular markers. . *Ph. D Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Rustamani, M.A., Naqui, S.M.S.H., Munshi, G.H. and Abbo, G.H., 1985, Relative resistance/susceptibility of different pulses against pulse beetle *Callosobruchus chinensis* L. *Pak. J. Zool.*, **17** (1) : 99-100.
- Sankrapandian, R., 2002, Identifying some pulse cultivars based on key characters alone among popular varieties of Tamil Nadu. *Seed Tech News*, **32** (1): 146.
- Santos, C. A. F., Menezes, E. A. and Araujo, F.de, 1997, Genetic diversity in genotypes of cowpea under 2 different environments. *Revista Ceres*, **44** (25 1): 35-42.
- Sarutayophat, T., Nualsri, C., Santipracha, Q. and Saereprasert, V., 2007, Characterization and genetic relatedness among 37 yard long bean and cowpea accessions based on morphological characters and RAPD analysis. *Songklanakarin J. Sci. Technol.* **29** (3): 591-600.

- Satya Vir, 1983, Varietal resistance and susceptibility of cowpea to *Callosobruchus maculatus* Fab. *Indian J. Ent.*, **45**(3): 213-217.
- Satya, V. and Jindal, S.K, 1981, Oviposition and development of *C. maculatus* (Fab.) on different host species. *Bull. Grain Tech.*, **19** : 180-184.
- Sebetha, E. T., Ayodele, V. I., Kutu, F. R. and Mariga, I. K., 2010, Yields and protein content of two cowpea varieties grown under different production practices in Limpopo province, South Africa. *Afr. J. Biotechnol.***9** (5): 628-634.
- Selvaraj, V., Annappan, R. S. and Giridharan, S., 1986, CO-4, A new high yielding drought tolerant cowpea variety. *Madras Agril. J.*, **73** (3) : 125-128.
- Shaheen, F. A. Khaliq, A. and Aslam, M., 2006, Resistance of Chickpea (*Cicer arietinum* L.) Cultivars Against Pulse Beetle. *Pak. J. Bot.*, **38**(4): 1237-1244
- Sharma, S. K., Teckchandani, C. K. and Nakhore, C. L., 1991, Physical characteristics of greengram varieties. *JNKVV Res. J.*, **25**: 1-4.
- Sharma, T.R. and Mishra, S.N., 1997, Genetic divergence and character association studies in cowpea. *Crop Res. Hissar.*, **13**: 109- 114.
- Shehnaz, A. and Theophilus, F., 1975, Effect of insect infestation on chemical composition and nutritive value of Bengal gram (*Cicer arietinum*) and field bean (*Doilchos lablab*). *J. Food Sci. and Tech.*, **12** : 29.
- Siddique, A. K. and Gupta, S. N., 1991, Genotypic and phenotypic variability for seed yield and other traits in cowpea [*Vigna unguiculata* (L.) Walp.]. *Int. J. Tropical Agric.*, **9** : 144-148.
- Siddiqui, P.M., 1972, Studies on longevity, oviposition, fecundity and development of *Callosobruchus chinensis* L. (Coleoptera:Bruchidae) *Zeitschrift fur Angewandte Entomologie*, **72** (1) : 66-72. (Abstr. Rev. Applied Ent., 1974, **62**: 536).
- Singh, A. B., Awasthi, C. P. and Singh, N., 1997a, Biochemical composition and nutrition quality of edible immature pods of broad bean (*Vicia faba* L.). *Prog. Hort.*, **29**(3-4) : 147-154.
- Singh, B. B., Mohan, D. R., Dashiell, K. E., and Jackai, L. E. N., 1997b, *Advances in Cowpea Research*, Copublication of Int. Inst. of Tropical Agril. (IITA) and Japan Int. Res. Centre for Agric. Sci., (JIRCAS), IITA, Ibadan, Nigeria.
- Singh, B. B., Singh, S. R. and Adjadi, V., 1985, Bruchid resistance in cowpea. *Crop Sci.*, **25** (5) : 736-739.
- Singh, D. P. and Sharma, S. S., 1984, Studies on grain damage and germination loss caused by *Callosobruchus maculatus* Fab. in different varieties of moong and mash during storage. *Bull. Grain Tech.*, **20** (1) 20 - 24.
- Singh, R. P. and Choudhary, B. D., 1977, *Biometrical Methods in Quantitative Genetic Analysis*, Kalyani Publishers, New Dehli.
- Singhal, S.K., Singh, Z. and Jaglan, R.S., 1989, Effect of different levels of bruchid *Callosobruchus chinensis* L. infestation on chickpea *Cicer arietinum* (L.) in India. *Trop. Pest Management*, **35** (2) : 187—189.
- Sisodia, G. S., 1987, Effect of seed size on yield in soybean. *Seeds and Farms*, **13**(4): 30-31.
- Sison, M. L. J., Adalla, C. B. and Mantala, J. P., 1996, Life history of *Callosobruchus chinensis* L. and new sources of mungbean resistance to this storage pest. *Philippine Entomologist*, **10**:175-187.
- Southgate, B. J., 1979, Biology of bruchidae. *Ann. Rev. Ent.* pp. 449 – 473.
- Sridhara, S., Thimmegowda, S. and Chalapathi, M. V., 1997, Nutritional values, physical and physico-chemical characteristics and cooking quality of soybean genotypes. *Crop Res.*, **13**(2) : 259-266.

- Srikantaradya, M.G., 1980, Genetic variability with respect to different seed characters in relation to viability and vigour in soybean (*Glycine max* (L.) Merrill) *M. Sc. (Agri) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Stahi, J. P. and Pandey, M. P., 1981, Association of seed impermeability with flowering and maturity duration in soybean. *Tropical Grain Legume Bull.*, **22** : 119 – 121.
- Steele, W. M. 1976, Cowpeas, *Vigna unguiculata*. In: *Evolution of crop plants*, (Eds. R. Summerfield and A. H. Bunting), HMSO, London, pp 183 – 185.
- Stoilova, T. and Berova, M., Morphological and agrobiological study on local germplasm of common beans (*Phaseolus vulgaris* L.) and cowpea (*V. unguiculata* L.). *XI Anniversary Scientific Conference*, Special Edition: 385-388.
- Sudhakar, N., Shridevi, O. and Salimath, P.M., 2007, Variability and character association analysis in sesame (*Sesamum indicum* L.). *J. Oilseeds Res.*, **24** (1): 56-58.
- Suganthi, S and Murugan, S., 2007, Variability studies in cowpea [*Vigna unguiculata* (L) Walp.]. *Crop Res. Hissar.*, **33**(1/3): 195-197.
- Suhasini, K.S., 2006, Characterization of sesame genotypes through morphological, chemical and RAPD markers, *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka, India.
- Sukprakaran, C., 1985, Pest problems and the use of pesticides in grain storage in Thailand. ACIAR proceedings series, Australian centre for *Int. Agric. Res.*, No. **14**, 31-35.
- Sulnathi, G., Prasanthi, L. and Sekhar, M. R., 2007, Character contribution to diversity in cowpea. *Legume Res.*, **31** (1) : 70 -72.
- Sun, J. and Chang, R., 1990, Analysis of the characteristics of green soybean in China. *Crop Genetic Resources*, (3): 4-6.
- Sundarraj, N., Nagaraju, S., Venkataram, M. N. and Jagannath, M. K., 1972, Design and analysis of field experiments. Univ. Agric. Sci., Bangalore, Karnataka, India.
- Surendra Prakash and Singhal, N. C., 1997, Characterization of some Indian pea (*Pisum sativum* L.) cultivars. *Seed Res.*, **25** (1) : 53 – 58.
- Suryawanshi, V. B., Patil, R. B., Mata, S. N., Gagare, K. C. and Manjare, M. R., 2002, Morphological characterization of soybean cultivars. *Seed Tech. News*, **32** (1) : 211.
- Talekar, N. S. and Lin, C. L. 1992, Characterization of *Callosobruchus chinensis*, resistance in mungbean. *J. of Eco. Ento.*, **85**: 1150-1153.
- Tarasatyavathi, C., Bharadwaj, C. H., Husain, S. M., Karmakar, P. G. and Yogendra Mohan, 2004, Identification key for soybean (*Glycine max*) varieties released or notified in (India). *Indian J. Agric. Sci.*, **74** (4). 215-218.
- Terao, H., 1986, Studies on the mesocotyl elongation of seedling in Japanese paddy rice cultivars. *Oryza sativa* L. *Bull. Institutional Tropical Agril.*, **9** : 77 – 87.
- Tiwari, D. K., Tiwari, J. P. and Agarwal, V. K., 1978, Evaluation of soybeans for high germinability and field emergence. *Seed Res.*, **6**(2): 125-128.
- Tunwar, N.S. and Singh, S.V., 1985, *Handbook of Cultivars*, India, p. 302.
- Umoren , U.E., Tewe O.O., Bokanga, M. and Jackai, L.E.N., 1997, Protein Quality Of Raw And Autoclaved Cowpeas: Comparison Between Some Insect Resistant And Susceptible Varieties, *Plant Foods for Human Nutrition*, **50**: 301-315
- Upadhyaya, M. D., Roomiroortiz, Daula, I., Bramel and Sube Singh, 2002, Phenotypic diversity for morphological and agronomic characteristics in chickpea core collection. *Emiphytica*, **12**(3): 333-342.
- Usha Kumari, R., Backiyarani, S. and Dhanakodi, 2000, Character contribution to diversity in cowpea. *Legume Res.*, **23**: 122-125.

- Vahab, M. A., Joseph, S., Mathe, S.K., Devadas, V. S. and Peter, K. V., 1991, Evaluation of selected varieties of vegetable cowpea. *Veg. Sci.*, 18(2): 222-224.
- Vavilov, N. I., 1951, *The origin, variation, immunity and plant breeding of cultivated plants*, Ronald press Co., New York, pp. 256-257.
- Venkatareddy, D. M., 1991, Investigations on seed technology of soybean, *Ph.D Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, (India).
- Venkategowda, N., 1984, Estimation of loss of stored soybean due to bruchid, *Callosobruchus maculatus* (Fabricius) and its biology, ecology and control. *M.Sc. (Agri) Thesis*. Univ. of Agric. Sci., Bangalore, Karnataka (India).
- Venkatesan, M., Prakash, M. and Ganesan, J., 2003, Correlation and path analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.*, 26: 105-108.
- Venkatesan, M., Veeramani, P., Thangavel and Ganeshan, J., 2004, Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.*, 27(3): 223-225.
- Villalobos, E. and Fournier, L. A., 1978, Morphological identification of some soybean selections introduced into costa Rica. *Agronomia Costarricense*, 2(10): 23-27.
- Vimala, V. and Pushpamma, P., 1983a, Storage quality of pulses studied in three Agro-climatic regions of Andra Pradesh I Qualitative changes. *Bull. Grain Tech.*, 21 (1) : 54 – 62.
- Vimala, V. and Pushpamma, P., 1983b, Storage quality of pulses studied in three Agro-climatic regions of Andra Pradesh II viability changes. *Bull. Grain Tech.*, 21 (3) : 217 – 222.
- Wadnerkar, D. W., Kaunsale, P. P. and Pawar, V. M., 1978, Studies on preference of pulse beetle (*Callosobruchus maculatus* F.) to some varieties of Arhar and gram. *Bulletin of Grain Technology*, 16(2) : 122-124.
- Wagner, C.K. and McDonald, M.B., 1982, Rapid laboratory tests useful for differentiation of soybean (*Glycine max* L.) cultivars. *Seed Sci. Technol.*, 10: 431-449.
- Weiss, E. A., 1971, Caster, sesame and safflower, *Leonard Hill books*, London, 311 – 355.
- Williams, J.H., Specht, J.E., Dreier, A.F, Moomaw, R.S and Elmore, R.W., 1984, Registration of 'Platte' soybean. *Crop Sci.*, 24: 334.
- Yadav, R. D. S. and Srivastava, J.P., 2002, DUS characteristics of chickpea varieties. *Seed Tech News*, 32(32): 29-30.
- Yadav, T.D. and Pant, N. C., 1978, Development response of *C. maculatus* and *C. chinensis* on different pulses. *Indian J. Ent.*, 40 (1) : 7 – 15.

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\* Original not seen

## APPENDIX

Appendix I. Physical and Chemical properties of soil in the experimental site.

Sr. No.	Properties	Value obtained	Methods Employed
I. Physical properties			
a.	Particle size analysis		
	Coarse sand (%)	7.24	International Pipette method (Piper, 1966)
	Fine sand (%)	13.84	
	Silt (%)	29.68	
	Clay (%)	49.24	
b.	Bulk Density (g/cc)	1.35	Core sampler method (Dastane, 1967)
c.	Maximum Water Holding Capacity (MWHC %)	60.15	Keens cup method (Piper, 1966).
II. Chemical properties			
a.	Available Nitrogen (kg/ha)	204.2	Modified Kjeldahl method (Jackson, 1973)
b.	Available P <sub>2</sub> O <sub>5</sub> (kg/ha)	50	Olsen's method (Jackson, 1967)
c.	Available K <sub>2</sub> O (kg/ha)	321	Flame photometry (Jackson, 1973)
d.	Organic carbon (%)	0.75	Wet oxidation method (Jackson, 1973)
e.	Soil pH (1:2.5 soil: water)	7.7	Potentiometry (Piper, 1966)
f.	Electrical conductivity (ds/m)	0.40	Conductivity Bridge (Jackson, 1967)
III. Micro-nutrients			
a.	Zn (mg/kg)	2.40	DTPA Extractable method (Lindsay and Norvell, 1978)
b.	Cu (mg/kg)	1.52	
c.	Mn (mg/kg)	19.45	
d.	Fe (mg/kg)	14.32	

Appendix II. Monthly meteorological data during crop growth period (2009-10) and the average of 60 years (1950 to March-2010) at Main Agricultural Research Station, UAS, Dharwad

Months	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
	2009-10	1950-2009	Mean maximum		Mean minimum		2009-10	1950-2009
			2009-10	1950-2009	2009-10	1950-2009		
April	52.8	39.05	36.5	36.0	21.1	20.1	81	78
May	91.6	68.0	35.5	34.4	21.5	20.95	84	75.65
June	144.8	107.9	30.3	28.75	20.9	21.7	77	86.45
July	256.8	136.7	26.0	28.65	20.9	20.85	88	89.2
August	72.2	155.85	28.1	26.9	20.6	20.05	80	88.75
September	229.0	133.65	28.5	28.15	20.7	19.95	83	86.75
October	141.0	93.65	29.3	30.15	18.8	18.65	65	79.65
November	46.0	52.6	28.6	29.7	18.0	15.9	69	73.7
December	76.4	2.6	28.8	28.95	15.4	13.15	66	69.3
January	0.8	0.05	28.2	29.7	15.5	13.95	63	64.85
February	0.4	0.55	32.4	32.2	17.3	16.55	50	54.5
March	Trace	15.65	35.6	33.7	20.3	19.7	49	64.5
Total	1272.6	806.25						

# PHENOTYPIC CHARACTERIZATION, ASSESSMENT OF GENETIC DIVERSITY, SCREENING FOR PROTEIN CONTENT AND BRUCHID INFESTATION IN COWPEA [*Vigna unguiculata* (L.) Walp.] GENOTYPES

BASAVARAJ MAKANUR      2010

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Major Advisor

## ABSTRACT

A field and laboratory experiments were conducted at Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad during *kharif* 2009 for phenotypic characterization, assessment of genetic diversity, screening for seed protein content and genotypic relative response to bruchid infestation.

Thirty five cowpea genotypes were grouped based on the seed and seedling morphological characters such as seed coat colour, hilum colour, seed shape, seed coat lusture, hundred seed weight, seed size and hypocotyl pigmentation. Further based on the plant morphological characters such as pigmentation on stem, growth pattern, 50 per cent flowering, flower colour, growth habit, pubescence on stem, leaf colour, immature pod pigmentation, raceme position, pod attachment, plant height, primary branches per plant, clusters per plant, pods per peduncle, pods per plant, mature pod constriction, days to maturity, pod length, seeds per pod, pod colour at maturity, seed yield per plant and hectare of genotypes were classified into different groups. Among 13 characters studied ten characters contributed to diversity, in which the highest contribution was recorded by the seed size followed by pod length.

Significant difference was recorded for seed protein content. The highest percentage of protein content (24.06%) was noticed in IC97787 and lowest (13.88%) was in IC259159-2 genotype. Significant difference was also observed among genotypes to their relative susceptibility to bruchid to immune. Correlation analysis indicated that seed size, weight and protein content of cowpea genotypes have no influence on the relative susceptibility to *Callosobruchus maculatus*. Comparatively least susceptible genotypes were IC202784, IC212872, IC4506 and IC198701 while highly susceptible genotypes were IC214757, IC198361 and Mumbai local and rest of all were moderate to highly susceptible to bruchid infestation.